

Topic
1.1 Moles and Molar Mass

2022 Practice Exam (from AP Classroom)

Q: Number of molecules in samples

A 100.0 g sample of which of the following compounds contains the most molecules?

(A) CO_2

(B) SO_2

* (C) H_2O

(D) N_2O

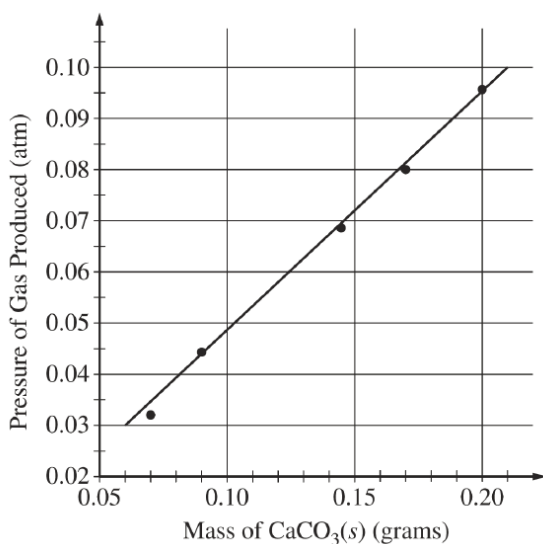
Topic
1.1 Moles and Molar Mass

2019 Practice Exam #36

Q: CaCO_3 in eggshells - mass percent in mixture

Questions X-Y refer to the following information.

An experiment is performed to measure the mass percent of $\text{CaCO}_3(s)$ in eggshells. Five different samples of $\text{CaCO}_3(s)$ of known mass react with an excess of $2.0\text{ M HCl}(aq)$ in identical sealed, rigid reaction vessels. The pressure of the gas produced is measured with a pressure gauge attached to the reaction vessel. Since the reaction is exothermic, the reaction system is cooled to its original temperature before the pressure is recorded. The experimental data are used to create the calibration line below.



The experiment is repeated with an eggshell sample, and the experimental data are recorded in the table below.

Mass of eggshell sample	0.200 g
Pressure prior to reaction	0.800 atm
Pressure at completion of reaction	0.870 atm

The mass percent of $\text{CaCO}_3(s)$ in the eggshell sample is closest to

(A) 30%

(B) 45%

(C) 60%

* (D) 75%

Topic
1.1 Moles and Molar Mass

2017 Practice Exam #12

Q: Cu + HNO₃ - percent Cu by mass from data

Questions X-Y refer to the following information.



Each student in a class placed a 2.00 g sample of a mixture of Cu and Al in a beaker and placed the beaker in a fume hood. The students slowly poured 15.0 mL of 15.8 M HNO₃(aq) into their beakers. The reaction between the copper in the mixture and the HNO₃(aq) is represented by the equation above. The students observed that a brown gas was released from the beakers and that the solutions turned blue, indicating the formation of Cu²⁺(aq). The solutions were then diluted with distilled water to known volumes.

The students determined that the reaction produced 0.010 mol of Cu(NO₃)₂. Based on the measurement, what was the percent of Cu by mass in the original 2.00 g sample of the mixture?

- (A) 16%
- * (B) 32%
- (C) 64%
- (D) 96%

Topic
1.1 Moles and Molar Mass

2014 Practice Exam #1

Q: 1.00g of which oxide has greatest mass of oxygen

Compound	Molar Mass (grams)
Na_2O	62.0
MgO	40.3
K_2O	94.2
CaO	56.1

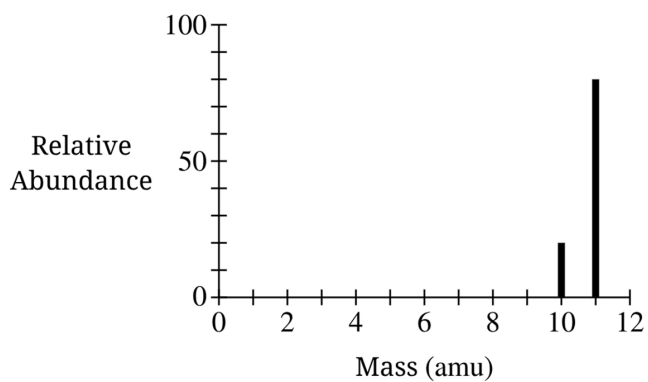
According to the information in the table above, a 1.00 g sample of which of the following contains the greatest mass of oxygen?

- (A) Na_2O
- * (B) MgO
- (C) K_2O
- (D) CaO

Topic
1.2 Mass Spectra of Elements

2023 Practice Exam (from AP Classroom)

Q: Relative abundance of Boron



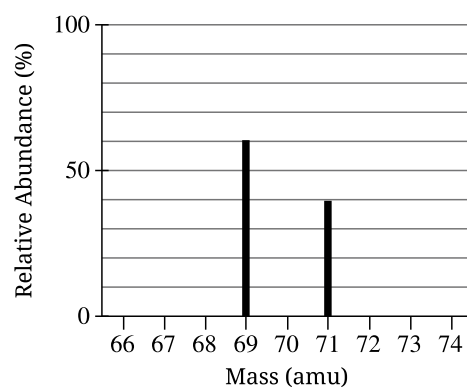
Based on the mass spectrum of a sample of boron shown above, how many neutrons are in the most common isotope of boron?

- (A) 5
- * (B) 6
- (C) 10
- (D) 11

Topic
1.2 Mass Spectra of Elements

2022 Practice Exam (from AP Classroom)

Q: Identify element from mass spectrum



The mass spectrum of an element is represented above. Which of the following is most likely the identity of the element?

- * (A) Ga
- (B) Ge
- (C) Tm
- (D) Lu

Topic
1.2 Mass Spectra of Elements

2021 Practice Exam (from AP Classroom)

Q: Atoms of element not identical

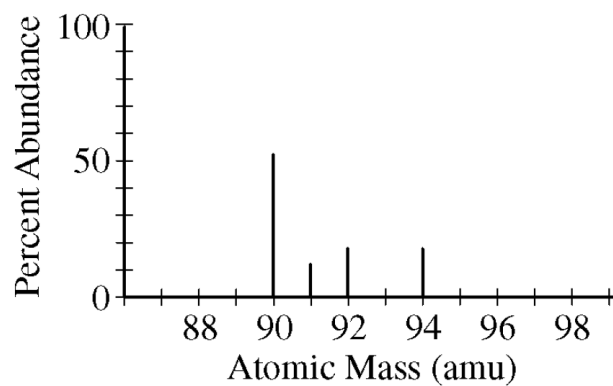
In his atomic theory, Dalton proposed that all atoms of a given element are identical. Which of the following observations provides the best evidence that the proposal is incorrect?

- * (A) The mass spectrum of Cu has a peak at 63 amu and another peak at 65 amu.
- (B) The ionic radius of Cl^- is 0.181 nm, and the atomic radius of Cl is 0.079 nm.
- (C) The dipole moment of O_3 is 0.53 debye, and the dipole moment of O_2 is 0.00 debye.
- (D) Elemental P can exist in both white and red forms.

Topic
1.2 Mass Spectra of Elements

2017 Practice Exam #1

Q: Identify element from mass spectrum



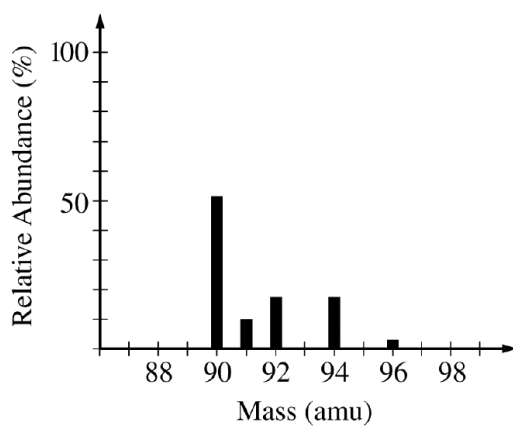
The mass spectrum of an average sample of a pure element is shown in the figure above. Which of the following is the identity of the element?

- (A) Y
- * (B) Zr
- (C) Nb
- (D) Th

Topic
1.2 Mass Spectra of Elements

2015 Practice Exam #3

Q: Mass spectrum of element X - what can be concluded



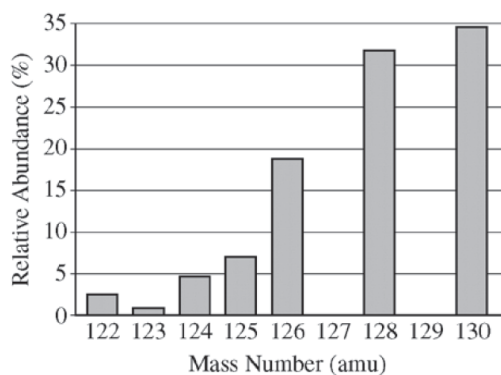
The mass spectrum of element X is presented in the diagram above. Based on the spectrum, which of the following can be concluded about element X?

- (A) X is a transition metal, and each peak represents an oxidation state of the metal.
- (B) X contains five electron sublevels.
- (C) The atomic mass of X is 90.
- * (D) The atomic mass of X is between 90 and 92.

Topic
1.2 Mass Spectra of Elements

2013 Practice Exam #10

Q: Te-I mix - conclude purity of Te from mass spec



The elements I and Te have similar average atomic masses. A sample that was believed to be a mixture of I and Te was run through a mass spectrometer, resulting in the data above. All of the following statements are true. Which one would be the best basis for concluding that the sample was pure Te?

- (A) Te forms ions with a -2 charge, whereas I forms ions with a -1 charge.
- (B) Te is more abundant than I in the universe.
- * (C) I consists of only one naturally occurring isotope with 74 neutrons, whereas Te has more than one isotope.
- (D) I has a higher first ionization energy than Te does.

Topic
1.3 Elemental Composition of Pure Substances

2023 Practice Exam (from AP Classroom)

Q: Molecular formula of compound

A compound made up of only carbon and hydrogen is completely combusted in excess $\text{O}_2(g)$. Equimolar quantities of $\text{CO}_2(g)$ and $\text{H}_2\text{O}(g)$ are produced. Which of the following could be the molecular formula of the compound?

- (A) CH_4
- (B) C_2H_2
- * (C) C_2H_4
- (D) C_2H_6

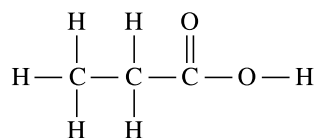
Topic
1.3 Elemental Composition of Pure Substances

2022 Practice Exam (from AP Classroom)

Q: Percent C in compound

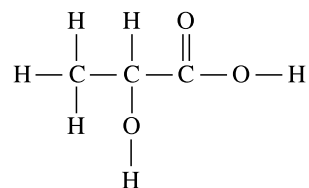
A student determines that an unknown compound contains 49 percent C by mass. Which of the following could be the compound?

* (A)



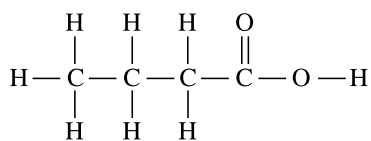
Propanoic acid
(74 g/mol)

(C)



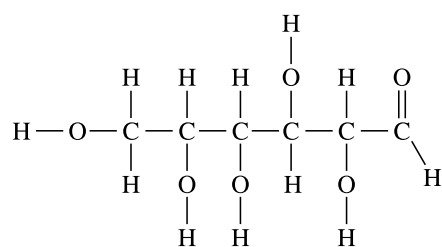
Lactic acid
(90 g/mol)

(B)



Butanoic acid
(88 g/mol)

(D)



Glucose
(180 g/mol)

Topic
1.3 Elemental Composition of Pure Substances

2021 Practice Exam (from AP Classroom)

Q: Formula of compound

A sample of a pure compound is analyzed and found to contain approximately 30 percent N and 70 percent O by mass. The formula for the compound could be

- (A) NO
- * (B) NO₂
- (C) N₂O
- (D) N₂O₂

Topic
1.3 Elemental Composition of Pure Substances

2018 Practice Exam #2

Q: Hydrocarbon with same empirical formula as C_3H_6

Sample	Mass of Carbon	Mass of Hydrogen
A	60. g	12 g
B	72 g	12 g
C	84 g	10. g
D	90. g	10. g

The masses of carbon and hydrogen in samples of four pure hydrocarbons are given above. The hydrocarbon in which sample has the same empirical formula as propene, C_3H_6 ?

- (A) Sample A
- * (B) Sample B
- (C) Sample C
- (D) Sample D

Topic
1.3 Elemental Composition of Pure Substances

2017 Practice Exam #17

Q: Empirical formula of S and O if 40 percent S

If a pure sample of an oxide of sulfur contains 40. percent sulfur and 60. percent oxygen by mass, then the empirical formula of the oxide is

- * (A) SO_3
- (B) SO_4
- (C) S_2O_6
- (D) S_2O_8

Topic
1.3 Elemental Composition of Pure Substances

2016 Practice Exam #11

Q: Empirical formula - C H O from mass data

A 23.0 g sample of a compound contains 12.0 g of C, 3.0 g of H, and 8.0 g of O. Which of the following is the empirical formula of the compound?

- (A) CH_3O
- * (B) $\text{C}_2\text{H}_6\text{O}$
- (C) $\text{C}_3\text{H}_9\text{O}_2$
- (D) $\text{C}_4\text{H}_{12}\text{O}_2$

Topic
1.3 Elemental Composition of Pure Substances

2015 Practice Exam #32

Q: Empirical formula - C H N from combustion analysis

A sample of a compound that contains only the elements C, H, and N is completely burned in O_2 to produce 44.0 g of CO_2 , 45.0 g of H_2O , and some NO_2 . A possible empirical formula of the compound is

- (A) CH_2N
- * (B) CH_5N
- (C) C_2H_5N
- (D) $C_3H_3N_2$

Topic
1.3 Elemental Composition of Pure Substances

2014 Practice Exam #8

Q: MCl gravimetric analysis - identify metal chloride

Questions X-Y refer to the following.

M^+ is an unknown metal cation with a +1 charge. A student dissolves the chloride of the unknown metal, MCl, in enough water to make 100.0 mL of solution. The student then mixes the solution with excess $AgNO_3$ solution, causing AgCl to precipitate. The student collects the precipitate by filtration, dries it, and records the data shown below. (The molar mass of AgCl is 143 g/mol.)

Mass of unknown chloride, MCl	0.74 g
Mass of filter paper	0.80 g
Mass of filter paper plus AgCl precipitate	2.23 g

What is the identity of the metal chloride?

- (A) NaCl
- * (B) KCl
- (C) CuCl
- (D) LiCl

Topic
1.3 Elemental Composition of Pure Substances

2013 Practice Exam #1

Q: Hydrocarbon - combustion yields equimolar CO₂ H₂O

Complete combustion of a sample of a hydrocarbon in excess oxygen produces equimolar quantities of carbon dioxide and water. Which of the following could be the molecular formula of the compound?

- (A) C₂H₂
- (B) C₂H₆
- * (C) C₄H₈
- (D) C₆H₆

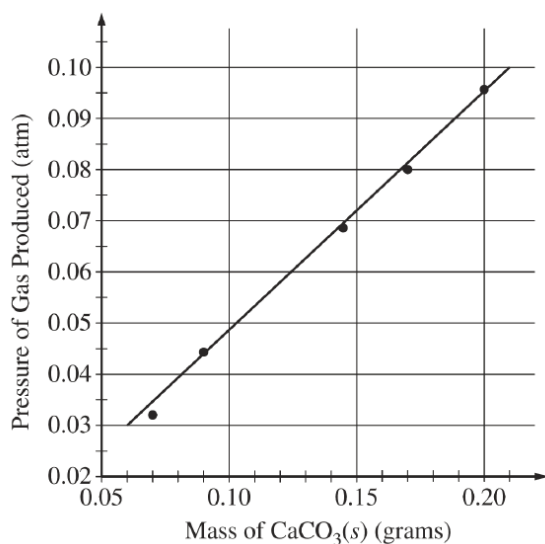
Topic
1.4 Composition of Mixtures

2019 Practice Exam #36

Q: CaCO_3 in eggshells - mass percent in mixture

Questions X-Y refer to the following information.

An experiment is performed to measure the mass percent of $\text{CaCO}_3(s)$ in eggshells. Five different samples of $\text{CaCO}_3(s)$ of known mass react with an excess of $2.0\text{ M HCl}(aq)$ in identical sealed, rigid reaction vessels. The pressure of the gas produced is measured with a pressure gauge attached to the reaction vessel. Since the reaction is exothermic, the reaction system is cooled to its original temperature before the pressure is recorded. The experimental data are used to create the calibration line below.



The experiment is repeated with an eggshell sample, and the experimental data are recorded in the table below.

Mass of eggshell sample	0.200 g
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The mass percent of $\text{CaCO}_3(s)$ in the eggshell sample is closest to

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(B) 45%

(C) 60%

* (D) 75%

Topic
1.4 Composition of Mixtures

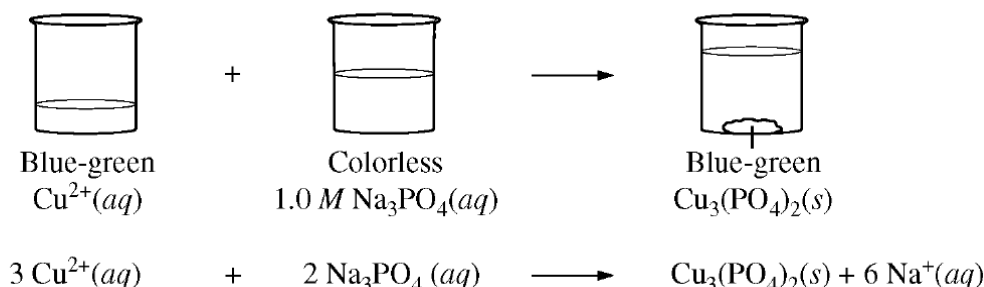
2018 Practice Exam #23

Q: Cu recovery - error to explain higher mass of Cu

Questions X-Y refer to the following information.

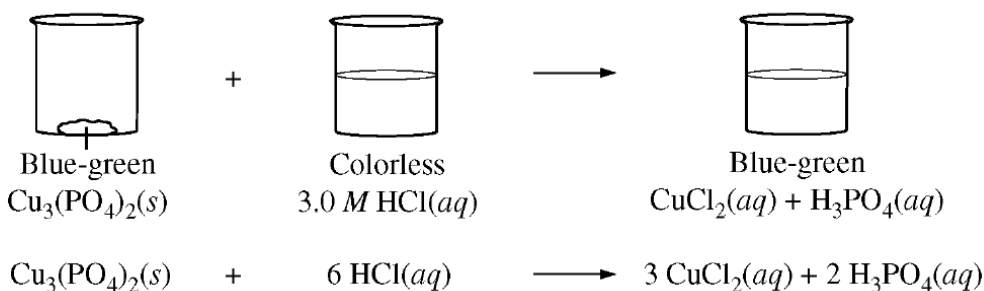
A group of students was asked to recover $\text{Cu}(s)$ from a blue-green aqueous solution containing an unknown concentration of $\text{Cu}^{2+}(aq)$. The students took a 100.0 mL sample of the solution and added an excess of 1.0 M $\text{Na}_3\text{PO}_4(aq)$, causing the $\text{Cu}^{2+}(aq)$ to precipitate as $\text{Cu}_3(\text{PO}_4)_2(s)$, as shown in step 1 below.

Step 1



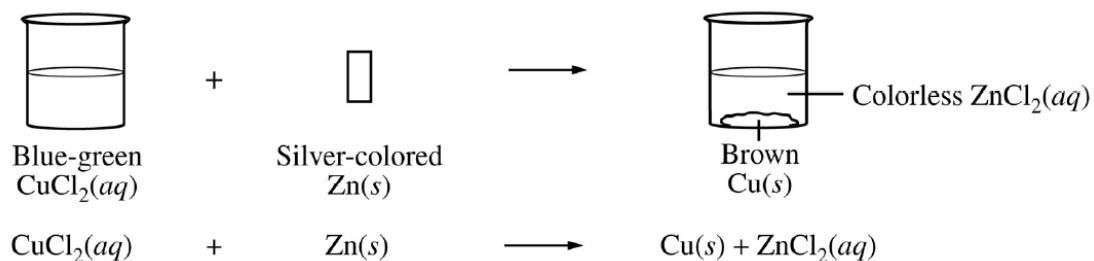
The $\text{Cu}_3(\text{PO}_4)_2(s)$ was filtered, dried, and weighed. Then the $\text{Cu}_3(\text{PO}_4)_2(s)$ was dissolved in a 3.0 M $\text{HCl}(aq)$ solution, as shown in step 2 below.

Step 2



The students added a strip of $\text{Zn}(s)$ to the solution to recover the $\text{Cu}(s)$, as shown in step 3 below.

Step 3



Finally, the $\text{Cu}(s)$ was filtered, dried, and weighed.

(This question is continued on the next page.)

Topic
1.4 Composition of Mixtures

(This question is continued from the previous page.)

2018 Practice Exam #23

Q: Cu recovery - error to explain higher mass of Cu

The mass of the $\text{Cu}(s)$ produced in step 3 was slightly more than the mass predicted from the 3.8 g of $\text{Cu}_3(\text{PO}_4)_2(s)$ recovered from step 1. Which of the following could account for the discrepancy in the yield of $\text{Cu}(s)$ from step 3?

- (A) All of the $\text{Cu}_3(\text{PO}_4)_2(s)$ dissolved in the $\text{HCl}(aq)$.
- (B) Some of the $\text{Cu}(s)$ adhered to the side of the funnel used to filter the solution.
- * (C) Some unreacted $\text{Zn}(s)$ was mixed in with the $\text{Cu}(s)$.
- (D) Too much $\text{Na}_3\text{PO}_4(aq)$ was added to the original $\text{Cu}^{2+}(aq)$ solution.

Topic
1.4 Composition of Mixtures

2017 Practice Exam #12

Q: Cu + HNO₃ - percent Cu by mass from data

Questions X-Y refer to the following information.



Each student in a class placed a 2.00 g sample of a mixture of Cu and Al in a beaker and placed the beaker in a fume hood. The students slowly poured 15.0 mL of 15.8 M HNO₃(aq) into their beakers. The reaction between the copper in the mixture and the HNO₃(aq) is represented by the equation above. The students observed that a brown gas was released from the beakers and that the solutions turned blue, indicating the formation of Cu²⁺(aq). The solutions were then diluted with distilled water to known volumes.

The students determined that the reaction produced 0.010 mol of Cu(NO₃)₂. Based on the measurement, what was the percent of Cu by mass in the original 2.00 g sample of the mixture?

- (A) 16%
- * (B) 32%
- (C) 64%
- (D) 96%

Topic
1.4 Composition of Mixtures

2017 Practice Exam #16

Q: Impurity in NaCl if percent Cl is too large

A sample of a solid labeled as NaCl may be impure. A student analyzes the sample and determines that it contains 75 percent chlorine by mass. Pure NaCl(s) contains 61 percent chlorine by mass. Which of the following statements is consistent with the data?

- (A) The sample contains only NaCl(s).
- (B) The sample contains NaCl(s) and NaI(s).
- (C) The sample contains NaCl(s) and KCl(s).
- * (D) The sample contains NaCl(s) and LiCl(s).

Topic
1.4 Composition of Mixtures

2015 Practice Exam #31

Q: Analyze Ag content in jewelry - step after HNO_3

To gravimetrically analyze the silver content of a piece of jewelry made from an alloy of Ag and Cu, a student dissolves a small preweighed sample in $\text{HNO}_3(aq)$. $\text{Ag}^+(aq)$ and $\text{Cu}^{2+}(aq)$ ions form in the solution. Which of the following should be the next step in the analytical process?

- (A) Centrifuging the solution to isolate the heavier ions
- (B) Evaporating the solution to recover the dissolved nitrates
- (C) Adding enough base solution to bring the pH up to 7.0
- * (D) Adding a solution containing an anion that forms an insoluble salt with only one of the metal ions

Topic
1.4 Composition of Mixtures

2013 Practice Exam #21

Q: Impurity that would lower percent C in glucose

The mass percent of carbon in pure glucose, $C_6H_{12}O_6$, is 40.0 percent. A chemist analyzes an impure sample of glucose and determines that the mass percent of carbon is 38.2 percent. Which of the following impurities could account for the low mass percent of carbon in the sample?

- * (A) Water, H_2O
- (B) Ribose, $C_5H_{10}O_5$
- (C) Fructose, $C_6H_{12}O_6$, an isomer of glucose
- (D) Sucrose, $C_{12}H_{22}O_{11}$

Topic
1.5 Atomic Structure and Electron Configuration

2023 Practice Exam (from AP Classroom)

Q: Electron configuration

Which of the following is the ground-state electron configuration for the Na^+ ion?

- (A) $1s^2 2s^2 2p^5$
- * (B) $1s^2 2s^2 2p^6$
- (C) $1s^2 2s^2 2p^6 3s^1$
- (D) $1s^2 2s^2 2p^6 3s^2$

Topic
1.5 Atomic Structure and Electron Configuration

2021 Practice Exam (from AP Classroom)

Q: Largest radius

Cl^-	Ar	K^+	Ca^{2+}
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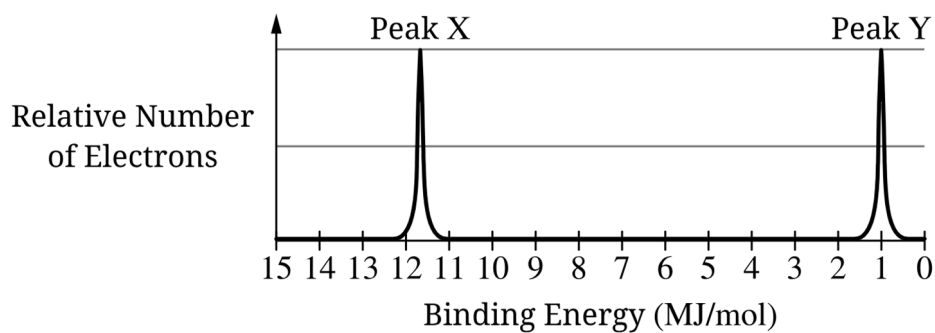
The four species above have the same electron configuration, $1s^22s^22p^63s^23p^6$. Which of the following statements correctly identifies the species with the largest radius and provides an explanation based on Coulomb's law?

- * (A) Cl^- , because its nuclear charge exerts the least attractive force on the electrons in the $3p$ sublevel.
- (B) Ar, because it is a neutral atom and the net force on the electrons in the $3p$ sublevel is zero.
- (C) K^+ , because the loss of an electron results in a smaller attractive force between the nucleus and the electrons in the $3p$ sublevel.
- (D) Ca^{2+} , because the large positive charge on a cation causes increased repulsion among the electrons in the $3p$ sublevel.

Topic
1.6 Photoelectron Spectroscopy

2023 Practice Exam (from AP Classroom)

Q: PES Li or Be



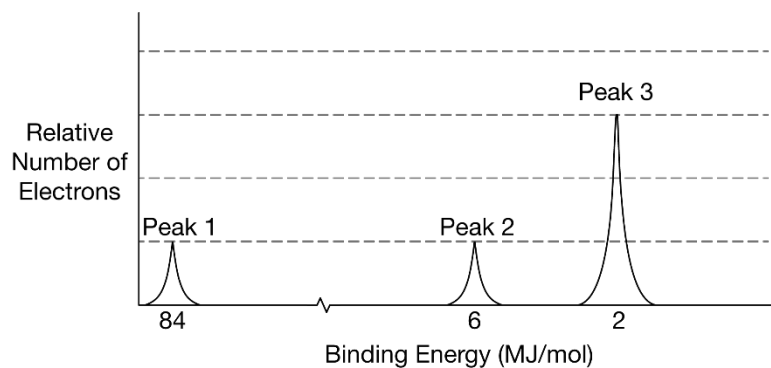
The complete photoelectron spectrum of a pure element is represented above. Which of the following correctly identifies both the element and the atomic orbitals represented by peak X and peak Y?

	Element	Peak X	Peak Y
(A)	Li	1s	2s
(B)	Li	2s	1s
* (C)	Be	1s	2s
(D)	Be	2s	1s

Topic
1.6 Photoelectron Spectroscopy

2021 Practice Exam (from AP Classroom)

Q: Identify element



The complete photoelectron spectrum of a pure element is shown in the diagram above.

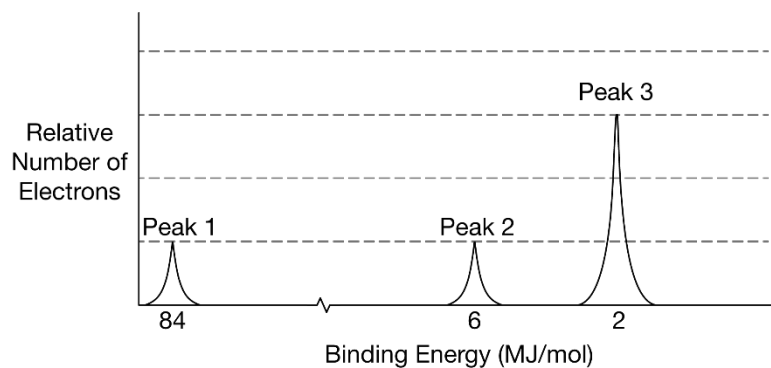
According to the complete photoelectron spectrum, which of the following is the identity of the element?

- (A) Be
- (B) C
- (C) O
- * (D) Ne

Topic
1.6 Photoelectron Spectroscopy

2021 Practice Exam (from AP Classroom)

Q: Sublevel of peak



The complete photoelectron spectrum of a pure element is shown in the diagram above.

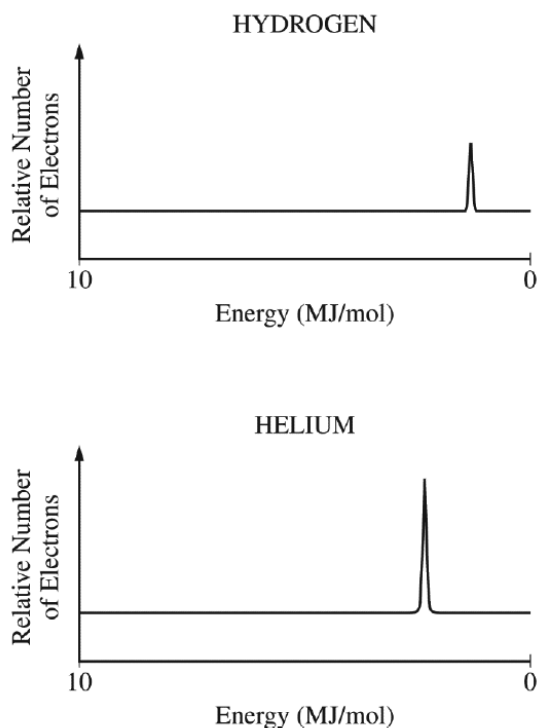
If peaks 1 and 2 represent *s* sublevels, which of the following sublevels is represented by peak 3?

- (A) *s*
- * (B) *p*
- (C) *d*
- (D) *f*

Topic
1.6 Photoelectron Spectroscopy

2019 Practice Exam #14

Q: PES - He peak further left and higher than H



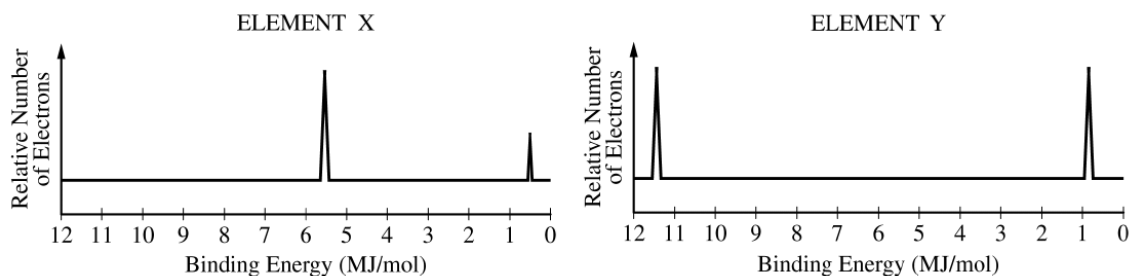
The photoelectron spectra for H and He are represented above. Which of the following statements best accounts for the fact that the peak on the He spectrum is farther to the left and higher than the peak on the H spectrum?

- (A) He has an additional valence electron in a higher energy level than the valence electron in H.
- * (B) He has a greater nuclear charge than H and an additional electron in the same energy level.
- (C) He has a completely filled valence shell in which the electrons are a greater distance from the nucleus than the distance between the H nucleus and its electron.
- (D) It takes longer for the electrons in He to be removed due to the higher nuclear mass of He.

Topic
1.6 Photoelectron Spectroscopy

2017 Practice Exam #19

Q: PES of X and Y - what can be inferred from data



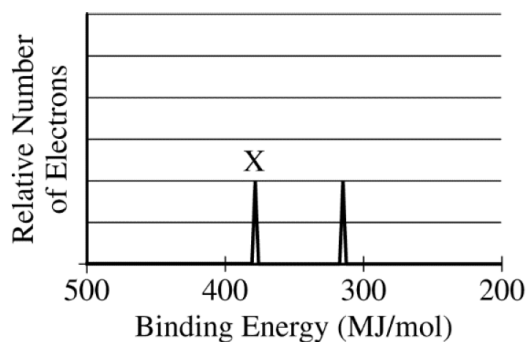
The complete photoelectron spectra of neutral atoms of two unknown elements, X and Y, are shown above. Which of the following can be inferred from the data?

- (A) Element X has a greater electronegativity than element Y does.
- (B) Element X has a greater ionization energy than element Y does.
- * (C) Element Y has a greater nuclear charge than element X does.
- (D) The isotopes of element Y are approximately equal in abundance, but those of element X are not.

Topic
1.6 Photoelectron Spectroscopy

2016 Practice Exam #35

Q: PES Ca^{2+} Ar - 1s peak with higher binding energy



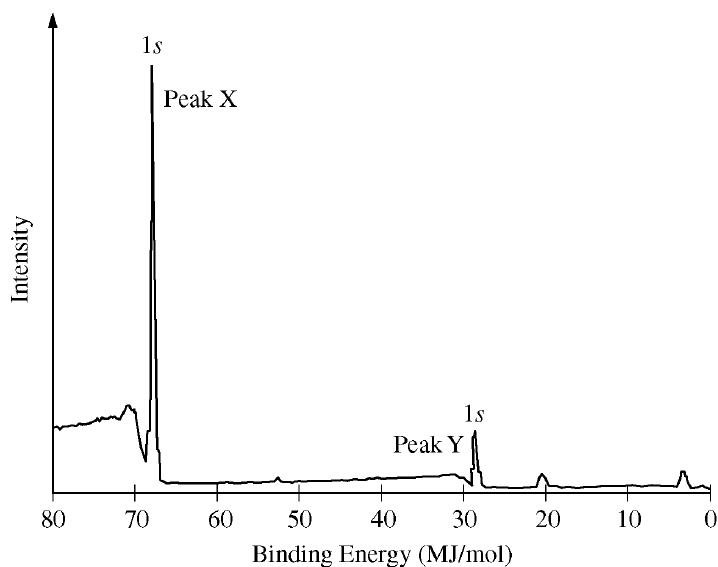
The photoelectron spectra of the 1s electrons of two isoelectronic species, Ca^{2+} and Ar, are shown above. Which of the following correctly identifies the species associated with peak X and provides a valid justification?

- (A) Ar, because it has completely filled energy levels
- (B) Ar, because its radius is smaller than the radius of Ca^{2+}
- (C) Ca^{2+} , because its nuclear mass is greater than that of Ar
- * (D) Ca^{2+} , because its nucleus has two more protons than the nucleus of Ar has

Topic
1.6 Photoelectron Spectroscopy

2014 Practice Exam #31

Q: PES - identify 1s peak for F and explain why



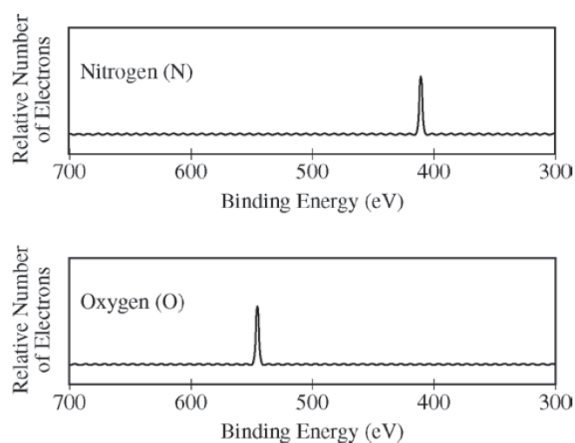
A sample containing atoms of C and F was analyzed using x-ray photoelectron spectroscopy. The portion of the spectrum showing the 1s peaks for atoms of the two elements is shown above. Which of the following correctly identifies the 1s peak for the F atoms and provides an appropriate explanation?

- (A) Peak X, because F has a smaller first ionization energy than C has.
- * (B) Peak X, because F has a greater nuclear charge than C has.
- (C) Peak Y, because F is more electronegative than C is.
- (D) Peak Y, because F has a smaller atomic radius than C has.

Topic
1.6 Photoelectron Spectroscopy

2013 Practice Exam #43

Q: Differences in PES of 1s sublevel for N and O



The photoelectron spectra above show the energy required to remove a 1s electron from a nitrogen atom and from an oxygen atom. Which of the following statements best accounts for the peak in the upper spectrum being to the right of the peak in the lower spectrum?

- (A) Nitrogen atoms have a half-filled p subshell.
- (B) There are more electron-electron repulsions in oxygen atoms than in nitrogen atoms.
- (C) Electrons in the p subshell of oxygen atoms provide more shielding than electrons in the p subshell of nitrogen atoms.
- * (D) Nitrogen atoms have a smaller nuclear charge than oxygen atoms.

Topic
1.7 Periodic Trends

2023 Practice Exam (from AP Classroom)

Q: Likely formula from ionization energies

	Ionization Energy (kJ/mol)
First	786
Second	1,577
Third	3,232
Fourth	4,356
Fifth	16,091

Based on the successive ionization energies of element X shown in the table above, which of the following is most likely the formula of the compound produced when element X reacts with fluorine?

- (A) XF
- (B) XF_2
- * (C) XF_4
- (D) XF_5

Topic
1.7 Periodic Trends

2023 Practice Exam (from AP Classroom)

Q: Ionization energies of alkaline earth metals

Which of the following best accounts for the decrease in the first-ionization energy of the alkaline earth metals going down the group?

- (A) The number of protons in the nucleus increases, resulting in increased attraction between the nucleus and the electron being removed.
- (B) The number of protons in the nucleus increases, resulting in a greater effective nuclear charge attracting the electron being removed.
- * (C) The number of electron shells increases, resulting in a greater average distance between the nucleus and the electron being removed.
- (D) The number of electron shells increases, resulting in less shielding between the nucleus and the electron being removed.

Topic
1.7 Periodic Trends

2022 Practice Exam (from AP Classroom)

Q: Compound formed based on ionization energies

	Ionization Energies (kJ/mol)
First	590
Second	1150
Third	4910
Fourth	6490

Based on the ionization energies of element X given in the table above, which of the following is most likely the formula of the compound formed between element X and SO_4^{2-} ?

- * (A) XSO_4
- (B) X_2SO_4
- (C) $\text{X}_2(\text{SO}_4)_3$
- (D) $\text{X}(\text{SO}_4)_2$

Topic
1.7 Periodic Trends

2022 Practice Exam (from AP Classroom)

Q: Relative atomic radii

Which of the following correctly compares the atomic radius of F to that of O and provides the best explanation?

- (A) The atomic radius of F is larger than that of O because F has more occupied subshells than O does.
- (B) The atomic radius of F is larger than that of O because F has more protons in the nucleus than O does.
- * (C) The atomic radius of F is smaller than that of O because F has a greater effective nuclear charge than O does.
- (D) The atomic radius of F is smaller than that of O because valence electrons in F experience more shielding than those in O.

Topic
1.7 Periodic Trends

2021 Practice Exam (from AP Classroom)

Q: Second ionization energy

Element	Second Ionization Energy (kJ/mol)
Li	7300
Na	4560
K	3050
Rb	2630

The decrease in the second ionization energy of alkali metals going down the group, as shown in the table above, can be best attributed to a decrease in the coulombic force of attraction due to

- (A) the removal of core electrons
- (B) an increase in effective nuclear charge
- * (C) an increase in the average distance of the outermost electron from the nucleus
- (D) a decrease in electron-electron repulsion within the outermost shell

Topic
1.7 Periodic Trends

2019 Practice Exam #4

Q: Identify element from successive IE - large IE4

	Ionization Energy (kJ/mol)
First	578
Second	1,817
Third	2,745
Fourth	11,577
Fifth	14,842

The first five ionization energies of an unknown element are listed in the table above. Which of the following statements correctly identifies the element and cites the evidence supporting the identification?

- (A) Na, because of the large difference between the first and the second ionization energies
- * (B) Al, because of the large difference between the third and the fourth ionization energies
- (C) Si, because the fifth ionization energy has the greatest value
- (D) P, because a neutral atom of P has five valence electrons

Topic
1.7 Periodic Trends

2019 Practice Exam #31

Q: Why Na is more reactive than Mg

Which of the following best helps to explain why Na(s) is more reactive with water than Mg(s) is?

- (A) Na(s) is softer than Mg(s).
- (B) The atomic mass of Na is less than that of Mg.
- (C) The Na⁺ ion has weaker Coulombic attraction to an anion than the Mg²⁺ ion has.
- * (D) The first ionization energy of Na is less than that of Mg.

Topic
1.7 Periodic Trends

2018 Practice Exam #10

Q: Compare periodic atomic properties of 2 elements

Which of the following correctly compares periodic properties of two elements and provides an accurate explanation for that difference?

- (A) The first ionization energy of Al is greater than that of B because Al has a larger nuclear charge than B does.
- (B) The first ionization energy of F is greater than that of O because O has a higher electronegativity than F has.
- (C) The atomic radius of Ca is larger than that of Mg because the valence electrons in Mg experience more shielding than the valence electrons in Ca do.
- * (D) The atomic radius of Cl is smaller than that of S because Cl has a larger nuclear charge than S does.

Topic
1.7 Periodic Trends

2018 Practice Exam #9

Q: Empirical formula of X and P given successive IE

	Ionization Energy (kJ/mol)
First	730
Second	1450
Third	7700
Fourth	10,500

The ionization energies of an unknown element, X, are listed in the table above. Which of the following is the most likely empirical formula of a compound formed from element X and phosphorus, P?

(A) XP

(B) X₃P

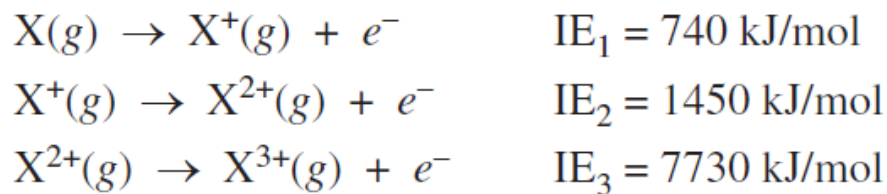
* (C) X₃P₂

(D) X₃P₄

Topic
1.7 Periodic Trends

2016 Practice Exam #8

Q: Atomic reason for large third ionization energy



For element X represented above, which of the following is the most likely explanation for the large difference between the second and third ionization energies?

- (A) The effective nuclear charge decreases with successive ionizations.
- (B) The shielding of outer electrons increases with successive ionizations.
- * (C) The electron removed during the third ionization is, on average, much closer to the nucleus than the first two electrons removed were.
- (D) The ionic radius increases with successive ionizations.

Topic
1.7 Periodic Trends

2016 Practice Exam #41

Q: Empirical formula of X and O given successive IE

	Ionization Energy (kJ/mol)
First	577
Second	1,816
Third	2,745
Fourth	11,577
Fifth	14,482

Based on the ionization energies of element X given in the table above, which of the following is most likely to be the empirical formula of an oxide of element X?

(A) XO_2

(B) X_2O

* (C) X_2O_3

(D) X_2O_5

Topic
1.7 Periodic Trends

2015 Practice Exam #12

Q: Identify B vs N from successive ionization energy

	Ionization Energy (kJ/mol)
First	801
Second	2,430
Third	3,660
Fourth	25,000
Fifth	32,820

The first five ionization energies of a second-period element are listed in the table above. Which of the following correctly identifies the element and best explains the data in the table?

- (A) B, because it has five core electrons
- * (B) B, because it has three valence electrons
- (C) N, because it has five valence electrons
- (D) N, because it has three electrons in the *p* sublevel

Topic
1.7 Periodic Trends

2014 Practice Exam #3

Q: Justify highest 1st ionization energy - Cl or Ar

Which of the following correctly identifies which has the higher first-ionization energy, Cl or Ar, and supplies the best justification?

- (A) Cl, because of its higher electronegativity
- (B) Cl, because of its higher electron affinity
- (C) Ar, because of its completely filled valence shell
- * (D) Ar, because of its higher effective nuclear charge

Topic
1.7 Periodic Trends

2014 Practice Exam #12

Q: 1st ionization energy - deviation from trend for O

Element	First Ionization Energy (kJ/mol)	Atomic Radius (pm)
B	801	85
C	1086	77
N	1400	75
O	1314	73
F	1680	72
Ne	2080	70

The table above shows the first ionization energy and atomic radius of several elements. Which of the following best helps to explain the deviation of the first ionization energy of oxygen from the overall trend?

- (A) The atomic radius of oxygen is greater than the atomic radius of fluorine.
- (B) The atomic radius of oxygen is less than the atomic radius of nitrogen.
- * (C) There is repulsion between paired electrons in oxygen's $2p$ orbitals.
- (D) There is attraction between paired electrons in oxygen's $2p$ orbitals.

Topic
1.7 Periodic Trends

2013 Practice Exam #4

Q: Which has more effective reducing ability than Zn

$\text{Zn}(s)$ is used to reduce other compounds in chemical reactions. If a chemist needs a substance that is more effective in its reducing ability, which of the following species would be the best choice?

- * (A) Na
- (B) H^+
- (C) K^+
- (D) Cl^-

Topic
1.7 Periodic Trends

2013 Practice Exam #58

Q: Radius and ionization energy of K given Ca data

Element	Atomic Radius	First Ionization Energy
Calcium	194 pm	590 kJ/mol
Potassium	—	—

Based on periodic trends and the data in the table above, which of the following are the most probable values of the atomic radius and the first ionization energy for potassium, respectively?

- (A) 242 pm, 633 kJ/mol
- * (B) 242 pm, 419 kJ/mol
- (C) 120 pm, 633 kJ/mol
- (D) 120 pm, 419 kJ/mol

Topic
1.8 Valence Electrons and Ionic Compounds

2023 Practice Exam (from AP Classroom)

Q: Likely formula from ionization energies

	Ionization Energy (kJ/mol)
First	786
Second	1,577
Third	3,232
Fourth	4,356
Fifth	16,091

Based on the successive ionization energies of element X shown in the table above, which of the following is most likely the formula of the compound produced when element X reacts with fluorine?

- (A) XF
- (B) XF₂
- * (C) XF₄
- (D) XF₅

Topic
1.8 Valence Electrons and Ionic Compounds

2022 Practice Exam (from AP Classroom)

Q: Compounds with similar properties

Based on the positions of elements in the periodic table, which of the following groups contains compounds that are most likely to have similar chemical properties?

- * (A) KCl, KBr, and KI
- (B) AsCl₃, SCl₂, and ClF
- (C) CF₄, PF₃, and SeF₂
- (D) NH₃, H₂O, and HF

Topic
1.8 Valence Electrons and Ionic Compounds

2019 Practice Exam #31

Q: Why Na is more reactive than Mg

Which of the following best helps to explain why Na(s) is more reactive with water than Mg(s) is?

- (A) Na(s) is softer than Mg(s).
- (B) The atomic mass of Na is less than that of Mg.
- (C) The Na⁺ ion has weaker Coulombic attraction to an anion than the Mg²⁺ ion has.

* (D) The first ionization energy of Na is less than that of Mg.

Topic
1.8 Valence Electrons and Ionic Compounds

2018 Practice Exam #9

Q: Empirical formula of X and P given successive IE

	Ionization Energy (kJ/mol)
First	730
Second	1450
Third	7700
Fourth	10,500

The ionization energies of an unknown element, X, are listed in the table above. Which of the following is the most likely empirical formula of a compound formed from element X and phosphorus, P?

- (A) XP
- (B) X₃P
- * (C) X₃P₂
- (D) X₃P₄

Topic
1.8 Valence Electrons and Ionic Compounds

2017 Practice Exam #44

Q: Halogen compound is fire-resistant like CCl_4

The compound CCl_4 is nonflammable and was once commonly used in fire extinguishers. On the basis of the periodic properties, which of the following compounds can most likely be used as a fire-resistant chemical?

- (A) BCl_3
- (B) CH_4
- * (C) CBr_4
- (D) PbCl_2

Topic
1.8 Valence Electrons and Ionic Compounds

2016 Practice Exam #41

Q: Empirical formula of X and O given successive IE

	Ionization Energy (kJ/mol)
First	577
Second	1,816
Third	2,745
Fourth	11,577
Fifth	14,482

Based on the ionization energies of element X given in the table above, which of the following is most likely to be the empirical formula of an oxide of element X?

(A) XO_2

(B) X_2O

* (C) X_2O_3

(D) X_2O_5

Topic
1.8 Valence Electrons and Ionic Compounds

2016 Practice Exam #49

Q: Likely oxides of Rb given table of group 1 oxides

Element	Known Oxides
H	H ₂ O, H ₂ O ₂
Li	Li ₂ O, Li ₂ O ₂
Na	Na ₂ O, Na ₂ O ₂ , NaO ₂
K	K ₂ O, K ₂ O ₂ , KO ₂

Based on the information above and periodic trends, which of the following is the best hypothesis regarding the oxide(s) formed by Rb?

- (A) Rb will form only Rb₂O.
- (B) Rb will form only RbO₂.
- (C) Rb will form only Rb₂O and Rb₂O₂.
- * (D) Rb will form Rb₂O, Rb₂O₂, and RbO₂.

Topic
1.8 Valence Electrons and Ionic Compounds

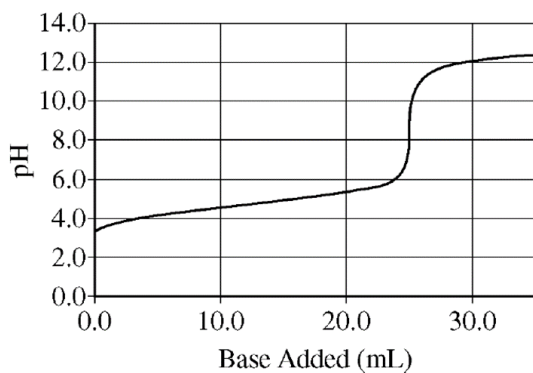
2015 Practice Exam #18

Q: $\text{Li} + \text{H}_2\text{O}$ - volume of gas produced with K vs Li

Questions X-Y refer to the following information.

A 0.35 g sample of $\text{Li}(s)$ is placed in an Erlenmeyer flask containing 100 mL of water at 25°C . A balloon is placed over the mouth of the flask to collect the hydrogen gas that is generated.

After all of the $\text{Li}(s)$ has reacted with $\text{H}_2\text{O}(l)$, the solution in the flask is added to a clean, dry buret and used to titrate an aqueous solution of a monoprotic acid. The pH curve for this titration is shown in the diagram below.



What will be the effect on the amount of gas produced if the experiment is repeated using 0.35 g of $\text{K}(s)$ instead of 0.35 g of $\text{Li}(s)$?

- (A) No gas will be produced when $\text{K}(s)$ is used.
- * (B) Some gas will be produced but less than the amount of gas produced with $\text{Li}(s)$.
- (C) Equal quantities of gas will be produced with the two metals.
- (D) More gas will be produced with $\text{K}(s)$ than with $\text{Li}(s)$.

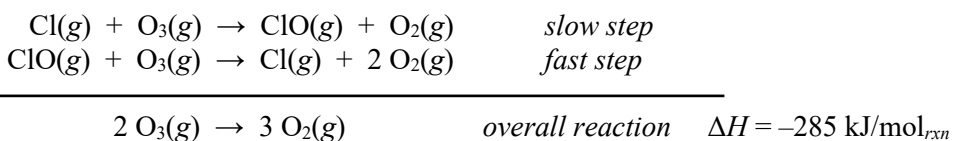
Topic
1.8 Valence Electrons and Ionic Compounds

2015 Practice Exam #44

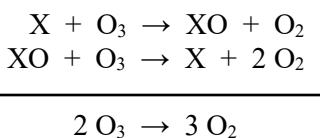
Q: Cl + O₃ mechanism - best substitute for Cl

Questions X-Y refer to the following information.

When free Cl(g) atoms encounter O₃(g) molecules in the upper atmosphere, the following reaction mechanism is proposed to occur.



The proposed mechanism can be written in a more general form, as shown below.



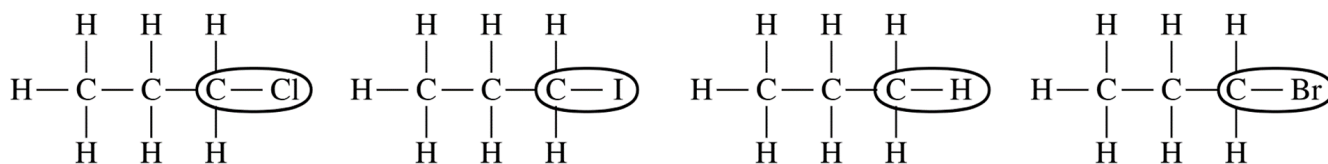
Species other than Cl can also decompose O₃ through the same mechanism. Which of the following chemical species is most likely to decompose O₃ in the upper atmosphere through the above mechanism?

- (A) He
- * (B) Br
- (C) N₂
- (D) O₂

Topic
2.1 Types of Chemical Bonds

2023 Practice Exam (from AP Classroom)

Q: Bond polarity with halogens



Which of the following bonds represented in the diagram above is the most polar?

- * (A) C-Cl
- (B) C-I
- (C) C-H
- (D) C-Br

Topic
2.1 Types of Chemical Bonds

2023 Practice Exam (from AP Classroom)

Q: Ionic character bonding with chlorine

An atom of chlorine and an atom of which of the following elements will form a bond with the most ionic character?

- (A) Germanium (Ge)
- (B) Carbon (C)
- (C) Copper (Cu)
- * (D) Potassium (K)

Topic
2.1 Types of Chemical Bonds

2022 Practice Exam (from AP Classroom)

Q: Ionic character

PCl_3 , Cl_2 , CaCl_2

Which of the following correctly ranks the substances listed above in order of increasing ionic character in their bonding?

- * (A) Cl_2 , PCl_3 , CaCl_2
- (B) Cl_2 , CaCl_2 , PCl_3
- (C) CaCl_2 , PCl_3 , Cl_2
- (D) CaCl_2 , Cl_2 , PCl_3

Topic
2.1 Types of Chemical Bonds

2021 Practice Exam (from AP Classroom)

Q: Ionic bonds

Which of the following substances has bonds with the greatest ionic character?

- (A) CCl_4
- (B) CuCl_2
- * (C) CaCl_2
- (D) NCl_3

Topic
2.1 Types of Chemical Bonds

2017 Practice Exam #4

Q: Arrange bonds in order of decreasing polarity

Which of the following has the bonds arranged in order of decreasing polarity?

- * (A) $\text{H-F} > \text{N-F} > \text{F-F}$
- (B) $\text{H-I} > \text{H-Br} > \text{H-F}$
- (C) $\text{O-N} > \text{O-S} > \text{O-Te}$
- (D) $\text{Sb-I} > \text{Sb-Te} > \text{Sb-Cl}$

Topic
2.1 Types of Chemical Bonds

2016 Practice Exam #7

Q: Arrange binary compounds in order of polarity

Element	Electronegativity
H	2.1
C	2.5
S	2.5
F	4.0
Cl	3.0
Si	1.8

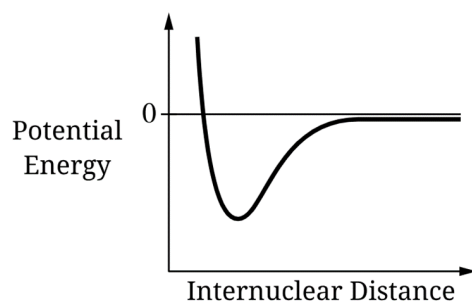
On the basis of the information above, which of the following arranges the binary compounds in order of increasing bond polarity?

- * (A) $\text{CH}_4 < \text{SiCl}_4 < \text{SF}_4$
- (B) $\text{CH}_4 < \text{SF}_4 < \text{SiCl}_4$
- (C) $\text{SF}_4 < \text{CH}_4 < \text{SiCl}_4$
- (D) $\text{SiCl}_4 < \text{SF}_4 < \text{CH}_4$

Topic
2.2 Intramolecular Force and Potential Energy

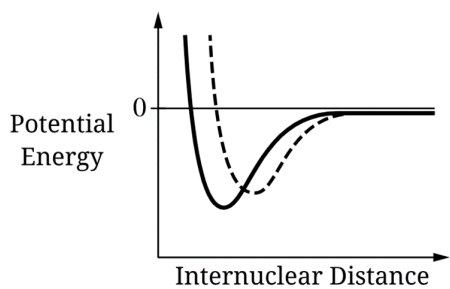
2023 Practice Exam (from AP Classroom)

Q: Potential energy plot for HBr

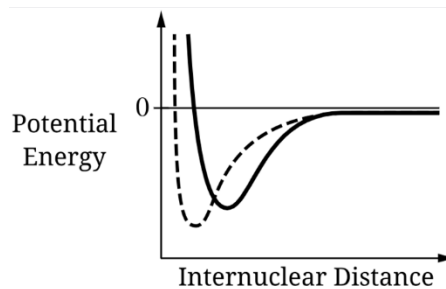


The graph of potential energy versus internuclear distance for the HCl molecule is shown. Which of the following graphs includes the plot for the HBr molecule, shown as a dashed line?

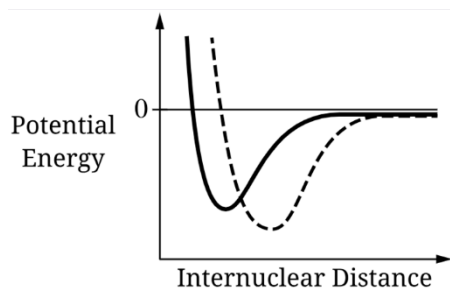
* (A)



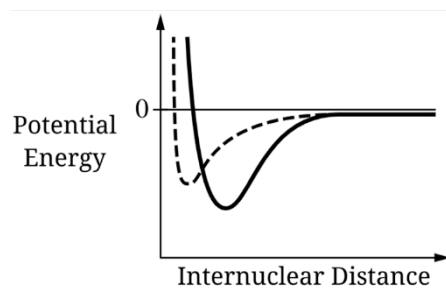
(C)



(B)



(D)

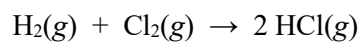


Topic
2.2 Intramolecular Force and Potential Energy

2023 Practice Exam (from AP Classroom)

Q: Rank Internuclear Distances

Gaseous hydrogen and gaseous chlorine can react to form hydrogen chloride gas, as represented by the following equation.



Which of the following correctly ranks the internuclear distances for the H_2 , Cl_2 , and HCl molecules from shortest to longest?

- (A) $\text{H}_2 < \text{Cl}_2 < \text{HCl}$
- * (B) $\text{H}_2 < \text{HCl} < \text{Cl}_2$
- (C) $\text{Cl}_2 < \text{HCl} < \text{H}_2$
- (D) $\text{Cl}_2 < \text{H}_2 < \text{HCl}$

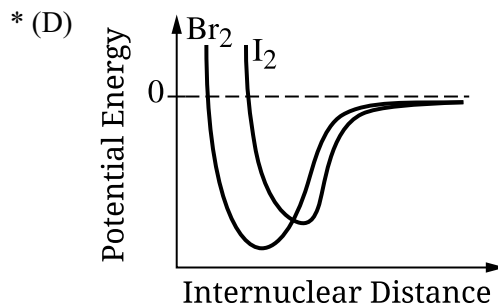
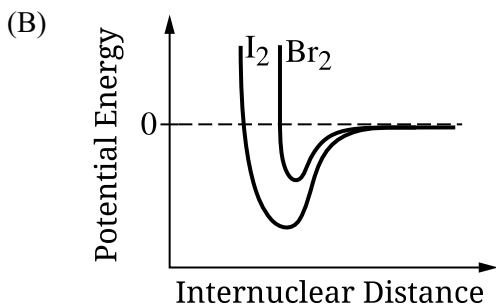
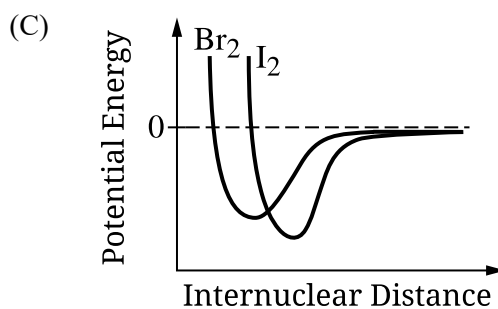
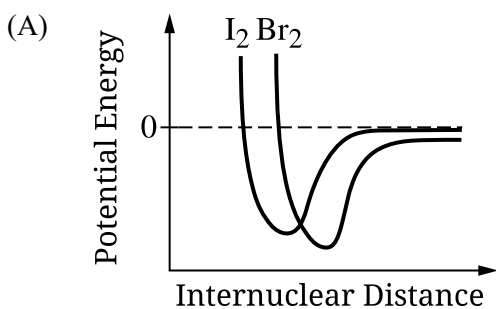
Topic
2.2 Intramolecular Force and Potential Energy

2022 Practice Exam (from AP Classroom)

Q: Morse potential of Br_2 and I_2

Molecule	Bond Dissociation Energy (kJ/mol)
Br_2	193
I_2	151

The table above shows the bond dissociation energies for Br_2 and I_2 at 298 K. Which of the following correctly shows the potential energy as a function of internuclear distance for two bromine atoms and two iodine atoms?



Topic
2.2 Intramolecular Force and Potential Energy

2021 Practice Exam (from AP Classroom)

Q: Explain higher melting point

Compound	Melting Point (°C)
MgO	2852
NaF	993

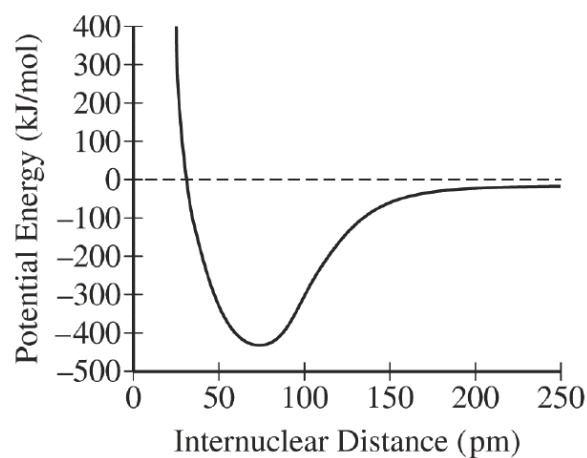
The table above shows the melting points of $\text{MgO}(s)$ and $\text{NaF}(s)$. Which of the following best helps explain why the melting point of $\text{MgO}(s)$ is much higher than that of $\text{NaF}(s)$?

- (A) The mass of F^- ions is greater than that of O^{2-} ions.
- (B) The mass of Mg^{2+} ions is greater than that of Na^+ ions.
- (C) The difference between the electronegativity values of Mg and O is smaller than the difference between the values of Na and F.
- * (D) The charges of Mg^{2+} and O^{2-} ions are greater than those of Na^+ and F^- ions.

Topic
2.2 Intramolecular Force and Potential Energy

2019 Practice Exam #24

Q: Bond length from Morse potential diagram



Which of the following can be inferred from the diagram above that shows the dependence of potential energy on the internuclear distance between two atoms?

- (A) The atoms form a bond with a bond length of 25 pm.
- * (B) The atoms form a bond with a bond length of 75 pm.
- (C) The net force between the atoms is attractive at 25 pm.
- (D) The net force between the atoms is attractive at 75 pm.

Topic
2.2 Intramolecular Force and Potential Energy

2015 Practice Exam #2

Q: Lattice energy - ion pair hardest to separate

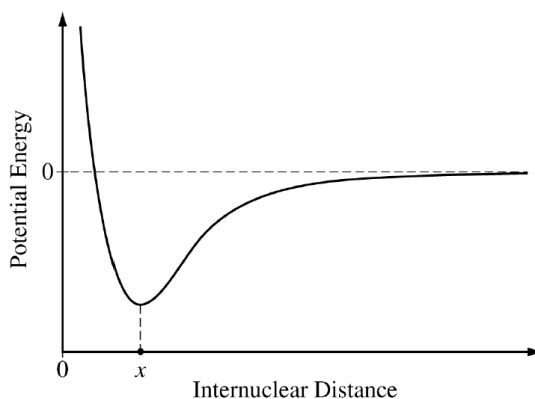
The lattice energy of a salt is related to the energy required to separate the ions. For which of the following pairs of ions is the energy that is required to separate the ions largest? (Assume that the distance between the ions in each pair is equal to the sum of the ionic radii.)

- (A) $\text{Na}^+(g)$ and $\text{Cl}^-(g)$
- (B) $\text{Cs}^+(g)$ and $\text{Br}^-(g)$
- * (C) $\text{Mg}^{2+}(g)$ and $\text{O}^{2-}(g)$
- (D) $\text{Ca}^{2+}(g)$ and $\text{O}^{2-}(g)$

Topic
2.2 Intramolecular Force and Potential Energy

2015 Practice Exam #47

Q: Morse potential diagram - forces at point x



The potential energy of a system of two atoms as a function of their internuclear distance is shown in the diagram above. Which of the following is true regarding the forces between the atoms when their internuclear distance is x ?

- * (A) The attractive and repulsive forces are balanced, so the atoms will maintain an average internuclear distance x .
- (B) There is a net repulsive force pushing the atoms apart, so the atoms will move farther apart.
- (C) There is a net attractive force pulling the atoms together, so the atoms will move closer together.
- (D) It cannot be determined whether the forces between atoms are balanced, attractive, or repulsive, because the diagram shows only the potential energy.

Topic
2.2 Intramolecular Force and Potential Energy

2014 Practice Exam #5

Q: Why enthalpy of dissolution is positive for CaF_2

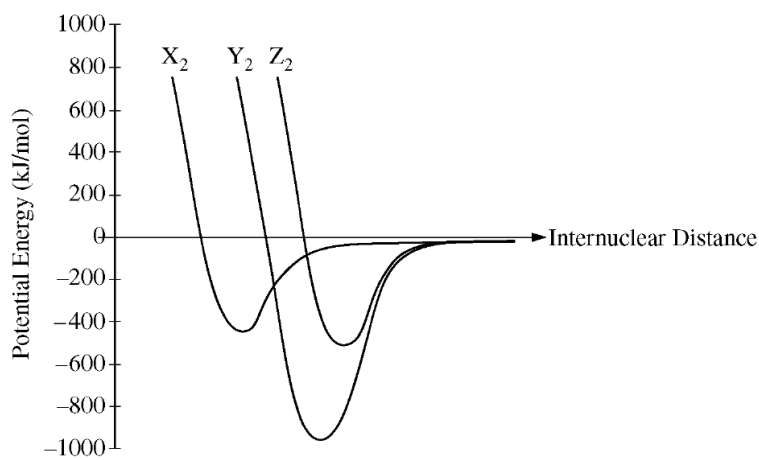
Which of the following best helps to explain why the value of ΔH° for the dissolving of CaF_2 in water is positive?

- (A) $\text{CaF}_2(s)$ is insoluble in water.
- (B) $\text{CaF}_2(s)$ dissolves in water to form $\text{CaF}_2(aq)$ particles.
- * (C) Ca^{2+} ions have very strong ion-ion interactions with F^- ions in the crystal lattice.
- (D) Ca^{2+} ions have very strong ion-dipole interactions with water molecules in the solution.

Topic
2.2 Intramolecular Force and Potential Energy

2014 Practice Exam #17

Q: Identify H₂ N₂ O₂ from Morse potential diagram



The potential energy as a function of internuclear distance for three diatomic molecules, X₂, Y₂, and Z₂, is shown in the graph above. Based on the data in the graph, which of the following correctly identifies the diatomic molecules, X₂, Y₂, and Z₂ ?

	X ₂	Y ₂	Z ₂
* (A)	H ₂	N ₂	O ₂
(B)	H ₂	O ₂	N ₂
(C)	N ₂	O ₂	H ₂
(D)	O ₂	H ₂	N ₂

Topic
2.2 Intramolecular Force and Potential Energy

2013 Practice Exam #54

Q: Given ionic radius and charge - predict BP of NaCl

	NaF	MgO
Boiling Point (°C)	1695	3600

	Na ⁺	Mg ²⁺	F ⁻	Cl ⁻	O ²⁻
Ionic Radius (pm)	76	72	133	181	140

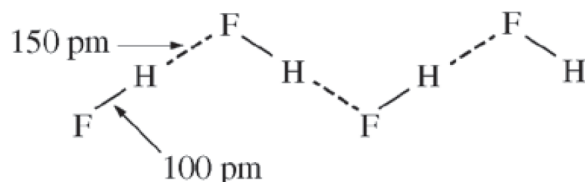
Based on the data in the tables above, which of the following statements provides the best prediction for the boiling point of NaCl?

- * (A) NaCl will have a lower boiling point than NaF because the coulombic attractions are weaker in NaCl than in NaF.
- (B) NaCl will have a boiling point between that of NaF and MgO because the covalent character of the bonds in NaCl is intermediate between that of MgO and NaF.
- (C) NaCl will have a higher boiling point than MgO because the ions are spaced farther apart in NaCl.
- (D) NaCl will have a higher boiling point than MgO because the energy required to transfer electrons from the anion to the cation is larger in NaCl than in MgO.

Topic
2.2 Intramolecular Force and Potential Energy

2013 Practice Exam #59

Q: Solid HF - reason for bond length vs IMF distance



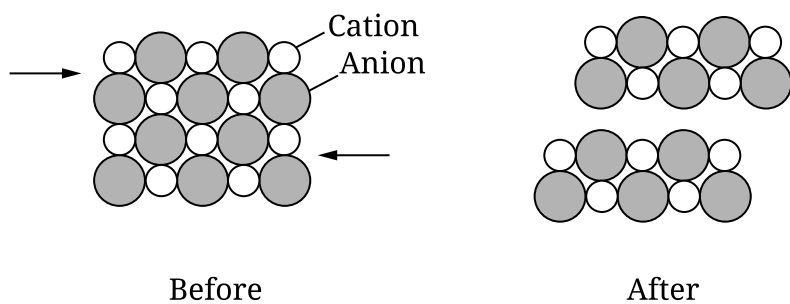
The figure above shows that in solid hydrogen fluoride there are two different distances between H atoms and F atoms. Which of the following best accounts for the two different distances?

- (A) Accommodation of the necessary bond angles in the formation of the solid
- * (B) Difference in strength between covalent bonds and intermolecular attractions
- (C) Different isotopes of fluorine present in the samples
- (D) Uneven repulsions among nonbonding electron pairs

Topic
2.3 Structure of Ionic Solids

2022 Practice Exam (from AP Classroom)

Q: Stress on ionic crystal



When a stress is applied to an ionic crystal, the planes of the ions slide and separate due to the alignment of like charges, as shown in the diagram above. Which of the following characteristics of the crystal is represented by the observation?

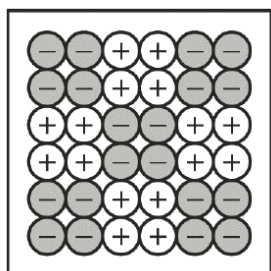
- (A) Luster
- * (B) Brittleness
- (C) High melting point
- (D) Solubility in water

Topic
2.3 Structure of Ionic Solids

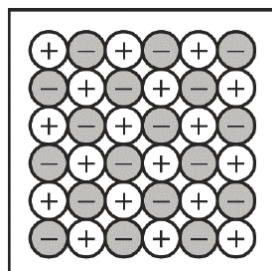
2019 Practice Exam #9

Q: Particle diagram - best representation of solid KF

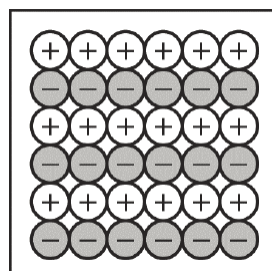
Of the following diagrams, which best represents the structure of solid KF?



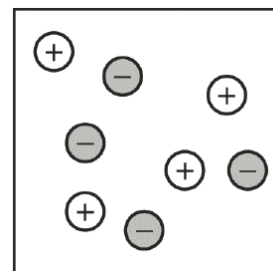
(A)



*(B)



(C)



(D)

Topic
2.3 Structure of Ionic Solids

2014 Practice Exam #47

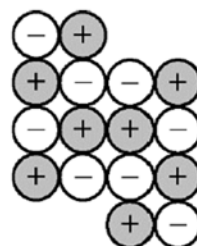
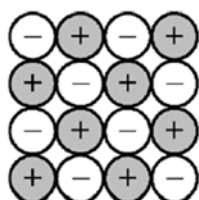
Q: Particle diagram - why an ionic crystal is brittle

Which of the following diagrams best illustrates how a displacement in an ionic crystal results in cleavage and brittleness?

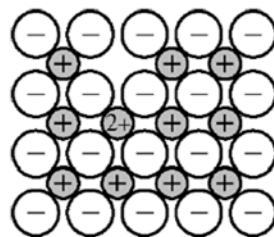
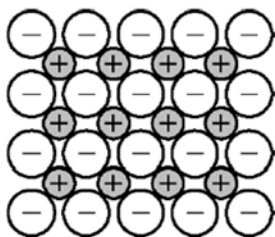
Before Displacement

After Displacement

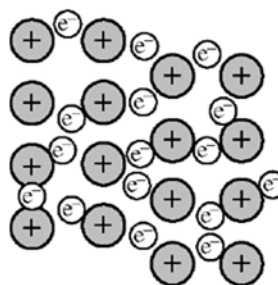
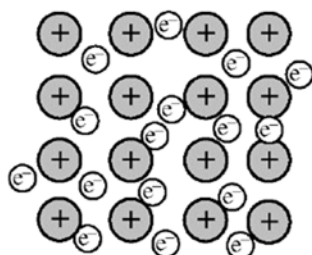
* (A)



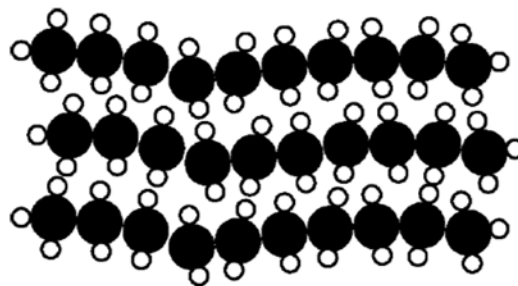
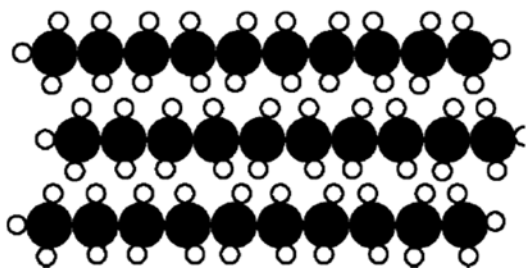
(B)



(C)



(D)



Topic
2.4 Structure of Metals and Alloys

2017 Practice Exam #27

Q: Why high-carbon steel more rigid than low-carbon

Type of Steel	% Carbon	Characteristics	Uses
Low-carbon steel	< 0.2 %	Malleable and ductile	Chains and nails
High-carbon steel	0.6 – 1.5 %	Hard and brittle	Cutting tools

The table above provides some information about two types of steel, both of which are alloys of iron and carbon. Which of the following best helps to explain why high-carbon steel is more rigid than low-carbon steel?

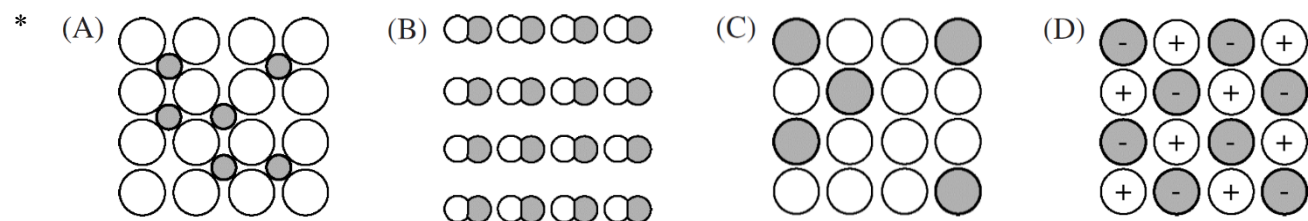
- (A) Elemental carbon is harder than elemental iron.
- (B) The additional carbon atoms within the alloy make the high-carbon steel less dense.
- (C) The additional carbon atoms within the alloy increase the thermal conductivity of the high-carbon steel.
- * (D) The additional carbon atoms within the alloy make it more difficult for the iron atoms to slide past one another.

Topic
2.4 Structure of Metals and Alloys

2015 Practice Exam #4

Q: Particulate diagram - an alloy of Ni and B

Which of the following diagrams best depicts an alloy of Ni and B?

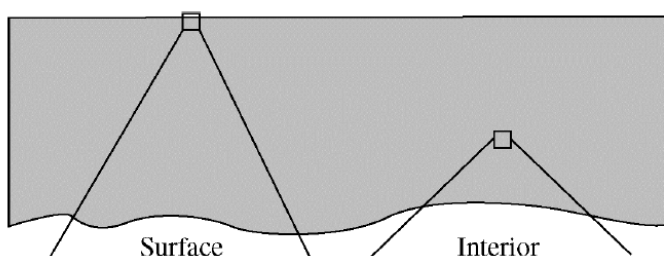


Topic
2.4 Structure of Metals and Alloys

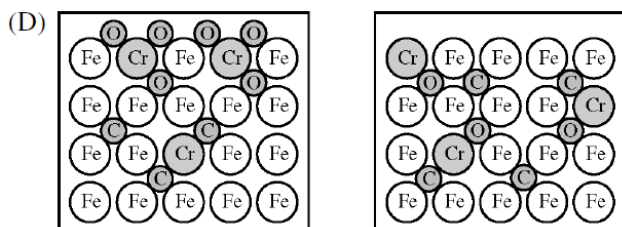
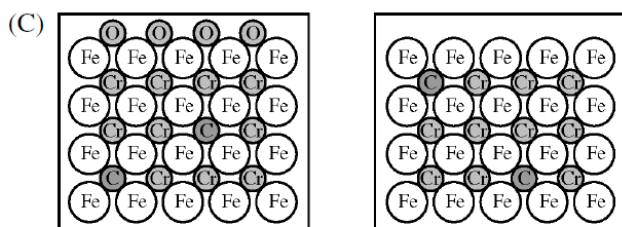
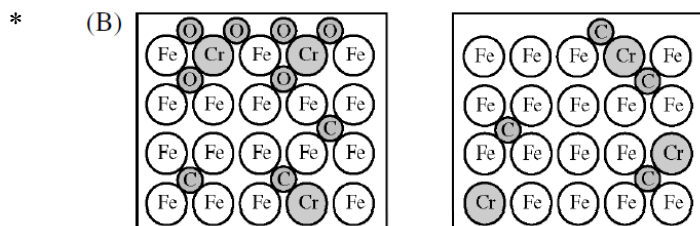
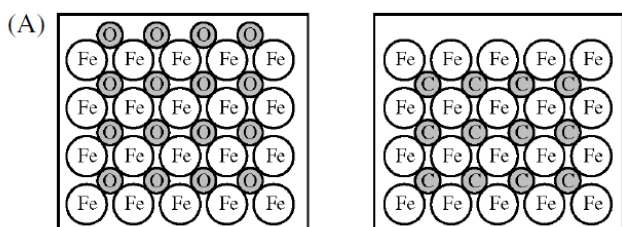
2014 Practice Exam #42

Q: Particle diagram of steel that is 15 percent Cr

Steel is an alloy consisting of Fe with a small amount of C. Elemental Cr can be added to steel to make the steel less likely to rust; Cr atoms react with oxygen in the air to form a nonreactive layer of chromium oxide on the surface of the steel, preventing the oxidation of underlying Fe atoms. A sample of steel-chromium alloy contains 15 percent Cr by mass. Which of the following diagrams best shows a particle-level view of a surface section and an interior section of the alloy represented below at the left? (The atomic radii of the atoms involved are given in the table below on the right.)



Element	Molar Mass (g/mol)	Atomic Radius (pm)
Fe	55.85	125
Cr	52.00	127
C	12.01	77
O	16.00	73



Topic
2.4 Structure of Metals and Alloys

2013 Practice Exam #42

Q: Explain why Au-Cu alloy is harder than Au-Ag alloy

Element	Metallic Radius (pm)	Melting Point (°C)	Common Oxidation State
Au	144	1064	1+, 3+
Cu	128	1085	1+, 2+
Ag	144	961	1+

To make Au stronger and harder, it is often alloyed with other metals, such as Cu and Ag. Consider two alloys, one of Au and Cu and one of Au and Ag, each with the same mole fraction of Au. If the Au/Cu alloy is harder than the Au/Ag alloy, then which of the following is the best explanation based on the information in the table above?

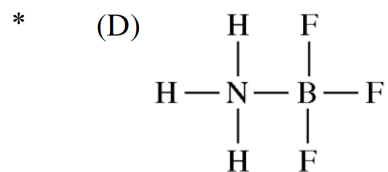
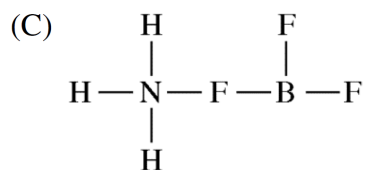
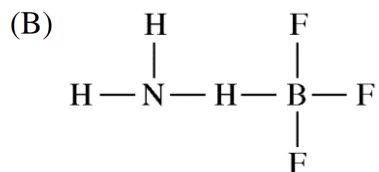
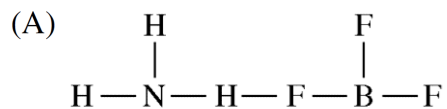
- (A) Cu has two common oxidation states, but Ag has only one.
- (B) Cu has a higher melting point than Au has, but Ag has a lower melting point than Au has.
- * (C) Cu atoms are smaller than Ag atoms; they interfere more with the displacement of atoms in the alloy.
- (D) Cu atoms are less polarizable than are Au or Ag atoms; Cu has weaker interparticle forces.

Topic
2.5 Lewis Diagrams

2017 Practice Exam #30

Q: Structure of product when NH_3 reacts with BF_3

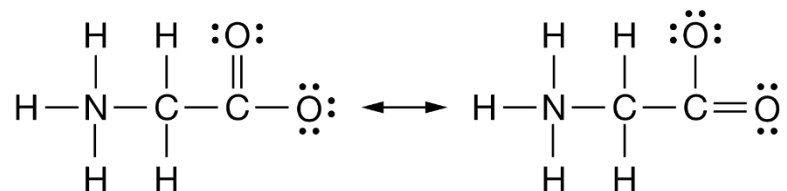
NH_3 reacts with BF_3 to form a single species. Which of the following structural diagrams is the most likely representation of the product of the reaction?



Topic
2.6 Resonance and Formal Charge

2021 Practice Exam (from AP Classroom)

Q: Bond orders



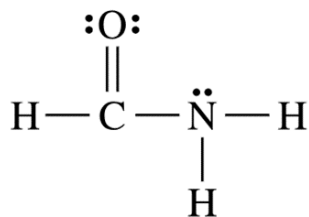
Based on the resonance structures shown above, what are the bond orders of the two carbon-oxygen bonds?

- (A) 1 and 1.5
- (B) 1 and 2
- * (C) 1.5 and 1.5
- (D) 2 and 2

Topic
2.7 VSEPR and Hybridization

2023 Practice Exam (from AP Classroom)

Q: Hybridization of carbon



The complete Lewis electron-dot diagram for HCONH_2 is shown above. Identify the hybridization of the valence orbitals for the carbon atom and the approximate hydrogen-carbon-nitrogen bond angle according to VSEPR theory.

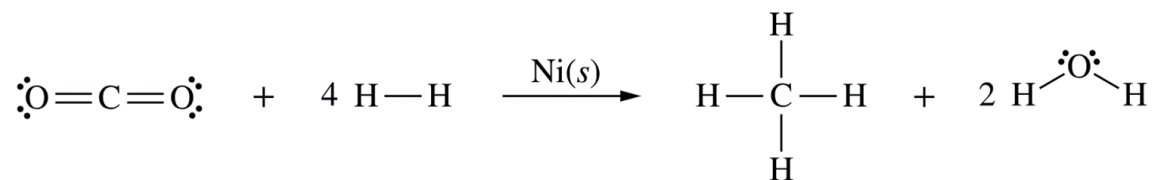
- (A) sp hybridized and 180°
- * (B) sp^2 hybridized and 120°
- (C) sp^2 hybridized and 180°
- (D) sp^3 hybridized and 120°

Topic
2.7 VSEPR and Hybridization

2023 Practice Exam (from AP Classroom)

Q: Hybridization of Methane and Water

In the gas-phase reaction represented by the following equation, methane (CH_4) and water (H_2O) are produced from carbon dioxide (CO_2) and hydrogen (H_2) at high temperature and pressure.



Which of the following identifies the hybridization of the valence orbitals of the central atoms of the methane and water molecules?

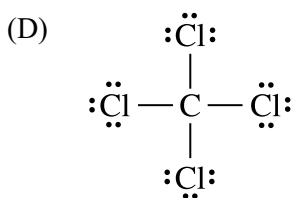
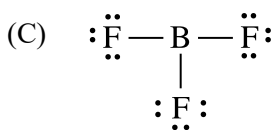
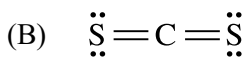
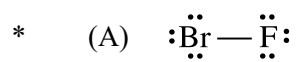
	CH_4	H_2O
(A)	sp^2	sp
(B)	sp^2	sp^2
(C)	sp^3	sp^2
* (D)	sp^3	sp^3

Topic
2.7 VSEPR and Hybridization

2022 Practice Exam (from AP Classroom)

Q: Largest dipole moment

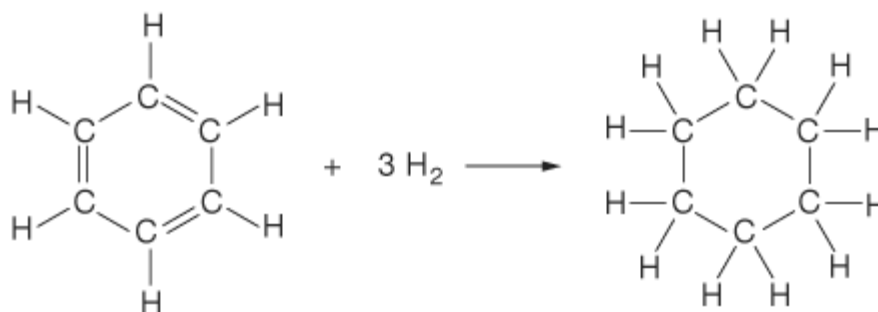
Which of the following molecules has the largest dipole moment?



Topic
2.7 VSEPR and Hybridization

2021 Practice Exam (from AP Classroom)

Q: Hybridization



Set	Before	After
A	sp^2	sp^2
B	sp^2	sp^3
C	sp^3	sp^2
D	sp^3	sp^3

In the reaction represented above, which of the following sets correctly identifies the hybridization of the C atoms before and after the reaction occurs?

- (A) Set A
- * (B) Set B
- (C) Set C
- (D) Set D

Topic
2.7 VSEPR and Hybridization

2021 Practice Exam (from AP Classroom)

Q: Dipole moment

CS_2	PCl_3	SF_6	CF_4
$\text{:}\ddot{\text{S}}=\text{C}=\ddot{\text{S}}\text{:}$	$\begin{array}{c} \text{:}\ddot{\text{Cl}}\text{:} \\ \\ \text{:}\ddot{\text{Cl}}-\text{P}-\ddot{\text{Cl}}\text{:} \\ \\ \text{:}\ddot{\text{Cl}}\text{:} \end{array}$	$\begin{array}{c} \text{:}\ddot{\text{F}}\text{:} \\ / \quad \backslash \\ \text{:}\ddot{\text{F}}\text{:} \quad \text{:}\ddot{\text{F}}\text{:} \\ \quad \\ \text{:}\ddot{\text{S}}\text{:} \\ \quad \\ \text{:}\ddot{\text{F}}\text{:} \quad \text{:}\ddot{\text{F}}\text{:} \\ \backslash \quad / \\ \text{:}\ddot{\text{F}}\text{:} \end{array}$	$\begin{array}{c} \text{:}\ddot{\text{F}}\text{:} \\ \\ \text{:}\ddot{\text{F}}-\text{C}-\ddot{\text{F}}\text{:} \\ \\ \text{:}\ddot{\text{F}}\text{:} \end{array}$

Based on the diagrams shown above, which of the following would have the greatest dipole moment, and why?

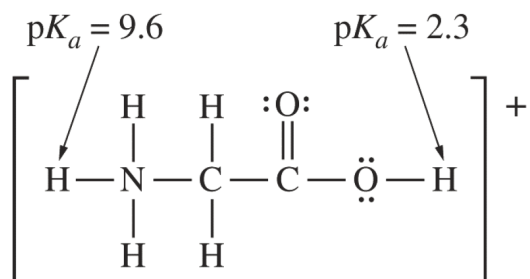
- (A) CS_2 , because the double bonds create an area of higher electron density around the C atom.
- * (B) PCl_3 , because the Cl atoms draw electron density away from the P atom and the bond dipoles do not cancel one another.
- (C) SF_6 , because it has the greatest number of polar bonds.
- (D) CF_4 , because the large electronegativity difference between C and F results in very polar bonds.

Topic
2.7 VSEPR and Hybridization

2019 Practice Exam #42

Q: Glycinium cation - H-O-C bond angle

Questions X-Y refer to the following.



The structural formula of the glycinium cation is shown above. Arrows indicate the $\text{p}K_a$ values for the labile protons in the molecule.

What is the approximate H-O-C bond angle in the glycinium cation?

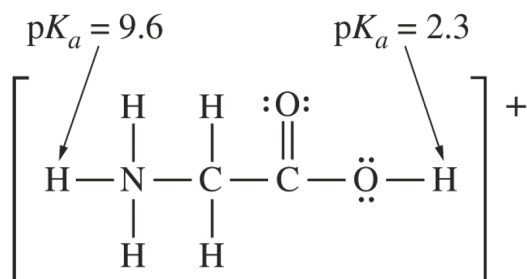
- (A) 180°
- (B) 120°
- * (C) 105°
- (D) 90°

Topic
2.7 VSEPR and Hybridization

2019 Practice Exam #43

Q: Glycinium cation - geometry

Questions X-Y refer to the following.



The structural formula of the glycinium cation is shown above. Arrows indicate the $\text{p}K_a$ values for the labile protons in the molecule.

Which of the following is true about the geometry of the glycinium cation?

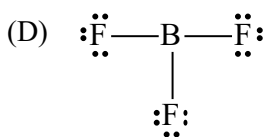
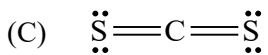
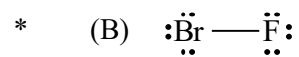
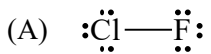
- (A) The leftmost C atom and all the atoms directly bonded to it lie in the same plane.
- * (B) Both C atoms and both O atoms lie in the same plane.
- (C) The N–C–C bond angle is 180° .
- (D) The geometry around the N atom is planar.

Topic
2.7 VSEPR and Hybridization

2018 Practice Exam #18

Q: Most polar molecule given Lewis structure

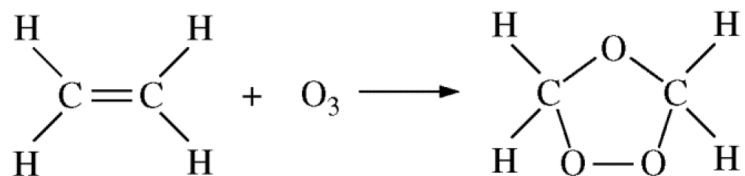
Which of the following Lewis electron-dot diagrams represents the molecule that is the most polar?



Topic
2.7 VSEPR and Hybridization

2017 Practice Exam #7

Q: Hybridization on C atoms before and after reaction



In the reaction represented above, what is the hybridization of the C atoms before and after the reaction occurs?

	Before	After
(A)	sp	sp^2
(B)	sp	sp^3
(C)	sp^2	sp
* (D)	sp^2	sp^3

Topic
2.7 VSEPR and Hybridization

2017 Practice Exam #21

Q: Given compound formula - most soluble in H₂O

On the basis of molecular structure and bond polarity, which of the following compounds is most likely to have the greatest solubility in water?

- (A) CH₄
- (B) CCl₄
- * (C) NH₃
- (D) PH₃

Topic
2.7 VSEPR and Hybridization

2016 Practice Exam #5

Q: Order N₂, O₂, and F₂ by bond enthalpy

Which of the following arranges the molecules N₂, O₂, and F₂ in order of their bond enthalpies, from least to greatest?

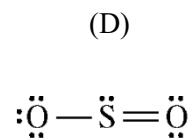
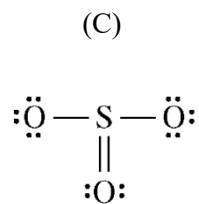
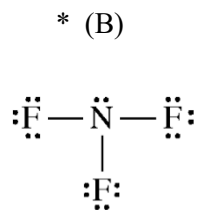
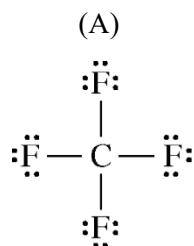
- * (A) F₂ < O₂ < N₂
- (B) O₂ < N₂ < F₂
- (C) N₂ < O₂ < F₂
- (D) N₂ < F₂ < O₂

Topic
2.7 VSEPR and Hybridization

2016 Practice Exam #27

Q: Given Lewis structures - smallest bond angle

Which of the following Lewis electron-dot diagrams represents the molecule that contains the smallest bond angle?

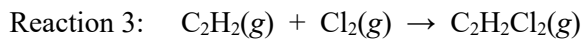
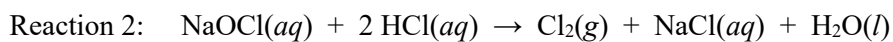
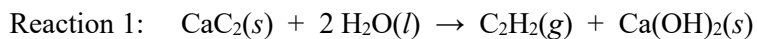


Topic
2.7 VSEPR and Hybridization

2015 Practice Exam #36

Q: CaC₂ rxn - hybridization change on C in Rxn 3

Questions X-Y refer to the reactions represented below, which are involved in a demonstration commonly known as "underwater fireworks."



When Reaction 3 occurs, does the hybridization of the carbon atoms change?

- * (A) Yes; it changes from sp to sp^2 .
- (B) Yes; it changes from sp to sp^3 .
- (C) Yes; it changes from sp^2 to sp^3 .
- (D) No; it does not change.

Topic
2.7 VSEPR and Hybridization

2014 Practice Exam #35

Q: Why BF_3 is nonpolar and NF_3 is polar

The BF_3 molecule is nonpolar, whereas the NF_3 molecule is polar. Which of the following statements accounts for the difference in polarity of the two molecules?

- (A) In NF_3 , each F is joined to N with multiple bonds, whereas in BF_3 , each F is joined to B with single bonds.
- (B) N – F bonds are polar, whereas B – F bonds are nonpolar.
- (C) NF_3 is an ionic compound, whereas BF_3 is a molecular compound.
- * (D) Unlike BF_3 , NF_3 has nonplanar geometry due to an unshared pair of electrons on the N atom.

Topic
2.7 VSEPR and Hybridization

2013 Practice Exam #23

Q: Compare geometry and polarity of CO₂ and SO₂



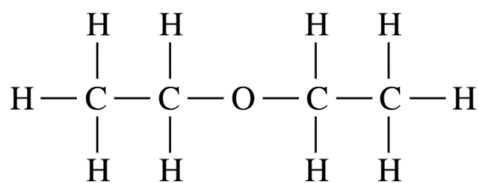
Lewis electron-dot diagrams for CO₂ and SO₂ are given above. The molecular geometry and polarity of the two substances are

- (A) the same because the molecular formulas are similar
- (B) the same because C and S have similar electronegativity values
- (C) different because the lone pair of electrons on the S atom make it the negative end of a dipole
- * (D) different because S has a greater number of electron domains (regions of electron density) surrounding it than C has

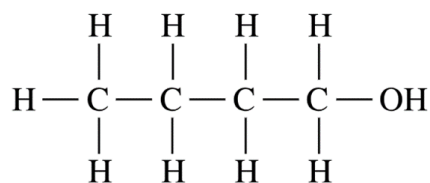
Topic
3.1 Intermolecular and Interparticle Forces

2023 Practice Exam (from AP Classroom)

Q: IMF comparison of liquids



Compound 1



Compound 2

The structural formulas of two compounds that are liquids at room temperature are shown above. Which of the following statements best explains the observation that compound 1 boils at 35°C, whereas its structural isomer, compound 2, boils at 118°C?

- (A) Molecules of compound 1 have a linear shape and no net dipole, whereas molecules of compound 2 have a bent shape and are polar.
- (B) Molecules of compound 1 are bent less than molecules of compound 2; thus they have weaker dipole-dipole attractions.
- (C) There are dipole-dipole attractions among molecules of compound 1, whereas there are only dispersion forces among molecules of compound 2.
- * (D) Although there are dipole-dipole attractions among molecules of both compound 1 and compound 2, the –OH group in compound 2 allows strong hydrogen bonding to occur.

Topic
3.1 Intermolecular and Interparticle Forces

2022 Practice Exam (from AP Classroom)

Q: IMFs and boiling point

Substance	Structural Formula	Molar Mass (g/mol)
Propylamine	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{N} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \end{array} $	59
Pentane	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} - \text{H} \\ & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	72
2-Propanol	$ \begin{array}{ccccccc} & & & \text{H} & & & \\ & & & & & & \\ & \text{H} & & \text{O} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \end{array} $	60
Propanoic acid	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{O} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{O} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & & \end{array} $	74

A student was given samples of four different unknown liquids. The unknown liquids are propylamine, pentane, 2-propanol, and propanoic acid. The structures and molar masses of the compounds are shown in the table above. On the basis of this information, the student designed some experiments to identify the samples.

Which of the following statements correctly identifies which compound, pentane or propanoic acid, has the higher boiling point and provides a valid justification?

- (A) Pentane, because it has greater London dispersion forces than propanoic acid does
- (B) Pentane, because it can form more hydrogen bonds per molecule than propanoic acid can
- (C) Propanoic acid, because double bonds are harder to break than single bonds
- * (D) Propanoic acid, because it forms hydrogen bonds, whereas pentane does not

Topic
3.1 Intermolecular and Interparticle Forces

2022 Practice Exam (from AP Classroom)

Q: Ne Xe boiling points

Which element, Ne or Xe, has the lower boiling point, and why?

- * (A) Ne, because it has a smaller, less polarizable electron cloud than Xe
- (B) Ne, because its atoms have a faster average speed at a given temperature than Xe atoms
- (C) Xe, because it has a larger, more polarizable electron cloud than Ne
- (D) Xe, because its atoms have a slower average speed at a given temperature than Ne atoms

Topic
3.1 Intermolecular and Interparticle Forces

2022 Practice Exam (from AP Classroom)

Q: Physical states of Br₂ and I₂

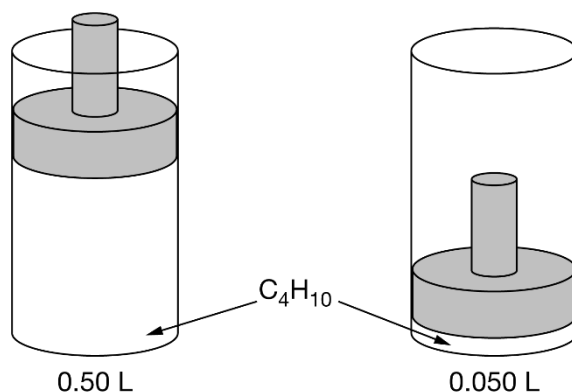
At 298 K and 1 atm, Br₂ is a liquid and I₂ is a crystalline solid. Which of the following statements best explains the different physical states of Br₂ and I₂ at 298 K and 1 atm?

- * (A) The London dispersion forces among I₂ molecules are stronger than those among Br₂ molecules.
- (B) The London dispersion forces among Br₂ molecules are stronger than those among I₂ molecules.
- (C) The Br–Br bond is stronger than the I–I bond.
- (D) The I–I bond is stronger than the Br–Br bond.

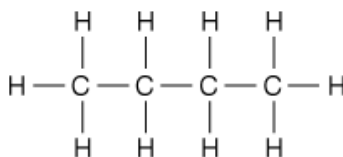
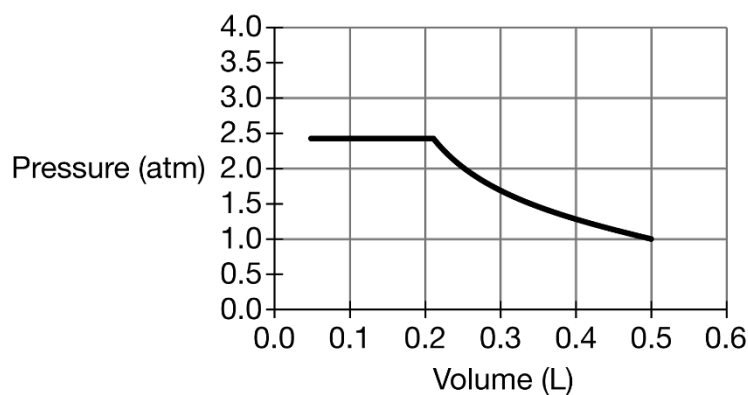
Topic
3.1 Intermolecular and Interparticle Forces

2021 Practice Exam (from AP Classroom)

Q: IMF in C_4H_{10}



A sample of $C_4H_{10}(g)$ is placed in a rigid vessel with a movable piston. The volume of the gas is reduced by moving the piston downward while the temperature is maintained at 25°C , as shown above. The pressure of the gas versus its volume is plotted in the graph below.



The Lewis electron-dot diagram for C_4H_{10} is shown above. Which of the following is the predominant type of intermolecular force among C_4H_{10} molecules?

- (A) Hydrogen bonding
- * (B) London dispersion forces
- (C) Dipole-dipole attractions
- (D) Dipole-induced dipole attractions

Topic
3.1 Intermolecular and Interparticle Forces

2021 Practice Exam (from AP Classroom)

Q: Reason for higher boiling point

Compound	Structure	Boiling Point (°C)
Methanol	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	65
Ethanol	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	78
Propanal	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{:O:} \\ \quad \quad // \\ \text{H}-\text{C}-\text{C}-\text{C} \\ \quad \quad \backslash \\ \text{H} \quad \text{H} \quad \text{H} \end{array} $	49
Hexane	$ \begin{array}{cccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $	69

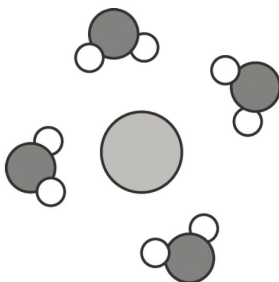
Which of the following best helps to explain why hexane has a higher boiling point than methanol has?

- (A) Methanol molecules can form hydrogen bonds with other methanol molecules.
- (B) Hexane cannot form hydrogen bonds with other hexane molecules.
- (C) Methanol molecules have attractions to one another due to London dispersion forces.
- * (D) Hexane molecules have electron clouds that are larger than those of methanol molecules.

Topic
3.1 Intermolecular and Interparticle Forces

2019 Practice Exam #5

Q: Ion charge from H₂O orientation in solution



The diagram above represents a particle in aqueous solution. Which of the following statements about the particle is correct?

- (A) The particle must be a cation because the negative end of each water molecule is pointed toward it.
- * (B) The particle must be an anion because the positive end of each water molecule is pointed toward it.
- (C) The charge of the particle cannot be determined because water molecules have no net charge.
- (D) The charge of the particle cannot be determined because the water molecules are arranged symmetrically, and their partial charges cancel.

Topic
3.1 Intermolecular and Interparticle Forces

2019 Practice Exam #17

Q: Combustion rxn enthalpy - compound soluble in H₂O

Questions X-Y are based on the information in the table below.

Compound	Molar Mass	Balanced Equation for the Combustion of One Mole of the Compound	ΔH_{comb}° (kJ/mol _{rxn})
$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \\ \text{Ethane} \end{array}$	30. g/mol	$\text{C}_2\text{H}_6(g) + \frac{7}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$	-1560
$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \\ \text{Propanol} \end{array}$	60. g/mol	$\text{C}_3\text{H}_8\text{O}(l) + \frac{9}{2}\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2020
Unknown	?	$? + 5\text{O}_2(g) \rightarrow 4\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2240

Based on the structural formulas, which of the following identifies the compound that is more soluble in water and best helps to explain why?

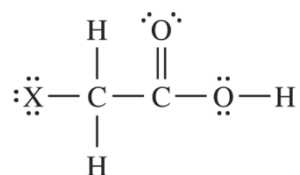
- (A) Ethane, because the electron clouds of its molecules are more polarizable than those of propanol.
- (B) Ethane, because its molecules can fit into the spaces between water molecules more easily than those of propanol can.
- (C) Propanol, because its molecules have a greater mass than the molecules of ethane have.
- * (D) Propanol, because its molecules can form hydrogen bonds with water molecules but those of ethane cannot.

Topic
3.1 Intermolecular and Interparticle Forces

2019 Practice Exam #26

Q: Haloacetic acids - lowest boiling point and why

Questions X-Y are based on the following information.



The structure of haloacetic acids, XCH_2COOH (where X is either F, Cl, Br, or I), is shown above. The dissociation constants and molar masses of four haloacetic acids are listed in the table below.

Acid	$\text{p}K_a$	K_a	Molar Mass (g/mol)
Fluoroacetic acid	2.59	2.57×10^{-3}	78.0
Chloroacetic acid	2.87	1.35×10^{-3}	94.5
Bromoacetic acid	2.90	1.26×10^{-3}	138.9
Iodoacetic acid	3.18	6.61×10^{-4}	185.9

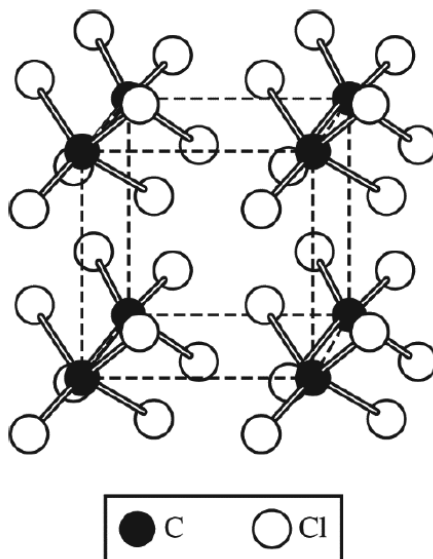
Which compound, chloroacetic acid or iodoacetic acid, most likely has the lower boiling point, and why?

- * (A) Chloroacetic acid, because the London dispersion forces among its molecules are weaker.
- (B) Chloroacetic acid, because the dipole-dipole forces among its molecules are weaker.
- (C) Iodoacetic acid, because the London dispersion forces among its molecules are stronger.
- (D) Iodoacetic acid, because the dipole-dipole forces among its molecules are stronger.

Topic
3.1 Intermolecular and Interparticle Forces

2019 Practice Exam #45

Q: Attractions in carbon tetrachloride



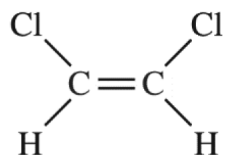
Solid carbon tetrachloride, $\text{CCl}_4(s)$, is represented by the diagram above. The attractions between the CCl_4 molecules that hold the molecules together in the solid state are best identified as

- (A) polar covalent bonds
- (B) nonpolar covalent bonds
- * (C) intermolecular attractions resulting from temporary dipoles
- (D) intermolecular attractions resulting from permanent dipoles

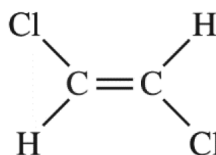
Topic
3.1 Intermolecular and Interparticle Forces

2019 Practice Exam #48

Q: Dichloroethene isomer with higher vapor pressure



cis-isomer



trans-isomer

The structural formulas for two isomers of 1,2-dichloroethene are shown above. Which of the two liquids has the higher equilibrium vapor pressure at 20°C, and why?

- (A) The *cis*-isomer, because it has dipole-dipole interactions, whereas the *trans*-isomer has only London dispersion forces
- (B) The *cis*-isomer, because it has only London dispersion forces, whereas the *trans*-isomer also has dipole-dipole interactions
- (C) The *trans*-isomer, because it has dipole-dipole interactions, whereas the *cis*-isomer has only London dispersion forces
- * (D) The *trans*-isomer, because it has only London dispersion forces, whereas the *cis*-isomer also has dipole-dipole interactions

Topic
3.1 Intermolecular and Interparticle Forces

2018 Practice Exam #4

Q: Compound with highest BP based on Lewis structures

Compound Name	Structural Formula	Molar Mass (g/mol)
Butanal	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{:O:} \\ & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} - \text{H} \\ & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \end{array} $	72.10
Pentane	$ \begin{array}{ccccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} - \text{H} \\ & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	72.15
Propanoic acid	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{:O:} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \ddot{\text{O}} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & & \end{array} $	74.08

Based on the information in the table above, which of the compounds has the highest boiling point, and why?

- (A) Butanal, because it can form intermolecular hydrogen bonds
- (B) Pentane, because it has the longest carbon chain
- (C) Pentane, because it has the most C–H bonds

* (D) Propanoic acid, because it can form intermolecular hydrogen bonds

Topic
3.1 Intermolecular and Interparticle Forces

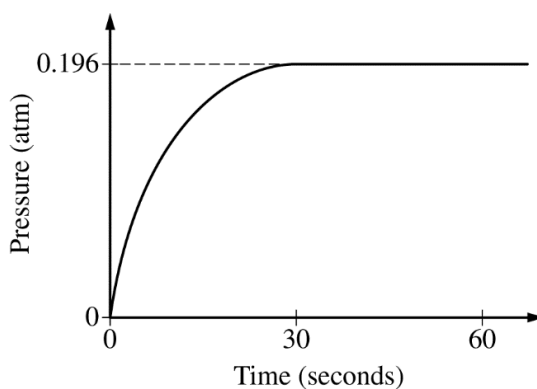
2018 Practice Exam #17

Q: CH₃OH vaporization - Pressure of C₂H₅OH

Questions X-Y refer to the following information.

Substance	Lewis Diagram	Boiling Point
CH ₃ OH	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	338 K
C ₂ H ₅ OH	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	351 K

Equimolar samples of CH₃OH(*l*) and C₂H₅OH(*l*) are placed in separate, previously evacuated, rigid 2.0 L vessels. Each vessel is attached to a pressure gauge, and the temperatures are kept at 300 K. In both vessels, liquid is observed to remain present at the bottom of the container at all times. The change in pressure inside the vessel containing CH₃OH(*l*) is shown below.



Compared to the equilibrium vapor pressure of CH₃OH(*l*) at 300 K, the equilibrium vapor pressure of C₂H₅OH(*l*) at 300 K is

- (A) the same, because both compounds have hydrogen bonding among their molecules
- (B) higher, because London dispersion forces among C₂H₅OH molecules are greater than those among CH₃OH molecules
- * (C) lower, because London dispersion forces among C₂H₅OH molecules are greater than those among CH₃OH molecules
- (D) lower, because of the larger number of hydrogen bonds among C₂H₅OH molecules

Topic
3.1 Intermolecular and Interparticle Forces

2018 Practice Exam #19

Q: Ionic radius - strongest anion attraction to H₂O

Ion	Ionic Radius (pm)
Cl ⁻	181
I ⁻	216
S ²⁻	184
Te ²⁻	221

Based on Coulomb's law and the information in the table above, which of the following anions is most likely to have the strongest interactions with nearby water molecules in an aqueous solution?

- (A) Cl⁻
- (B) I⁻
- * (C) S²⁻
- (D) Te²⁻

Topic
3.1 Intermolecular and Interparticle Forces

2018 Practice Exam #26

Q: Explains why CCl_4 is liquid and CI_4 is solid

Which of the following best helps to explain why CCl_4 is a liquid whereas CI_4 is a solid when both are at 25°C ?

- (A) The dipole moment of the CCl_4 molecule is larger than that of the CI_4 molecule because Cl is more electronegative than I.
- (B) The dipole moment of the CI_4 molecule is larger than that of the CCl_4 molecule because there is stronger repulsion between electrons in the C–I bonds compared to the repulsion between electrons in the C–Cl bonds.
- (C) The London dispersion forces are stronger in CCl_4 than in CI_4 because Cl is more electronegative than I.
- * (D) The London dispersion forces are stronger in CI_4 than in CCl_4 because CI_4 has a more polarizable electron cloud than CCl_4 .

Topic
3.1 Intermolecular and Interparticle Forces

2017 Practice Exam #3

Q: Br₂ vs Cl₂ at 298K - stronger forces of attraction

At 298 K and 1 atm, Br₂ is a liquid with a high vapor pressure, and Cl₂ is a gas. Those observations provide evidence that under the given conditions, the

- *
- (A) forces among Br₂ molecules are stronger than those among Cl₂ molecules
 - (B) forces among Cl₂ molecules are stronger than the Cl–Cl bond
 - (C) Br–Br bond is stronger than the Cl–Cl bond
 - (D) Cl–Cl bond is stronger than the Br–Br bond

Topic
3.1 Intermolecular and Interparticle Forces

2017 Practice Exam #15

Q: Ne HF C₂H₆ CH₄ - substance with highest BP and why

Ne, HF, C₂H₆, CH₄

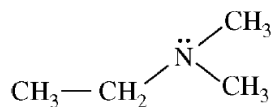
Which of the substances listed above has the highest boiling point, and why?

- (A) Ne, because its atoms have the largest radius
- * (B) HF, because its molecules form hydrogen bonds
- (C) C₂H₆, because each molecule can form multiple hydrogen bonds
- (D) CH₄, because its molecules have the greatest London dispersion forces

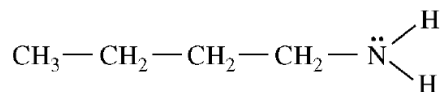
Topic
3.1 Intermolecular and Interparticle Forces

2017 Practice Exam #20

Q: Lewis structures for C₄H₁₁N - higher BP and why



Compound 1



Compound 2

Based on the structures shown above, which of the following statements identifies the compound with the higher boiling point and provides the best explanation for the higher boiling point?

- (A) Compound 1, because it has stronger dipole-dipole forces than compound 2
- (B) Compound 1, because it forms hydrogen bonds, whereas compound 2 does not.
- (C) Compound 2, because it is less polarizable and has weaker London dispersion forces than compound 1
- * (D) Compound 2, because it forms hydrogen bonds, whereas compound 1 does not

Topic
3.1 Intermolecular and Interparticle Forces

2016 Practice Exam #1

Q: Which liquid has dipole-dipole forces

In which of the following liquids do the intermolecular forces include dipole-dipole forces?

(A) $\text{F}_2(l)$

(B) $\text{CH}_4(l)$

(C) $\text{CF}_4(l)$

* (D) $\text{CH}_2\text{F}_2(l)$

Topic
3.1 Intermolecular and Interparticle Forces

2016 Practice Exam #6

Q: Given ionic radius, weakest attraction to water

Ion	Ionic Radius (pm)
Li^+	60
Na^+	95
Ca^{2+}	99
In^{3+}	81

Based on Coulomb's law and the information in the table above, which of the following cations is most likely to have the weakest interaction with an adjacent water molecule in an aqueous solution?

- (A) Li^+
- * (B) Na^+
- (C) Ca^{2+}
- (D) In^{3+}

Topic
3.1 Intermolecular and Interparticle Forces

2016 Practice Exam #19

Q: CS₂ and CCl₄ - higher vapor pressure given BP

	Molar Mass (g/mol)	Boiling Point (°C)
CS ₂ (l)	76	46.5
CCl ₄ (l)	154	76.7

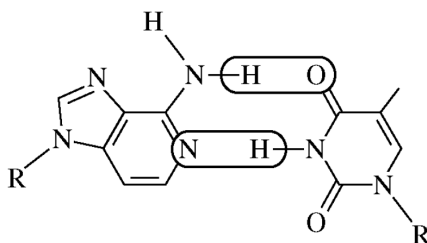
Based on the information in the table above, which liquid, CS₂(l) or CCl₄(l), has the higher equilibrium vapor pressure at 25°C, and why?

- (A) CS₂(l), because it has stronger London dispersion forces
- * (B) CS₂(l), because it has weaker London dispersion forces
- (C) CCl₄(l), because it has stronger London dispersion forces
- (D) CCl₄(l), because it has weaker London dispersion forces

Topic
3.1 Intermolecular and Interparticle Forces

2015 Practice Exam #5

Q: Strongest interaction between circled atoms



Which of the following is the strongest type of interaction that occurs between the atoms within the circled areas of the two molecules represented above?

- (A) Polar covalent bond
- (B) Nonpolar covalent bond
- * (C) Hydrogen bond
- (D) London dispersion forces

Topic
3.1 Intermolecular and Interparticle Forces

2015 Practice Exam #11

Q: Hydrocarbon with higher boiling point and why

Name	Molecular Formula	Molar Mass (g/mol)
Ethane	C ₂ H ₆	30
Butane	C ₄ H ₁₀	58

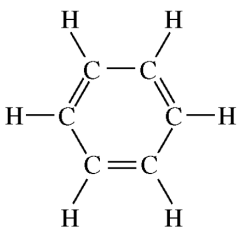
The molecular formula and molar mass of two straight-chain hydrocarbons are listed in the table above. Based on the information in the table, which compound has the higher boiling point, and why is that compound's boiling point higher?

- (A) C₄H₁₀, because it has more hydrogen atoms, resulting in more hydrogen bonding
- * (B) C₄H₁₀, because it has more electrons, resulting in greater polarizability and stronger dispersion forces
- (C) C₂H₆, because its molecules are smaller and they can get closer to one another, resulting in stronger dispersion forces
- (D) C₂H₆, because its molecules are more polar, resulting in stronger dipole-dipole attractions

Topic
3.1 Intermolecular and Interparticle Forces

2015 Practice Exam #21

Q: IMFs between water and benzene, C₆H₆



Benzene, C₆H₆, has the structure shown above. Considering the observation that benzene is only sparingly soluble in water, which of the following best describes the intermolecular forces of attraction between water and benzene?

- (A) Benzene is nonpolar, so there are no forces between water and benzene.
- (B) The H atoms in benzene form hydrogen bonds with the O atoms in water.
- (C) Benzene is hydrophobic, so there is a net repulsion between water and benzene.
- * (D) There are dipole-induced dipole and London dispersion interactions between water and benzene.

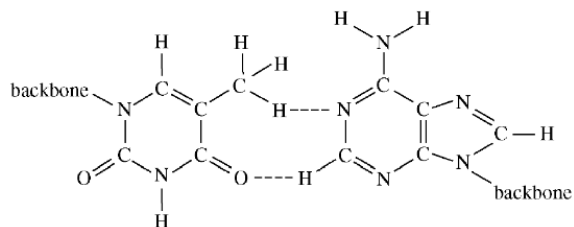
Topic
3.1 Intermolecular and Interparticle Forces

2014 Practice Exam #30

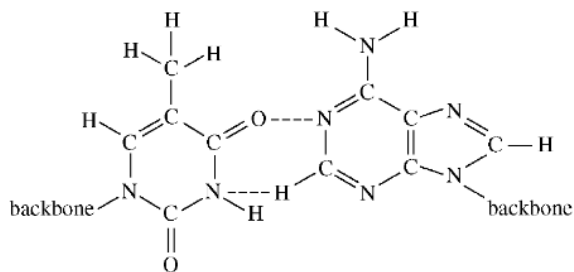
Q: Hydrogen bonding location - thymine and adenine

Thymine and adenine form a base pair in the DNA molecule. These two bases can form a connection between two strands of DNA via two hydrogen bonds. Which of the following diagrams shows the correct representation of the hydrogen bonding (denoted by dashed lines) between thymine and adenine base pairs? (In each diagram, thymine is shown at the left and adenine is shown at the right. The bases are attached to the backbone portion of the DNA strands.)

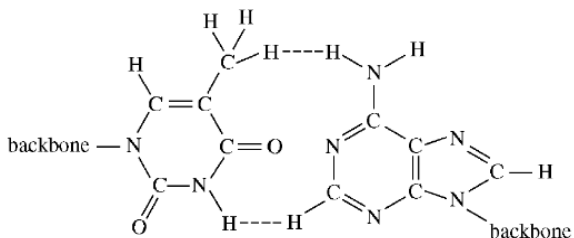
(A)



(B)

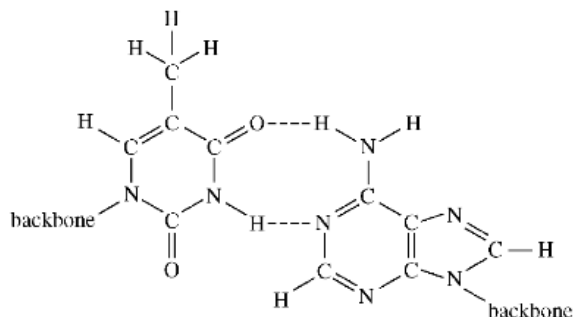


(C)



*

(D)



Topic
3.1 Intermolecular and Interparticle Forces

2013 Practice Exam #3

Q: Rank ion attraction to water - Zn^{2+} Ca^{2+} Ba^{2+}

Ion	Ionic Radius (pm)
Zn^{2+}	74
Ca^{2+}	100
Ba^{2+}	135

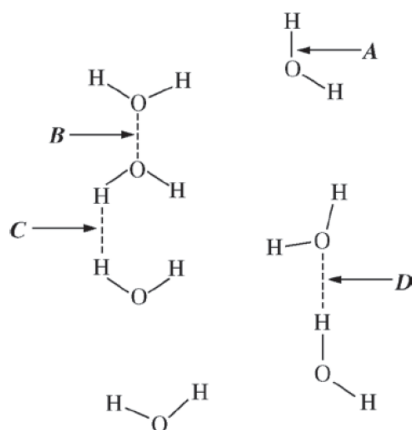
Based on the data in the table above, which of the following correctly predicts the relative strength of the attraction of Zn^{2+} , Ca^{2+} , and Ba^{2+} ions to water molecules in a solution, from strongest to weakest, and provides the correct reason?

- * (A) $\text{Zn}^{2+} > \text{Ca}^{2+} > \text{Ba}^{2+}$ because the smaller ions have a stronger coulombic attraction to water
- (B) $\text{Zn}^{2+} > \text{Ca}^{2+} > \text{Ba}^{2+}$ because the smaller ions are more electronegative
- (C) $\text{Ba}^{2+} > \text{Ca}^{2+} > \text{Zn}^{2+}$ because the larger ions are more polarizable
- (D) $\text{Ba}^{2+} > \text{Ca}^{2+} > \text{Zn}^{2+}$ because the larger ions are less electronegative

Topic
3.1 Intermolecular and Interparticle Forces

2013 Practice Exam #5

Q: Position of hydrogen bonding in water diagram



In the diagram above, which of the labeled arrows identifies hydrogen bonding in water?

(A) *A*

(B) *B*

(C) *C*

* (D) *D*

Topic
3.1 Intermolecular and Interparticle Forces

2013 Practice Exam #20

Q: C_xH_y gases - gas that condenses at lowest pressure

Questions X-Y refer to three gases in identical rigid containers under the conditions given in the table below.

Container	A	B	C
Gas	Methane	Ethane	Butane
Formula	CH ₄	C ₂ H ₆	C ₄ H ₁₀
Molar mass (g/mol)	16	30.	58
Temperature (°C)	27	27	27
Pressure (atm)	2.0	4.0	2.0

If the pressure of each gas is increased at constant temperature until condensation occurs, which gas will condense at the lowest pressure?

(A) Methane

(B) Ethane

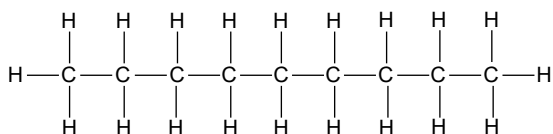
* (C) Butane

(D) All the gases will condense at the same pressure.

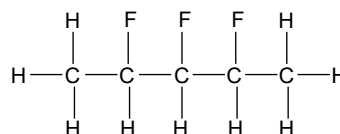
Topic
3.1 Intermolecular and Interparticle Forces

2013 Practice Exam #44

Q: Explain BP of nonane vs 2,3,4-trifluoropentane



Nonane



2,3,4-trifluoropentane

Consider the molecules represented above and the data in the table below.

Compound	Molecular Formula	Molar Mass (g/mol)	Boiling Point (°C)
Nonane	C ₉ H ₂₀	128	151
2,3,4-trifluoropentane	C ₅ H ₉ F ₃	126	89

Nonane and 2,3,4-trifluoropentane have almost identical molar masses, but nonane has a significantly higher boiling point. Which of the following statements best helps explain this observation?

- (A) The C–F bond is easier to break than the C–H bond.
- (B) The C–F bond is more polar than the C–H bond.
- * (C) The carbon chains are longer in nonane than they are in 2,3,4-trifluoropentane.
- (D) The carbon chains are farther apart in a sample of nonane than they are in 2,3,4-trifluoropentane.

Topic
3.2 Properties of Solids

2023 Practice Exam (from AP Classroom)

Q: Explain ductility

Which of the following best explains how the bonding in a metal allows it to be ductile (i.e., allows it to be drawn into a wire)?

- (A) Metal atoms are spherical; therefore, the solid metal can be easily drawn into wires that have a round cross-section.
- (B) Because of strongly directional bonding in the solid metal, the atoms both in front of and behind a given atom in a wire will bind together more strongly than the atoms not along the direction of the wire.
- * (C) Because the mobile electrons attract the metal cations equally in all directions, the metal cations can move easily past one another as the metal is drawn into a wire.
- (D) Metal atoms tend to be much smaller than nonmetal atoms; therefore, they can move easily past one another as the metal is drawn into a wire.

Topic
3.2 Properties of Solids

2023 Practice Exam (from AP Classroom)

Q: HCN and N₂ boiling points

Lewis Dot Diagram	Boiling Point (°C)
$\text{H} - \text{C} \equiv \text{N}:$	26
$:\text{N} \equiv \text{N}:$	-196

Which of the following best helps to explain why the boiling point of HCN is so much higher than that of N₂, as shown by the data in the table above?

- (A) HCN contains three atoms, whereas N₂ contains two atoms.
- * (B) HCN is polar, whereas N₂ is nonpolar.
- (C) HCN has a molar entropy greater than that of N₂.
- (D) The C≡N bond is stronger than the N≡N bond.

Topic
3.2 Properties of Solids

2022 Practice Exam (from AP Classroom)

Q: Metal versus nonmetal properties

A solid is tested in a laboratory to determine its properties. Which of the following provides the best evidence to support the hypothesis that the solid is a metal as opposed to a nonmetal?

- (A) It reacts with oxygen.
- * (B) It is lustrous and malleable.
- (C) It has a high melting point (1700°C).
- (D) It has the same density as aluminum (2.7 g/mL).

Topic
3.2 Properties of Solids

2022 Practice Exam (from AP Classroom)

Q: IMFs and boiling point

Substance	Structural Formula	Molar Mass (g/mol)
Propylamine	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{N} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \end{array} $	59
Pentane	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} - \text{H} \\ & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	72
2-Propanol	$ \begin{array}{ccccccc} & & & \text{H} & & & \\ & & & & & & \\ & \text{H} & & \text{O} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \end{array} $	60
Propanoic acid	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{O} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{O} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & & \end{array} $	74

A student was given samples of four different unknown liquids. The unknown liquids are propylamine, pentane, 2-propanol, and propanoic acid. The structures and molar masses of the compounds are shown in the table above. On the basis of this information, the student designed some experiments to identify the samples.

Which of the following statements correctly identifies which compound, pentane or propanoic acid, has the higher boiling point and provides a valid justification?

- (A) Pentane, because it has greater London dispersion forces than propanoic acid does
- (B) Pentane, because it can form more hydrogen bonds per molecule than propanoic acid can
- (C) Propanoic acid, because double bonds are harder to break than single bonds
- * (D) Propanoic acid, because it forms hydrogen bonds, whereas pentane does not

Topic
3.2 Properties of Solids

2019 Practice Exam #2

Q: 0.1 M solution with greatest conductivity and why

Solution
0.1 M $\text{HC}_2\text{H}_3\text{O}_2(aq)$
0.1 M $\text{KI}(aq)$
0.1 M $\text{CH}_3\text{OH}(aq)$

Of the three solutions listed in the table above, which one, if any, has the greatest electrical conductivity and why?

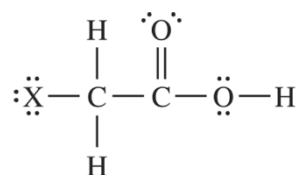
- (A) 0.1 M $\text{HC}_2\text{H}_3\text{O}_2(aq)$ because its molecules have the most atoms.
- * (B) 0.1 M $\text{KI}(aq)$ because KI completely dissociates in water to produce ions.
- (C) 0.1 M $\text{CH}_3\text{OH}(aq)$ because its molecules can form hydrogen bonds.
- (D) All three solutions have the same electrical conductivity because the concentrations are the same.

Topic
3.2 Properties of Solids

2019 Practice Exam #26

Q: Haloacetic acids - lowest boiling point and why

Questions X-Y are based on the following information.



The structure of haloacetic acids, XCH_2COOH (where X is either F, Cl, Br, or I), is shown above. The dissociation constants and molar masses of four haloacetic acids are listed in the table below.

Acid	$\text{p}K_a$	K_a	Molar Mass (g/mol)
Fluoroacetic acid	2.59	2.57×10^{-3}	78.0
Chloroacetic acid	2.87	1.35×10^{-3}	94.5
Bromoacetic acid	2.90	1.26×10^{-3}	138.9
Iodoacetic acid	3.18	6.61×10^{-4}	185.9

Which compound, chloroacetic acid or iodoacetic acid, most likely has the lower boiling point, and why?

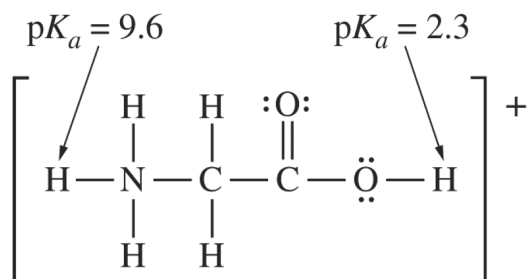
- * (A) Chloroacetic acid, because the London dispersion forces among its molecules are weaker.
- (B) Chloroacetic acid, because the dipole-dipole forces among its molecules are weaker.
- (C) Iodoacetic acid, because the London dispersion forces among its molecules are stronger.
- (D) Iodoacetic acid, because the dipole-dipole forces among its molecules are stronger.

Topic
3.2 Properties of Solids

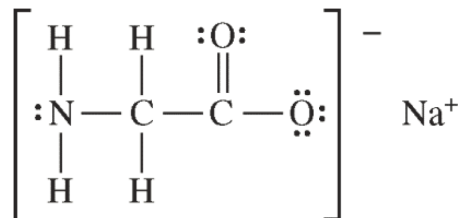
2019 Practice Exam #44

Q: Glycinium cation - properties of sodium glycinate

Questions X-Y refer to the following.



The structural formula of the glycinium cation is shown above. Arrows indicate the $\text{p}K_a$ values for the labile protons in the molecule.



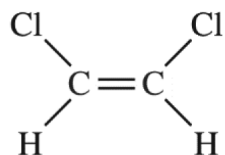
Which of the following statements is true about sodium glycinate, represented above?

- * (A) It is an ionic solid at room temperature.
- (B) It is not soluble in water.
- (C) It evaporates easily because of the lack of hydrogen bonding.
- (D) It dissolves in water to form an acidic solution.

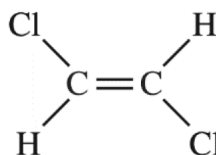
Topic
3.2 Properties of Solids

2019 Practice Exam #48

Q: Dichloroethene isomer with higher vapor pressure



cis-isomer



trans-isomer

The structural formulas for two isomers of 1,2-dichloroethene are shown above. Which of the two liquids has the higher equilibrium vapor pressure at 20°C, and why?

- (A) The *cis*-isomer, because it has dipole-dipole interactions, whereas the *trans*-isomer has only London dispersion forces
- (B) The *cis*-isomer, because it has only London dispersion forces, whereas the *trans*-isomer also has dipole-dipole interactions
- (C) The *trans*-isomer, because it has dipole-dipole interactions, whereas the *cis*-isomer has only London dispersion forces
- * (D) The *trans*-isomer, because it has only London dispersion forces, whereas the *cis*-isomer also has dipole-dipole interactions

Topic
3.2 Properties of Solids

2018 Practice Exam #3

Q: Types of bonding in 3 substances from properties

Substance	X	Y	Z
Melting Point (°C)	1600	650	1418
Electrical Conductivity In Solid Phase	None	High	None
Electrical Conductivity In Liquid Phase	None	High	High

Three substances were studied in the laboratory, and the data in the table above were collected. Based on the data, which of the following shows the type of bonding in each substance?

	Substance X	Substance Y	Substance Z
(A)	network covalent	ionic	metallic
(B)	ionic	molecular	network covalent
(C)	molecular	network covalent	metallic
* (D)	network covalent	metallic	ionic

Topic
3.2 Properties of Solids

2018 Practice Exam #4

Q: Compound with highest BP based on Lewis structures

Compound Name	Structural Formula	Molar Mass (g/mol)
Butanal	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{:O:} \\ & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\ & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \end{array} $	72.10
Pentane	$ \begin{array}{ccccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\ & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	72.15
Propanoic acid	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{:O:} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \ddot{\text{O}} & - & \text{H} \\ & & & & & & & \\ & \text{H} & & \text{H} & & & & \end{array} $	74.08

Based on the information in the table above, which of the compounds has the highest boiling point, and why?

- (A) Butanal, because it can form intermolecular hydrogen bonds
- (B) Pentane, because it has the longest carbon chain
- (C) Pentane, because it has the most C–H bonds

* (D) Propanoic acid, because it can form intermolecular hydrogen bonds

Topic
3.2 Properties of Solids

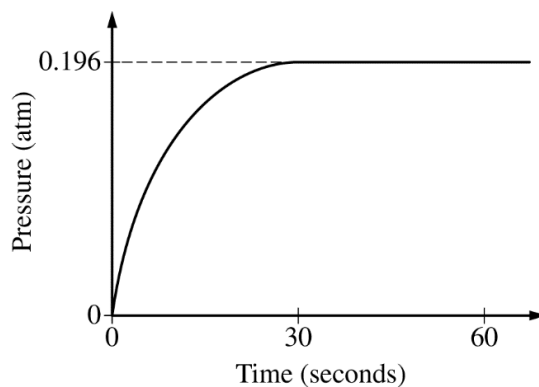
2018 Practice Exam #17

Q: CH₃OH vaporization - Pressure of C₂H₅OH

Questions X-Y refer to the following information.

Substance	Lewis Diagram	Boiling Point
CH ₃ OH	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	338 K
C ₂ H ₅ OH	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	351 K

Equimolar samples of CH₃OH(*l*) and C₂H₅OH(*l*) are placed in separate, previously evacuated, rigid 2.0 L vessels. Each vessel is attached to a pressure gauge, and the temperatures are kept at 300 K. In both vessels, liquid is observed to remain present at the bottom of the container at all times. The change in pressure inside the vessel containing CH₃OH(*l*) is shown below.



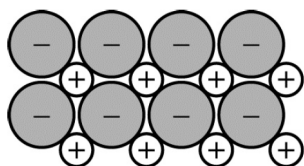
Compared to the equilibrium vapor pressure of CH₃OH(*l*) at 300 K, the equilibrium vapor pressure of C₂H₅OH(*l*) at 300 K is

- (A) the same, because both compounds have hydrogen bonding among their molecules
- (B) higher, because London dispersion forces among C₂H₅OH molecules are greater than those among CH₃OH molecules
- * (C) lower, because London dispersion forces among C₂H₅OH molecules are greater than those among CH₃OH molecules
- (D) lower, because of the larger number of hydrogen bonds among C₂H₅OH molecules

Topic
3.2 Properties of Solids

2018 Practice Exam #25

Q: Particulate diagram - properties ionic crystal



Which of the following most likely describes the solid represented in the diagram above?

- (A) It is soft and is a poor thermal and electrical conductor.
- (B) It has a low melting point and is a poor thermal and electrical conductor as a solid.
- * (C) It is a brittle, water-soluble electrolyte that is a poor thermal and electrical conductor as a solid.
- (D) It is malleable and is an excellent thermal and electrical conductor as a solid.

Topic
3.2 Properties of Solids

2018 Practice Exam #26

Q: Explains why CCl_4 is liquid and CI_4 is solid

Which of the following best helps to explain why CCl_4 is a liquid whereas CI_4 is a solid when both are at 25°C ?

- (A) The dipole moment of the CCl_4 molecule is larger than that of the CI_4 molecule because Cl is more electronegative than I.
- (B) The dipole moment of the CI_4 molecule is larger than that of the CCl_4 molecule because there is stronger repulsion between electrons in the C–I bonds compared to the repulsion between electrons in the C–Cl bonds.
- (C) The London dispersion forces are stronger in CCl_4 than in CI_4 because Cl is more electronegative than I.
- * (D) The London dispersion forces are stronger in CI_4 than in CCl_4 because CI_4 has a more polarizable electron cloud than CCl_4 .

Topic
3.2 Properties of Solids

2017 Practice Exam #3

Q: Br₂ vs Cl₂ at 298K - stronger forces of attraction

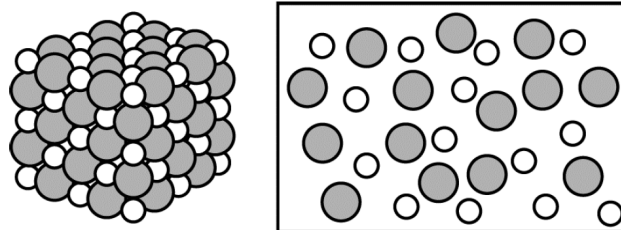
At 298 K and 1 atm, Br₂ is a liquid with a high vapor pressure, and Cl₂ is a gas. Those observations provide evidence that under the given conditions, the

- * (A) forces among Br₂ molecules are stronger than those among Cl₂ molecules
- (B) forces among Cl₂ molecules are stronger than the Cl–Cl bond
- (C) Br–Br bond is stronger than the Cl–Cl bond
- (D) Cl–Cl bond is stronger than the Br–Br bond

Topic
3.2 Properties of Solids

2017 Practice Exam #8

Q: Particle diagram - solid-liquid MgO conductivity



Solid MgO

Liquid MgO

Based on the diagram above, which of the following best helps to explain why $\text{MgO}(s)$ is not able to conduct electricity, but $\text{MgO}(l)$ is a good conductor of electricity?

- (A) $\text{MgO}(s)$ does not contain free electrons, but $\text{MgO}(l)$ contains free electrons that can flow.
- (B) $\text{MgO}(s)$ contains no water, but $\text{MgO}(l)$ contains water that can conduct electricity.
- (C) $\text{MgO}(s)$ consists of separate Mg^{2+} ions and O^{2-} ions, but $\text{MgO}(l)$ contains MgO molecules that can conduct electricity.
- * (D) $\text{MgO}(s)$ consists of separate Mg^{2+} ions and O^{2-} ions held in a fixed lattice, but in $\text{MgO}(l)$ the ions are free to move and conduct electricity.

Topic
3.2 Properties of Solids

2017 Practice Exam #14

Q: Method to determine if a substance is ionic

A student is given a sample of a pure, white crystalline substance. Which of the following would be most useful in providing data to determine if the substance is an ionic compound?

- (A) Examining the crystals of the substance under a microscope
- (B) Determining the density of the substance
- (C) Testing the electrical conductivity of the crystals
- * (D) Testing the electrical conductivity of an aqueous solution of the substance

Topic
3.2 Properties of Solids

2017 Practice Exam #15

Q: Ne HF C₂H₆ CH₄ - substance with highest BP and why

Ne, HF, C₂H₆, CH₄

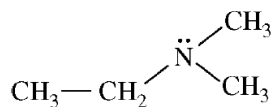
Which of the substances listed above has the highest boiling point, and why?

- (A) Ne, because its atoms have the largest radius
- * (B) HF, because its molecules form hydrogen bonds
- (C) C₂H₆, because each molecule can form multiple hydrogen bonds
- (D) CH₄, because its molecules have the greatest London dispersion forces

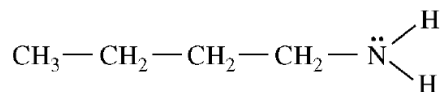
Topic
3.2 Properties of Solids

2017 Practice Exam #20

Q: Lewis structures for C₄H₁₁N - higher BP and why



Compound 1



Compound 2

Based on the structures shown above, which of the following statements identifies the compound with the higher boiling point and provides the best explanation for the higher boiling point?

- (A) Compound 1, because it has stronger dipole-dipole forces than compound 2
- (B) Compound 1, because it forms hydrogen bonds, whereas compound 2 does not.
- (C) Compound 2, because it is less polarizable and has weaker London dispersion forces than compound 1
- * (D) Compound 2, because it forms hydrogen bonds, whereas compound 1 does not

Topic
3.2 Properties of Solids

2016 Practice Exam #3

Q: Bonding in nonconductive solid but conducts in H₂O

A sample of a hard, solid binary compound at room temperature did not conduct electricity as a pure solid but became highly conductive when dissolved in water. Which of the following types of interactions is most likely found between the particles in the substance?

- * (A) Ionic bonds
- (B) Metallic bonds
- (C) Covalent bonds
- (D) Hydrogen bonds

Topic
3.2 Properties of Solids

2016 Practice Exam #18

Q: Characteristic of solid iodine with explanation

At room temperature $I_2(s)$ is a molecular solid. Which of the following provides a characteristic of $I_2(s)$ with a correct explanation?

- (A) It has a high melting point because it has weak intermolecular forces.
- (B) It is hard because it forms a three-dimensional covalent network.
- * (C) It is not a good conductor of electricity because its valence electrons are localized in bonding and nonbonding pairs.
- (D) It is very soluble in water because its molecules are polar.

Topic
3.2 Properties of Solids

2016 Practice Exam #19

Q: CS₂ and CCl₄ - higher vapor pressure given BP

	Molar Mass (g/mol)	Boiling Point (°C)
CS ₂ (l)	76	46.5
CCl ₄ (l)	154	76.7

Based on the information in the table above, which liquid, CS₂(l) or CCl₄(l), has the higher equilibrium vapor pressure at 25°C, and why?

- (A) CS₂(l), because it has stronger London dispersion forces
- * (B) CS₂(l), because it has weaker London dispersion forces
- (C) CCl₄(l), because it has stronger London dispersion forces
- (D) CCl₄(l), because it has weaker London dispersion forces

Topic
3.2 Properties of Solids

2015 Practice Exam #11

Q: Hydrocarbon with higher boiling point and why

Name	Molecular Formula	Molar Mass (g/mol)
Ethane	C ₂ H ₆	30
Butane	C ₄ H ₁₀	58

The molecular formula and molar mass of two straight-chain hydrocarbons are listed in the table above. Based on the information in the table, which compound has the higher boiling point, and why is that compound's boiling point higher?

- (A) C₄H₁₀, because it has more hydrogen atoms, resulting in more hydrogen bonding
- * (B) C₄H₁₀, because it has more electrons, resulting in greater polarizability and stronger dispersion forces
- (C) C₂H₆, because its molecules are smaller and they can get closer to one another, resulting in stronger dispersion forces
- (D) C₂H₆, because its molecules are more polar, resulting in stronger dipole-dipole attractions

Topic
3.2 Properties of Solids

2014 Practice Exam #2

Q: Identify white crystalline solid from properties

Which of the following could be the identity of a white crystalline solid that exhibits the following properties?

- It melts at 320°C .
- It does not conduct electricity as a solid.
- It conducts electricity in an aqueous solution.

(A) $\text{C}_6\text{H}_{12}\text{O}_6(s)$

* (B) $\text{NaOH}(s)$

(C) $\text{SiO}_2(s)$

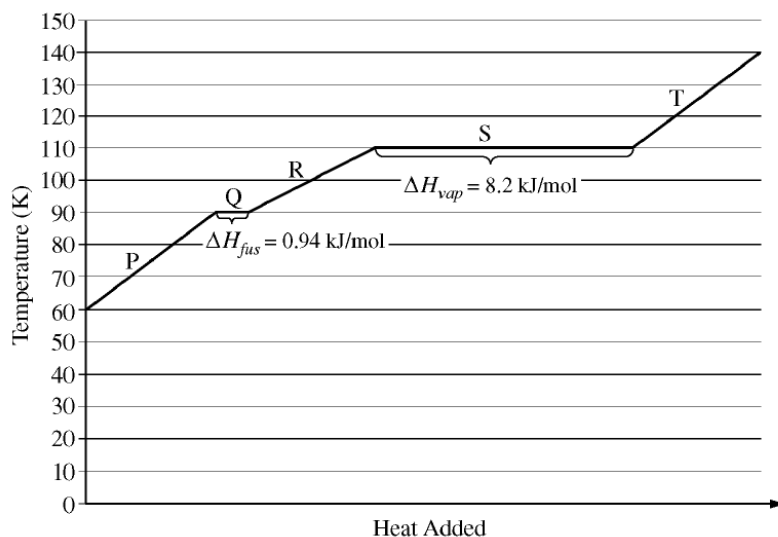
(D) $\text{Cu}(s)$

Topic
3.2 Properties of Solids

2014 Practice Exam #40

Q: CH₄ heating curve - more energy for vaporization

Questions X-Y refer to the following graph, which shows the heating curve for methane, CH₄.



Which of the following best explains why more energy is required for the process occurring at 110 K than for the process occurring at 90 K?

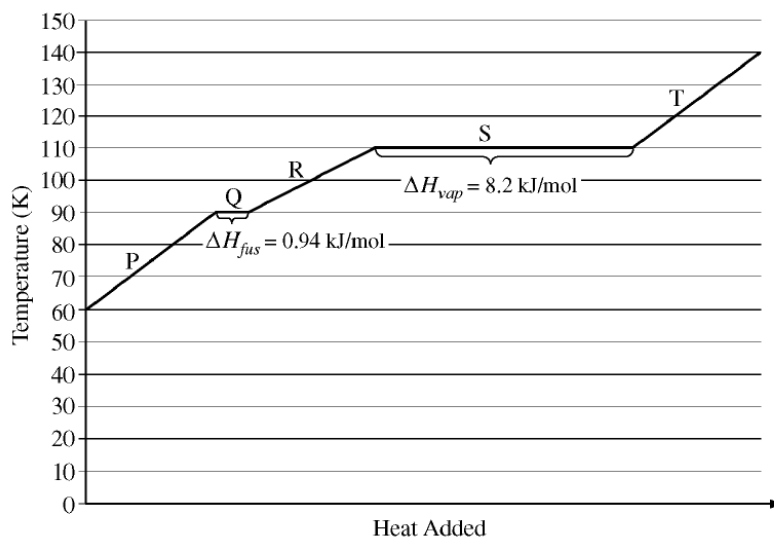
- * (A) Intermolecular attractions are completely overcome during vaporization.
- (B) Intermolecular attractions in the solid phase are weaker than in the liquid phase.
- (C) Electron clouds of methane molecules are less polarizable at lower temperatures.
- (D) Vaporization involves a large increase in temperature.

Topic
3.2 Properties of Solids

2014 Practice Exam #41

Q: CH₄ heating curve - dH_{vap} less for CH₄ than H₂O

Questions X-Y refer to the following graph, which shows the heating curve for methane, CH₄.



The enthalpy of vaporization of water is 40.7 kJ/mol. Which of the following best explains why the enthalpy of vaporization of methane is less than that of water?

- * (A) Methane does not exhibit hydrogen bonding, but water does.
- (B) A methane molecule is more polarizable than a water molecule.
- (C) Methane has a smaller molar mass than water has.
- (D) Methane has a much lower density than water has.

Topic
3.2 Properties of Solids

2014 Practice Exam #49

Q: Arrange acetone propanol butane by increasing BP

Name	Structural Formula	Molar Mass (g/mol)
Acetone	$ \begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \quad \text{H} \end{array} $	58.1
1-propanol	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array} $	60.1
Butane	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $	58.1

The table above shows the structural formulas and molar masses for three different compounds. Which of the following is a list of the compounds in order of increasing boiling points?

- (A) Butane < 1-propanol < acetone
- * (B) Butane < acetone < 1-propanol
- (C) 1-propanol < acetone < butane
- (D) Acetone = butane < 1-propanol

Topic
3.2 Properties of Solids

2013 Practice Exam #2

Q: Given vapor pressure, which has the weakest IMFs

Substance	Equilibrium Vapor Pressure at 20°C (torr)
$\text{C}_6\text{H}_6(l)$	75
$\text{C}_2\text{H}_5\text{OH}(l)$	44
$\text{CH}_3\text{OH}(l)$	92
$\text{C}_2\text{H}_6\text{O}_2(l)$	0.06

Based on the data in the table above, which of the following liquid substances has the weakest intermolecular forces?

- (A) $\text{C}_6\text{H}_6(l)$
- (B) $\text{C}_2\text{H}_5\text{OH}(l)$
- * (C) $\text{CH}_3\text{OH}(l)$
- (D) $\text{C}_2\text{H}_6\text{O}_2(l)$

Topic
3.2 Properties of Solids

2013 Practice Exam #20

Q: C_xH_y gases - gas that condenses at lowest pressure

Questions X-Y refer to three gases in identical rigid containers under the conditions given in the table below.

Container	A	B	C
Gas	Methane	Ethane	Butane
Formula	CH ₄	C ₂ H ₆	C ₄ H ₁₀
Molar mass (g/mol)	16	30.	58
Temperature (°C)	27	27	27
Pressure (atm)	2.0	4.0	2.0

If the pressure of each gas is increased at constant temperature until condensation occurs, which gas will condense at the lowest pressure?

(A) Methane

(B) Ethane

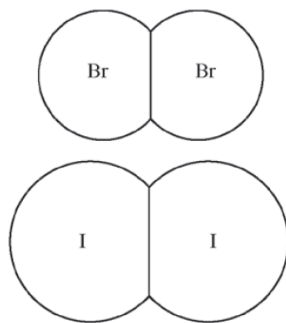
* (C) Butane

(D) All the gases will condense at the same pressure.

Topic
3.2 Properties of Solids

2013 Practice Exam #25

Q: Diagrams of Br₂ and I₂ - explain BP difference



The diagram above shows molecules of Br₂ and I₂ drawn to the same scale. Which of the following is the best explanation for the difference in the boiling points of liquid Br₂ and I₂, which are 59°C and 184°C, respectively?

- (A) Solid iodine is a network covalent solid, whereas solid bromine is a molecular solid.
- (B) The covalent bonds in I₂ molecules are weaker than those in Br₂ molecules.
- * (C) I₂ molecules have electron clouds that are more polarizable than those of Br₂ molecules; London dispersion forces are stronger in liquid I₂.
- (D) Bromine has a greater electronegativity than iodine; there are stronger dipole-dipole forces in liquid bromine than in liquid iodine.

Topic
3.2 Properties of Solids

2013 Practice Exam #54

Q: Given ionic radius and charge - predict BP of NaCl

	NaF	MgO
Boiling Point (°C)	1695	3600

	Na ⁺	Mg ²⁺	F ⁻	Cl ⁻	O ²⁻
Ionic Radius (pm)	76	72	133	181	140

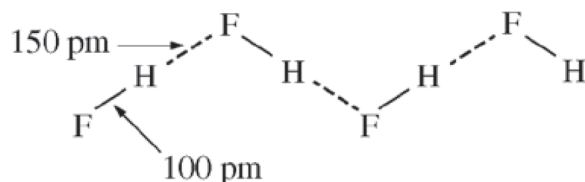
Based on the data in the tables above, which of the following statements provides the best prediction for the boiling point of NaCl?

- * (A) NaCl will have a lower boiling point than NaF because the coulombic attractions are weaker in NaCl than in NaF.
- (B) NaCl will have a boiling point between that of NaF and MgO because the covalent character of the bonds in NaCl is intermediate between that of MgO and NaF.
- (C) NaCl will have a higher boiling point than MgO because the ions are spaced farther apart in NaCl.
- (D) NaCl will have a higher boiling point than MgO because the energy required to transfer electrons from the anion to the cation is larger in NaCl than in MgO.

Topic
3.2 Properties of Solids

2013 Practice Exam #59

Q: Solid HF - reason for bond length vs IMF distance



The figure above shows that in solid hydrogen fluoride there are two different distances between H atoms and F atoms. Which of the following best accounts for the two different distances?

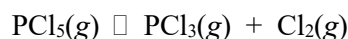
- (A) Accommodation of the necessary bond angles in the formation of the solid
- * (B) Difference in strength between covalent bonds and intermolecular attractions
- (C) Different isotopes of fluorine present in the samples
- (D) Uneven repulsions among nonbonding electron pairs

Topic
3.3 Solids, Liquids, and Gases

2013 Practice Exam #29

Q: PCl_5 equil. - cause of increase in pressure

Questions X-Y refer to the following.



$\text{PCl}_5(g)$ decomposes into $\text{PCl}_3(g)$ and $\text{Cl}_2(g)$ according to the equation above. A pure sample of $\text{PCl}_5(g)$ is placed in a rigid, evacuated 1.00 L container. The initial pressure of the $\text{PCl}_5(g)$ is 1.00 atm. The temperature is held constant until the $\text{PCl}_5(g)$ reaches equilibrium with its decomposition products. The figures below show the initial and equilibrium conditions of the system.

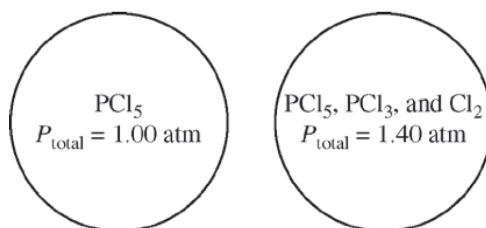


Figure 1: Initial

Figure 2: Equilibrium

Which of the following is the most likely cause for the increase in pressure observed in the container as the reaction reaches equilibrium?

- (A) A decrease in the strength of intermolecular attractions among molecules in the flask
- (B) An increase in the strength of intermolecular attractions among molecules in the flask
- * (C) An increase in the number of molecules, which increases the frequency of collisions with the walls of the container
- (D) An increase in the speed of the molecules that then collide with the walls of the container with greater force

Topic
3.4 Ideal Gas Law

2023 Practice Exam (from AP Classroom)

Q: Density of a gas

Three equimolar gas samples are at the conditions given in the following table. Assume that the gases behave ideally.

Gas	Volume (L)	Pressure (atm)	Temperature (K)
F ₂	10.	2.0	200.
N ₂	5.0	4.0	200.
O ₂	4.0	5.0	200.

Which gas, if any, has the greatest density?

(A) F₂

(B) N₂

* (C) O₂

(D) All three samples have the same density.

Topic
3.4 Ideal Gas Law

2023 Practice Exam (from AP Classroom)

Q: Moles of gas in a sample

Three equimolar gas samples are at the conditions given in the following table. Assume that the gases behave ideally.

Gas	Volume (L)	Pressure (atm)	Temperature (K)
F ₂	10.	2.0	200.
N ₂	5.0	4.0	200.
O ₂	4.0	5.0	200.

The number of moles of N₂(g) is closest to which of the following?

- (A) 0.10 mol
- * (B) 1.2 mol
- (C) 22 mol
- (D) 28 mol

Topic
3.4 Ideal Gas Law

2022 Practice Exam (from AP Classroom)

Q: Gas change temperature and pressure

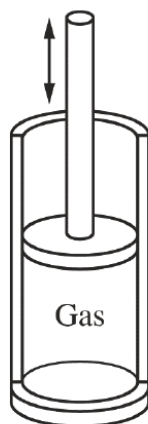
A sample of an ideal gas in a sealed container occupies a volume of 50.0 L at 200 K. The temperature of the gas is changed to 400 K, and the pressure doubles. Which of the following must occur and why?

- (A) Volume must decrease because the pressure is higher.
- (B) Volume must increase because the temperature is higher.
- * (C) Volume must remain the same because the pressure and temperature change proportionately.
- (D) Volume cannot be predicted without knowing the number of moles of gas in the sample.

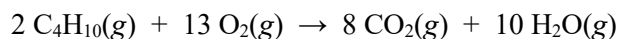
Topic
3.4 Ideal Gas Law

2019 Practice Exam #25

Q: Volume after reaction of C₄H₁₀ and O₂



A mixture of two gases, 0.01 mol of C₄H₁₀(g) and 0.065 mol of O₂(g), is pumped into a cylinder with a movable piston, as shown above. The mixture, originally at 200°C and 1.0 atm, is sparked and the reaction represented below occurs.



Which of the following is true after the product gases return to the original temperature and pressure, and why will the change occur? (Assume all gases behave ideally.)

- * (A) The piston will be higher than its original position, because the cylinder will contain a greater number of gas molecules.
- (B) The position of the piston will be unchanged, because the total mass of the gases in the cylinder does not change.
- (C) The position of the piston will be unchanged, because the temperature and pressure of the contents of the cylinder remain the same.
- (D) The piston will be lower than its original position, because the product molecules are smaller than the reactant molecules.

Topic
3.4 Ideal Gas Law

2018 Practice Exam #13

Q: Volume change of He balloon as it changes altitude

A balloon filled with 0.25 mol of He(g) at 273 K and 1 atm is allowed to rise through the atmosphere. Which of the following explains what happens to the volume of the balloon as it rises from ground level to an altitude where the air temperature is 220 K and the air pressure is 0.1 atm?

- * (A) The volume will increase because the decrease in air pressure will have a greater effect than the decrease in temperature.
- (B) The volume will remain unchanged because of the counteracting effects of the decrease in temperature and the decrease in air pressure.
- (C) The volume will decrease because the decrease in temperature will have a greater effect than the decrease in air pressure.
- (D) It cannot be determined whether the volume of the balloon will increase, decrease, or remain the same without knowing the initial volume of the balloon.

Topic
3.4 Ideal Gas Law

2017 Practice Exam #18

Q: Final P - 4.0L He 6.0L N₂ 10.L Ar pumped in 8.0L

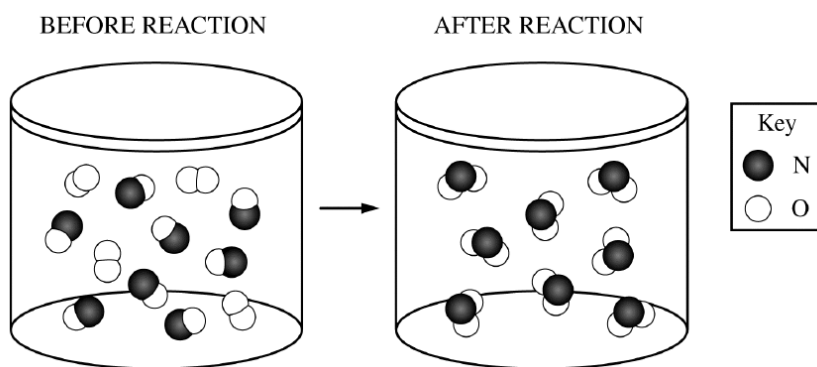
When 4.0 L of He(g), 6.0 L of N₂(g), and 10. L of Ar(g), all at 0°C and 1.0 atm, are pumped into an evacuated 8.0 L rigid container, the final pressure in the container at 0°C is

- (A) 0.5 atm
- (B) 1.0 atm
- * (C) 2.5 atm
- (D) 4.0 atm

Topic
3.4 Ideal Gas Law

2015 Practice Exam #24

Q: Particulate of $\text{NO} + \text{O}_2$ - pressure as rxn proceeds



The reaction between $\text{NO}(g)$ and $\text{O}_2(g)$ to produce $\text{NO}_2(g)$ in a rigid reaction vessel is represented in the diagram above. The pressure inside the container is recorded using a pressure gauge. Which of the following statements correctly predicts the change in pressure as the reaction goes to completion at constant temperature, and provides the correct explanation?

- (A) The pressure will increase because the product molecules have a greater mass than either of the reactant molecules.
- * (B) The pressure will decrease because there are fewer molecules of product than reactants.
- (C) The pressure will decrease because the product molecules have a lower average speed than the reactant molecules.
- (D) The pressure will not change because the total mass of the product molecules is the same as the total mass of the reactant molecules.

Topic
3.4 Ideal Gas Law

2014 Practice Exam #14

Q: Gases at 2.00 atm - which gas is in container 3

Questions X-Y refer to the following.

The table below contains information about samples of four different gases at 273 K. The samples are in four identical rigid containers numbered 1 through 4.

Container	Gas	Pressure (atm)	Mass of Sample (g)
1	He	2.00	?
2	Ne	2.00	?
3	?	2.00	16.0
4	SO ₂	1.96	64.1

On the basis of the data provided above, the gas in container 3 could be

- * (A) CH₄
- (B) O₂
- (C) Ar
- (D) CO₂

Topic
3.4 Ideal Gas Law

2014 Practice Exam #23

Q: CH₃OH equil. - total P after volume is halved

Questions X-Y refer to the following information.



The synthesis of CH₃OH(g) from CO(g) and H₂(g) is represented by the equation above. The value of K_c for the reaction at 483 K is 14.5.

A mixture of CO(g) and H₂(g) is pumped into a previously evacuated 2.0 L reaction vessel. The total pressure of the reaction system is 1.2 atm at equilibrium. What will be the total pressure of the system if the volume of the reaction vessel is reduced to 1.0 L at constant temperature?

- (A) Less than 1.2 atm
- * (B) Greater than 1.2 atm but less than 2.4 atm
- (C) 2.4 atm
- (D) Greater than 2.4 atm

Topic
3.4 Ideal Gas Law

2013 Practice Exam #19

Q: C_xH_y gases - greatest gas density in g/L

Questions X-Y refer to three gases in identical rigid containers under the conditions given in the table below.

Container	A	B	C
Gas	Methane	Ethane	Butane
Formula	CH ₄	C ₂ H ₆	C ₄ H ₁₀
Molar mass (g/mol)	16	30.	58
Temperature (°C)	27	27	27
Pressure (atm)	2.0	4.0	2.0

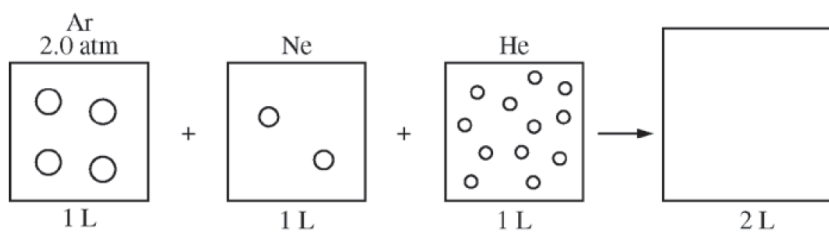
The density of the gas, in g/L, is

- (A) greatest in container A
- * (B) greatest in container B
- (C) greatest in container C
- (D) the same in all three containers

Topic
3.4 Ideal Gas Law

2013 Practice Exam #26

Q: Total pressure when combining Ar Ne and He in 2.0L



The figure above represents three sealed 1.0 L vessels, each containing a different inert gas at 298 K. The pressure of Ar in the first vessel is 2.0 atm. The ratio of the numbers of Ar, Ne, and He atoms in the vessels is 2:1:6, respectively. After all the gases are combined in a previously evacuated 2.0 L vessel, what is the total pressure of the gases at 298 K?

- (A) 3.0 atm
- * (B) 4.5 atm
- (C) 9.0 atm
- (D) 18 atm

Topic
3.5 Kinetic Molecular Theory

2023 Practice Exam (from AP Classroom)

Q: KE of gases

Three equimolar gas samples are at the conditions given in the following table. Assume that the gases behave ideally.

Gas	Volume (L)	Pressure (atm)	Temperature (K)
F ₂	10.	2.0	200.
N ₂	5.0	4.0	200.
O ₂	4.0	5.0	200.

Which gas, if any, has molecules with the greatest average kinetic energy?

(A) F₂

(B) N₂

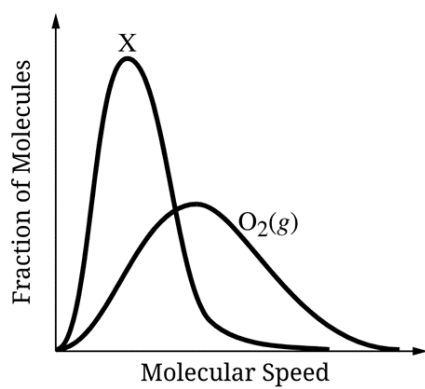
(C) O₂

* (D) The molecules in all three samples have the same average kinetic energy.

Topic
3.5 Kinetic Molecular Theory

2022 Practice Exam (from AP Classroom)

Q: Identify substance from Maxwell Boltzmann curve



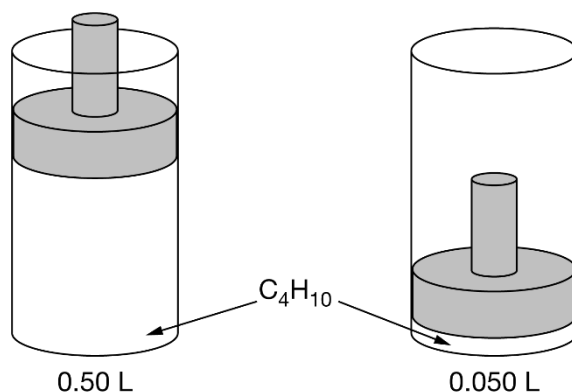
Based on the Maxwell-Boltzmann distributions at 300 K shown above, which of the following gases could be represented by curve X?

- * (A) Br₂(g)
 (B) CH₄(g)
 (C) He(g)
 (D) N₂(g)

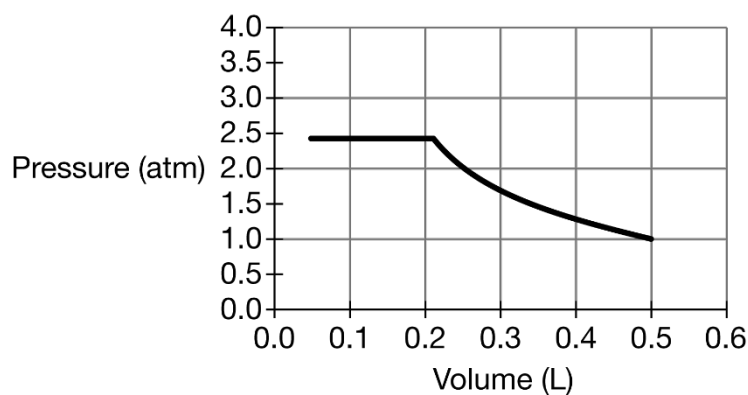
Topic
3.5 Kinetic Molecular Theory

2021 Practice Exam (from AP Classroom)

Q: Explain increase in pressure



A sample of $C_4H_{10}(g)$ is placed in a rigid vessel with a movable piston. The volume of the gas is reduced by moving the piston downward while the temperature is maintained at 25°C , as shown above. The pressure of the gas versus its volume is plotted in the graph below.



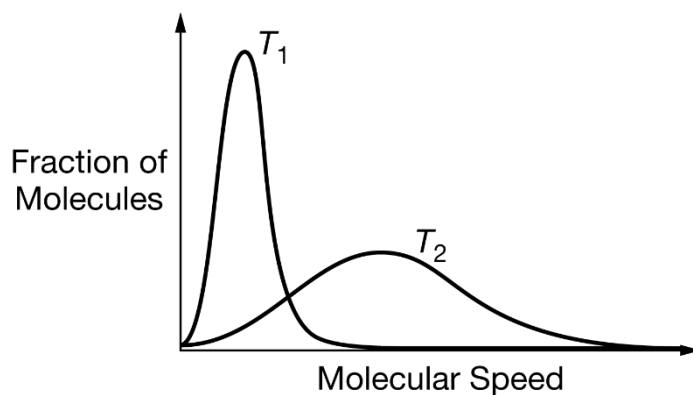
Which of the following best explains the increase in pressure of the $C_4H_{10}(g)$ when its volume is decreased from 0.50 L to 0.21 L?

- * (A) The molecules strike the walls of the vessel more frequently.
- (B) The molecules strike the walls of the vessel with different orientations.
- (C) The molecules strike the walls of the vessel with greater force.
- (D) The molecules decompose to produce a greater number of particles.

Topic
3.5 Kinetic Molecular Theory

2021 Practice Exam (from AP Classroom)

Q: Speed at different temperatures



The diagram above shows the distribution of molecular speed in a sample of gas at two different temperatures, T_1 and T_2 . Which of the following is a correct interpretation of the information provided by the diagram?

- (A) The average speed of the molecules is greater at T_1 than at T_2 .
- (B) The taller peak corresponds to the higher temperature, T_1 .
- (C) There are fewer molecules of gas at T_2 than at T_1 .
- * (D) The average kinetic energy of the molecules is greater at T_2 than at T_1 .

Topic
3.5 Kinetic Molecular Theory

2019 Practice Exam #19

Q: Combustion rxn enthalpy - speed of gas molecules

Questions X-Y are based on the information in the table below.

Compound	Molar Mass	Balanced Equation for the Combustion of One Mole of the Compound	ΔH_{comb}° (kJ/mol _{rxn})
$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \\ \text{Ethane} \end{array}$	30. g/mol	$\text{C}_2\text{H}_6(g) + \frac{7}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$	-1560
$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \\ \text{Propanol} \end{array}$	60. g/mol	$\text{C}_3\text{H}_8\text{O}(l) + \frac{9}{2}\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2020
Unknown	?	$? + 5\text{O}_2(g) \rightarrow 4\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2240

A sealed 10.0 L flask at 400 K contains equimolar amounts of ethane and propanol in gaseous form. Which of the following statements concerning the average molecular speed of ethane and propanol is true?

- (A) The average molecular speed of ethane is less than the average molecular speed of propanol.
- * (B) The average molecular speed of ethane is greater than the average molecular speed of propanol.
- (C) The average molecular speed of ethane is equal to the average molecular speed of propanol.
- (D) The average molecular speeds of ethane and propanol cannot be compared without knowing the total pressure of the gas mixture.

Topic
3.5 Kinetic Molecular Theory

2019 Practice Exam #30

Q: Change in KE and speed of Xe atoms with higher T

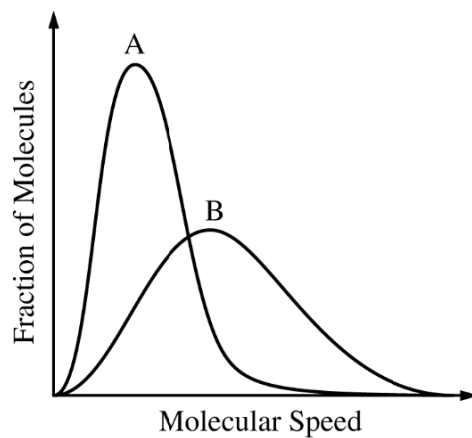
A 1.0 mol sample of He(g) at 25°C is mixed with a 1.0 mol sample of Xe(g) at 50°C. Which of the following correctly predicts the changes in average kinetic energy and the average speed of the Xe(g) atoms that will occur as the mixture approaches thermal equilibrium?

	Average Kinetic Energy of Xe Atoms	Average Speed of Xe Atoms
(A)	Will increase	Will increase
(B)	Will increase	Will decrease
(C)	Will decrease	Will increase
* (D)	Will decrease	Will decrease

Topic
3.5 Kinetic Molecular Theory

2018 Practice Exam #27

Q: Boltzmann distributions of 2 gases - greater MM



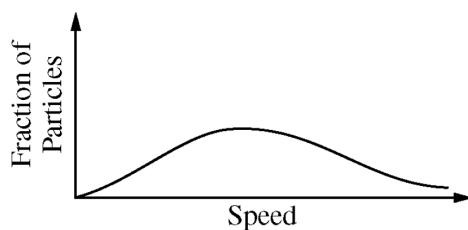
The Maxwell-Boltzmann distributions of molecular speeds in samples of two different gases at the same temperature are shown above. Which gas has the greater molar mass?

- * (A) Gas A
- (B) Gas B
- (C) Both gases have the same molar mass.
- (D) It cannot be determined unless the pressure of each sample is known.

Topic
3.5 Kinetic Molecular Theory

2016 Practice Exam #13

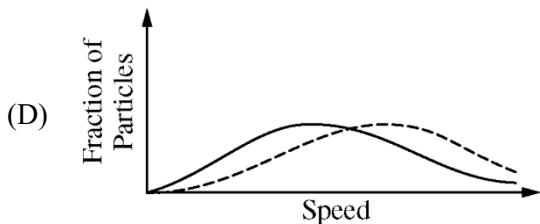
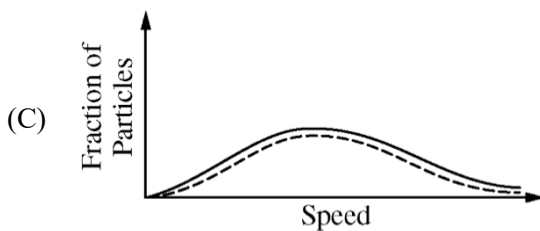
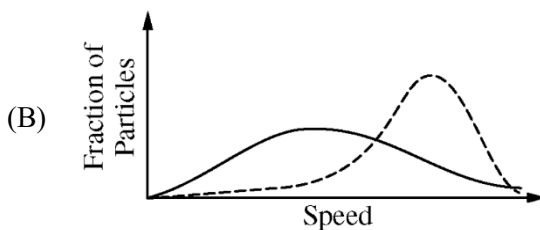
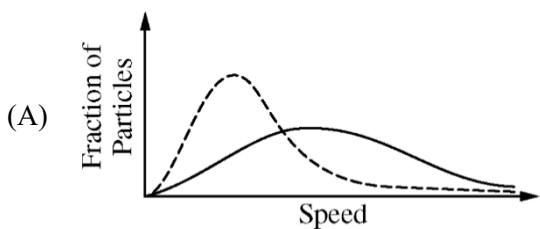
Q: Boltzmann distribution - compare He to H₂



The distribution of speeds of H₂(g) molecules at 273 K and 1 atm is shown in the diagram above. Which of the following best shows the speed distribution of He(g) atoms under the same conditions of temperature and pressure?

———— H₂(g) - - - - He(g)

*



Topic
3.5 Kinetic Molecular Theory

2015 Practice Exam #1

Q: He and Ne rate of escape through pinhole opening

A 0.5 mol sample of He(g) and a 0.5 mol sample of Ne(g) are placed separately in two 10.0 L rigid containers at 25°C. Each container has a pinhole opening. Which of the gases, He(g) or Ne(g), will escape faster through the pinhole and why?

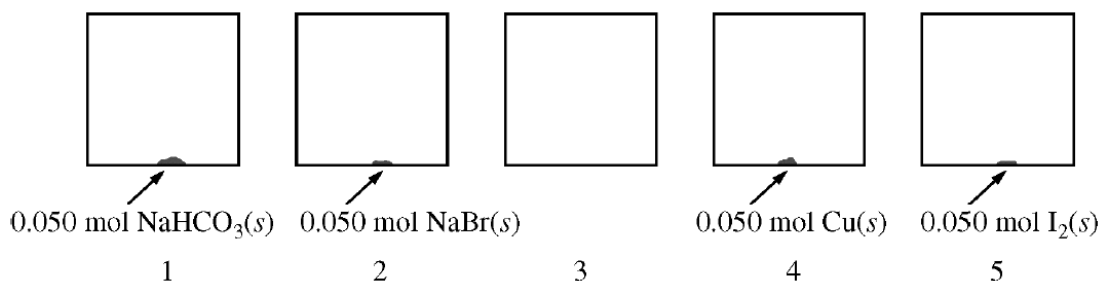
- * (A) He(g) will escape faster because the He(g) atoms are moving at a higher average speed than the Ne(g) atoms.
- (B) Ne(g) will escape faster because its initial pressure in the container is higher.
- (C) Ne(g) will escape faster because the Ne(g) atoms have a higher average kinetic energy than the He(g) atoms.
- (D) Both gases will escape at the same rate because the atoms of both gases have the same average kinetic energy.

Topic
3.5 Kinetic Molecular Theory

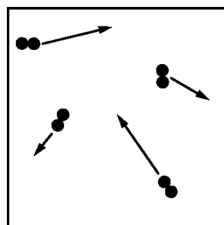
2015 Practice Exam #9

Q: 5 vessels - gas particle speed at high T vs. low T

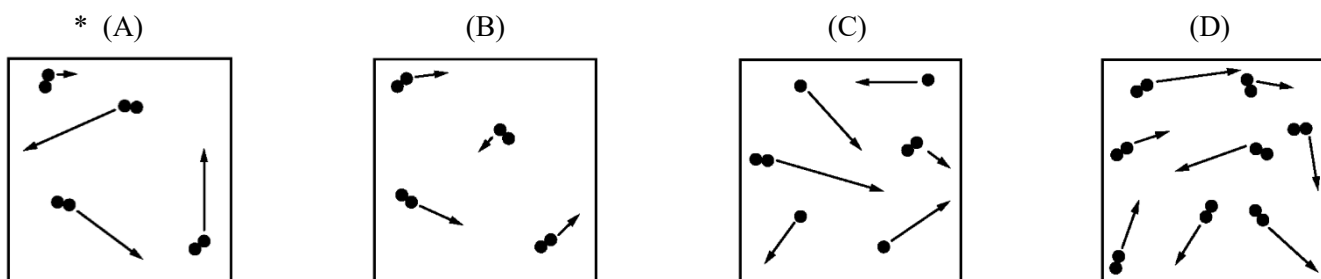
Questions X-Y refer to the following information.



At 27°C , five identical rigid 2.0 L vessels are filled with $\text{N}_2(g)$ and sealed. Four of the five vessels also contain a 0.050 mol sample of $\text{NaHCO}_3(s)$, $\text{NaBr}(s)$, $\text{Cu}(s)$, or $\text{I}_2(s)$, as shown in the diagram above. The volume taken up by the solids is negligible, and the initial pressure of $\text{N}_2(g)$ in each vessel is 720 mm Hg. All five vessels are heated to 127°C and allowed to reach a constant pressure.



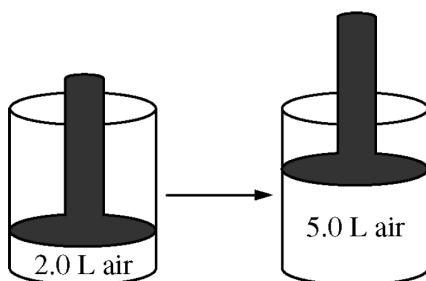
The gas particles in vessel 3 at 27°C are represented in the diagram above. The lengths of the arrows represent the speeds of the particles. Which of the following diagrams best represents the particles when vessel 3 is heated to 127°C ?



Topic
3.5 Kinetic Molecular Theory

2014 Practice Exam #7

Q: Effect of increasing V on average KE of a gas



The volume of a sample of air in a cylinder with a movable piston is 2.0 L at a pressure P_1 , as shown in the diagram above. The volume is increased to 5.0 L as the temperature is held constant. The pressure of the air in the cylinder is now P_2 . What effect do the volume and pressure changes have on the average kinetic energy of the molecules in the sample?

- (A) The average kinetic energy increases.
- (B) The average kinetic energy decreases.
- * (C) The average kinetic energy stays the same.
- (D) It cannot be determined how the kinetic energy is affected without knowing P_1 and P_2 .

Topic
3.5 Kinetic Molecular Theory

2014 Practice Exam #15

Q: Gases at 2.00 atm - average gas particle speed

Questions X-Y refer to the following.

The table below contains information about samples of four different gases at 273 K. The samples are in four identical rigid containers numbered 1 through 4.

Container	Gas	Pressure (atm)	Mass of Sample (g)
1	He	2.00	?
2	Ne	2.00	?
3	?	2.00	16.0
4	SO ₂	1.96	64.1

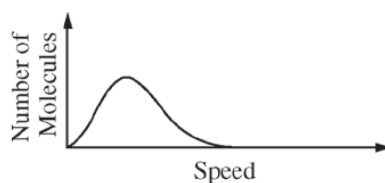
Under the conditions given, consider containers 1, 2, and 4 only. The average speed of the gas particles is

- * (A) greatest in container 1
- (B) greatest in container 2
- (C) greatest in container 4
- (D) the same in containers 1, 2, and 4

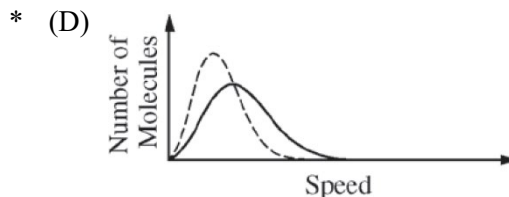
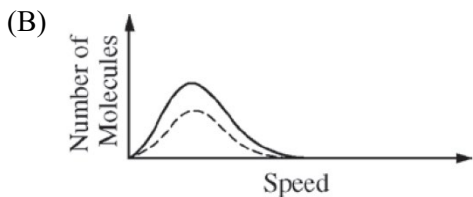
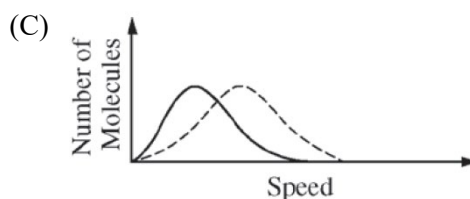
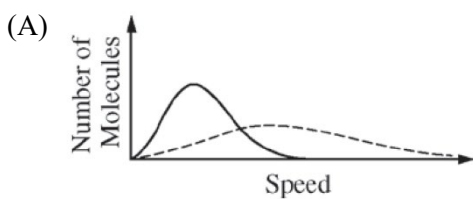
Topic
3.5 Kinetic Molecular Theory

2013 Practice Exam #8

Q: Boltzmann distribution at lower temperature



The graph above shows the speed distribution of molecules in a sample of gas at a certain temperature. Which of the following graphs shows the speed distribution of the same molecules at a lower temperature (as a dashed curve) ?



Topic
3.5 Kinetic Molecular Theory

2013 Practice Exam #18

Q: C_xH_y gases - average KE of the gas molecules

Questions X-Y refer to three gases in identical rigid containers under the conditions given in the table below.

Container	A	B	C
Gas	Methane	Ethane	Butane
Formula	CH ₄	C ₂ H ₆	C ₄ H ₁₀
Molar mass (g/mol)	16	30.	58
Temperature (°C)	27	27	27
Pressure (atm)	2.0	4.0	2.0

The average kinetic energy of the gas molecules is

(A) greatest in container A

(B) greatest in container B

(C) greatest in container C

* (D) the same in all three containers

Topic
3.5 Kinetic Molecular Theory

2013 Practice Exam #29

Q: PCl_5 equil. - cause of increase in pressure

Questions X-Y refer to the following.



$\text{PCl}_5(g)$ decomposes into $\text{PCl}_3(g)$ and $\text{Cl}_2(g)$ according to the equation above. A pure sample of $\text{PCl}_5(g)$ is placed in a rigid, evacuated 1.00 L container. The initial pressure of the $\text{PCl}_5(g)$ is 1.00 atm. The temperature is held constant until the $\text{PCl}_5(g)$ reaches equilibrium with its decomposition products. The figures below show the initial and equilibrium conditions of the system.

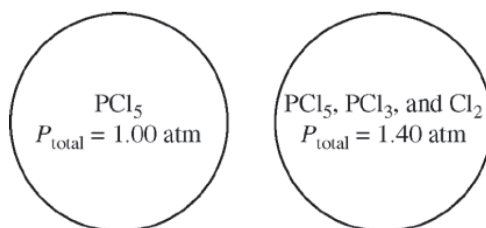


Figure 1: Initial

Figure 2: Equilibrium

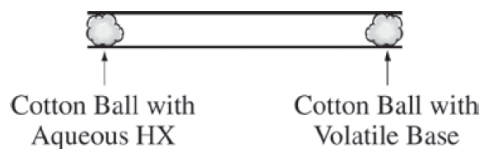
Which of the following is the most likely cause for the increase in pressure observed in the container as the reaction reaches equilibrium?

- (A) A decrease in the strength of intermolecular attractions among molecules in the flask
- (B) An increase in the strength of intermolecular attractions among molecules in the flask
- * (C) An increase in the number of molecules, which increases the frequency of collisions with the walls of the container
- (D) An increase in the speed of the molecules that then collide with the walls of the container with greater force

Topic
3.5 Kinetic Molecular Theory

2013 Practice Exam #39

Q: Diffusion of HX and volatile base in a tube



The experimental apparatus represented above is used to demonstrate the rates at which gases diffuse. When the cotton balls are placed in the ends of a tube at the same time, the gases diffuse from each end and meet somewhere in between, where they react to form a white solid. Which of the following combinations will produce a solid closest to the center of the tube?

- * (A) HCl and CH_3NH_2
- (B) HCl and NH_3
- (C) HBr and CH_3NH_2
- (D) HBr and NH_3

Topic
3.6 Deviation from Ideal Gas Law

2023 Practice Exam (from AP Classroom)

Q: H₂ behaves ideally

Which of the following best explains why H₂(g) behaves more ideally than most other gases?

- (A) The number of particles in a given volume of H₂(g) is smallest in comparison to other gases, because the molar mass of H₂ is smallest.
- (B) Collisions between gas particles and the walls of a container are more frequent for smaller molecules, because the average velocity is very high.
- (C) The average kinetic energy of H₂ molecules at a given temperature is large, because the average velocity of the H₂ molecules is very high.
- * (D) Intermolecular attractions between H₂ molecules are weak, because the electron clouds of H₂ molecules are small.

Topic
3.6 Deviation from Ideal Gas Law

2022 Practice Exam (from AP Classroom)

Q: Nonideal gas behavior

P (atm)	$V_{\text{experimental}}$ (L)	V_{ideal} (L)
0.200	122.2	122.2
2.000	12.17	12.22
8.000	2.925	3.055

The pressure of a sample of $\text{NH}_3(\text{g})$ was changed by adjusting the volume of the container. The experimental volumes that were needed to achieve the desired pressures were different from the volumes predicted by the ideal gas law as shown in the table above. Which of the following best explains the difference between the experimental volumes and the volumes predicted by the ideal gas law?

- * (A) The attraction between the molecules becomes significant at high pressure.
- (B) The repulsion between the molecules becomes significant at high pressure.
- (C) The average speed of the molecules decreases as the pressure increases.
- (D) The average speed of the molecules increases as the pressure increases.

Topic
3.6 Deviation from Ideal Gas Law

2021 Practice Exam (from AP Classroom)

Q: Nonideal behavior

$\text{CCl}_4(g)$ deviates more from ideal gas behavior than $\text{CH}_4(g)$ does. Which of the following statements best explains this observation?

- (A) The mass of the CCl_4 molecule is greater than that of the CH_4 molecule.
- (B) The bond energy of the C–Cl bond is greater than that of the C–H bond.
- (C) The dipole-dipole forces between CCl_4 molecules are greater than those between CH_4 molecules.
- * (D) The London dispersion forces between CCl_4 molecules are stronger than those between CH_4 molecules.

Topic
3.6 Deviation from Ideal Gas Law

2018 Practice Exam #5

Q: Reason gas pressure is lower than ideal gas law

A 1.0 L sample of a pure gas is found to have a lower pressure than that predicted by the ideal gas law. The best explanation for the observation is that the molecules of the gas

- (A) have a combined volume that is too large to be considered negligible when compared to the volume of the container
- (B) have a low molecular mass and therefore do not strike the container walls with as much force as expected
- * (C) are attracted to each other and do not exert as much force on the container walls as they would if they had no mutual attractions
- (D) are attracted to the sides of the container and strike the container walls with more force than expected

Topic
3.6 Deviation from Ideal Gas Law

2017 Practice Exam #2

Q: The ideal gas law best describes which gas at 1 atm

The ideal gas law best describes the properties of which of the following gases at 0°C and 1 atm?

(A) PH_3

(B) HBr

(C) SO_2

* (D) N_2

Topic
3.6 Deviation from Ideal Gas Law

2016 Practice Exam #36

Q: Why measured pressure of Ar is higher than ideal

A vessel contains Ar(g) at a high pressure. Which of the following statements best helps to explain why the measured pressure is significantly greater than the pressure calculated using the ideal gas law?

- (A) The molar mass of Ar is relatively large.
- (B) A significant number of Ar₂ molecules form.
- (C) The attractive forces among Ar atoms cause them to collide with the walls of the container with less force.
- * (D) The combined volume of the Ar atoms is too large to be negligible compared with the total volume of the container.

Topic
3.6 Deviation from Ideal Gas Law

2014 Practice Exam #6

Q: Conditions of T and P when H₂ behaves most ideally

Under which of the following conditions of temperature and pressure will H₂ gas be expected to behave most like an ideal gas?

- (A) 50 K and 0.10 atm
- (B) 50 K and 5.0 atm
- * (C) 500 K and 0.10 atm
- (D) 500 K and 50 atm

Topic
3.6 Deviation from Ideal Gas Law

2014 Practice Exam #16

Q: Gases at 2.00 atm - explain lower pressure for SO₂

Questions X-Y refer to the following.

The table below contains information about samples of four different gases at 273 K. The samples are in four identical rigid containers numbered 1 through 4.

Container	Gas	Pressure (atm)	Mass of Sample (g)
1	He	2.00	?
2	Ne	2.00	?
3	?	2.00	16.0
4	SO ₂	1.96	64.1

The best explanation for the lower pressure in container 4 is that SO₂ molecules

- (A) have a larger average speed than the other three gases
- (B) occupy a larger portion of the container volume than the other three gases
- * (C) have stronger intermolecular attractions than the other three gases
- (D) contain pi bonds, while the other gases contain only sigma bonds

Topic
3.7 Solutions and Mixtures

2023 Practice Exam (from AP Classroom)

Q: Method to prepare solution

Which of the following is the best method for preparing 100.0 mL of 1.00 M $KCl(aq)$?

- (A) Place 74.6 g of $KCl(s)$ in a 100 mL graduated cylinder and fill to the 100.0 mL mark with water.
- (B) Place 7.46 g of $KCl(s)$ in a 100 mL Erlenmeyer flask, add 92.54 g of water, and invert several times.
- * (C) Place 7.46 g of $KCl(s)$ in a 100 mL volumetric flask, partially fill with water, swirl flask to dissolve solid, fill to the 100.0 mL mark with water, and invert several times.
- (D) Place 7.46 g of $KCl(s)$ in a 100 mL volumetric flask, partially fill with water, swirl flask to dissolve solid, add 92.54 mL of water, and invert several times.

Topic
3.7 Solutions and Mixtures

2023 Practice Exam (from AP Classroom)

Q: Molarity of aqueous solution

A student dissolves a quantity of $\text{KNO}_3(s)$ in water. What information must the student use to calculate the molarity of the aqueous solution?

- (A) Grams of KNO_3 and the density of water
- (B) Liters of KNO_3 and liters of solution
- (C) Moles of KNO_3 and the density of water
- * (D) Moles of KNO_3 and liters of solution

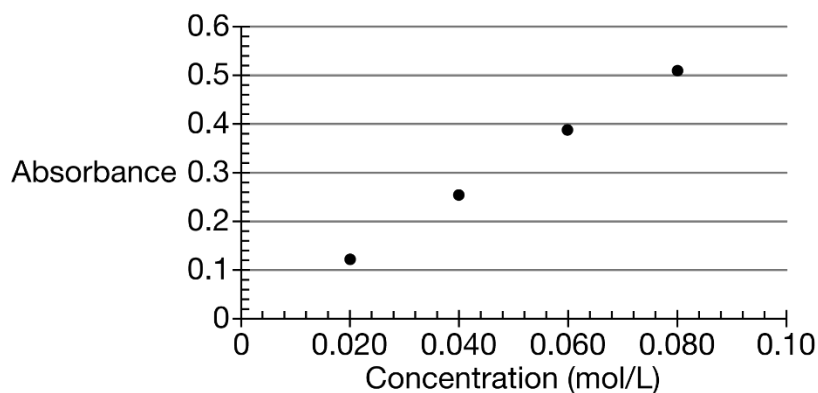
Topic
3.7 Solutions and Mixtures

2021 Practice Exam (from AP Classroom)

Q: Concentration of ions

An experiment was performed to investigate the reaction between Zn metal and $\text{Ni}^{2+}(aq)$ at different concentrations. Because the $\text{Ni}^{2+}(aq)$ ion is green, the extent of the reaction was determined using spectrophotometric analysis. Four 20.0 mL standard solutions of $\text{Ni}^{2+}(aq)$ were prepared by dissolving $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ (molar mass 240 g/mol) in water. The absorbance of each solution was measured; the results are shown both in the table below and in the following plot of the absorbance data.

Solution	$[\text{Ni}^{2+}]$	Absorbance
1	0.020	0.12
2	0.040	0.25
3	0.060	0.39
4	0.080	0.51



The concentration of $\text{Cl}^-(aq)$ ions in solution 2 was

(A) 0.020 M

(B) 0.040 M

(C) 0.060 M

* (D) 0.080 M

Topic
3.7 Solutions and Mixtures

2019 Practice Exam #2

Q: 0.1 M solution with greatest conductivity and why

Solution
0.1 M $\text{HC}_2\text{H}_3\text{O}_2(aq)$
0.1 M $\text{KI}(aq)$
0.1 M $\text{CH}_3\text{OH}(aq)$

Of the three solutions listed in the table above, which one, if any, has the greatest electrical conductivity and why?

- (A) 0.1 M $\text{HC}_2\text{H}_3\text{O}_2(aq)$ because its molecules have the most atoms.
- * (B) 0.1 M $\text{KI}(aq)$ because KI completely dissociates in water to produce ions.
- (C) 0.1 M $\text{CH}_3\text{OH}(aq)$ because its molecules can form hydrogen bonds.
- (D) All three solutions have the same electrical conductivity because the concentrations are the same.

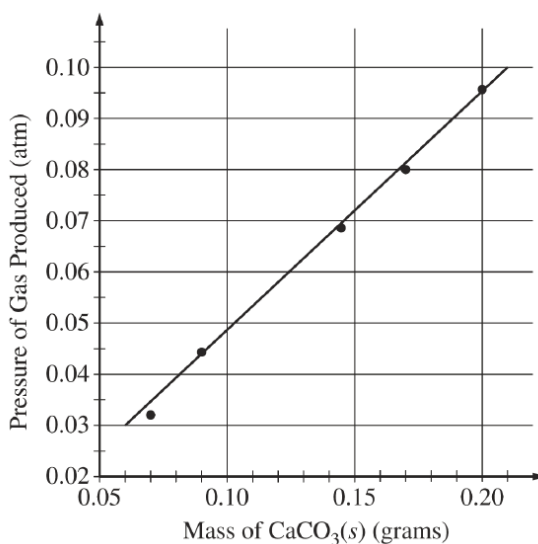
Topic
3.7 Solutions and Mixtures

2019 Practice Exam #37

Q: CaCO_3 in eggshells - concentration of HCl

Questions X-Y refer to the following information.

An experiment is performed to measure the mass percent of $\text{CaCO}_3(s)$ in eggshells. Five different samples of $\text{CaCO}_3(s)$ of known mass react with an excess of $2.0\text{ M HCl}(aq)$ in identical sealed, rigid reaction vessels. The pressure of the gas produced is measured with a pressure gauge attached to the reaction vessel. Since the reaction is exothermic, the reaction system is cooled to its original temperature before the pressure is recorded. The experimental data are used to create the calibration line below.



The experiment is repeated with an eggshell sample, and the experimental data are recorded in the table below.

Mass of eggshell sample	0.200 g
Pressure prior to reaction	0.800 atm
Pressure at completion of reaction	0.870 atm

Another sample of eggshell reacts completely with 4.0 mL of an $\text{HCl}(aq)$ solution of unknown concentration. If the reaction produced 0.095 atm of gas, the concentration of the $\text{HCl}(aq)$ solution was at least

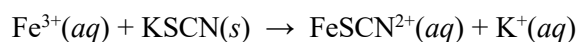
- (A) 0.0020 M
- (B) 0.050 M
- (C) 0.50 M

* (D) 1.0 M

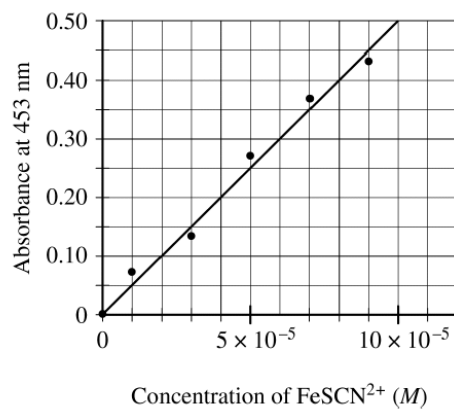
Topic
3.7 Solutions and Mixtures

2017 Practice Exam #5

Q: Moles of Fe³⁺ given Beer-Lambert plot absorbance



To determine the moles of Fe³⁺(aq) in a 100. mL sample of an unknown solution, excess KSCN(s) is added to convert all the Fe³⁺(aq) into the dark red species FeSCN²⁺(aq), as represented by the equation above. The absorbance of FeSCN²⁺(aq) at different concentrations is shown in the graph below.



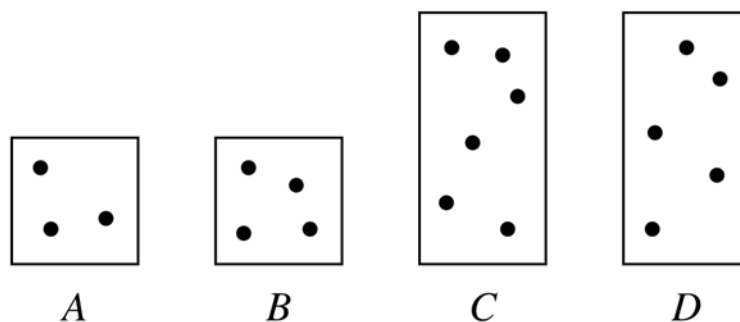
If the absorbance of the mixture is 0.20 at 453 nm, how many moles of Fe³⁺(aq) were present in the 100. mL sample? (Assume that any volume change due to adding the KSCN(s) is negligible.)

- (A) 4×10^{-4} mol
- (B) 3×10^{-4} mol
- * (C) 4×10^{-6} mol
- (D) 3×10^{-6} mol

Topic
3.8 Representations of Solutions

2022 Practice Exam (from AP Classroom)

Q: Particle diagrams of solutions



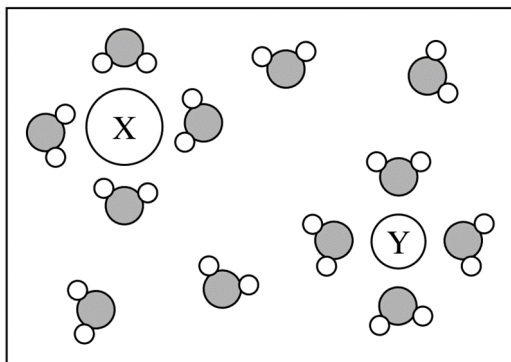
The diagrams above represent aqueous solutions of compound X at various molarities. Each dot represents one mole of the solute, and the volume of solution in the large boxes is twice the volume in the small boxes. Which solution has the highest molarity?

- (A) A
- * (B) B
- (C) C
- (D) D

Topic
3.8 Representations of Solutions

2022 Practice Exam (from AP Classroom)

Q: Water molecules around ions



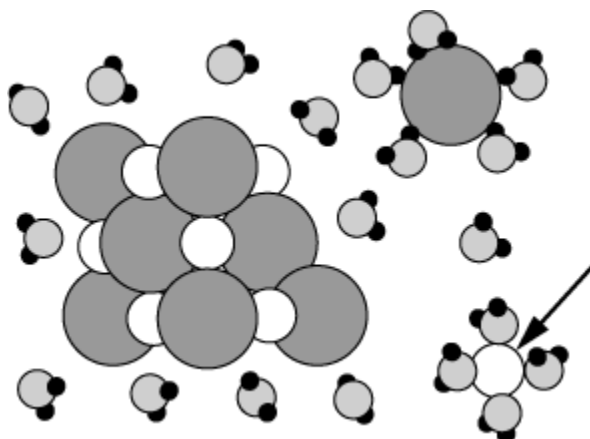
The diagram above represents a solution of ions in water. Which of the following are the most likely identities of ions X and Y?

- (A) Ion X is Na^+ , and ion Y is K^+ .
- (B) Ion X is Na^+ , and ion Y is F^- .
- * (C) Ion X is Cl^- , and ion Y is K^+ .
- (D) Ion X is Cl^- , and ion Y is F^- .

Topic
3.8 Representations of Solutions

2021 Practice Exam (from AP Classroom)

Q: Charge of hydrated particle



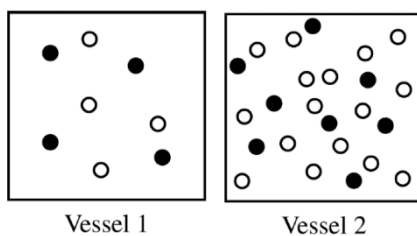
An ionic crystal is added to water and starts to dissolve as shown in the particulate representation above. Based on the orientation of the water molecules, what can be assumed about the charge of the hydrated particle indicated by the arrow?

- * (A) The particle is positively charged, because the oxygen atoms in water are attracted to it.
- (B) The particle is negatively charged, because hydrogen atoms in water are attracted to it.
- (C) The particle is both positively and negatively charged, because the water molecules are attracted to it.
- (D) The particle is neutral, because the dipoles of the water molecules neutralize the charge of the particle.

Topic
3.8 Representations of Solutions

2018 Practice Exam #6

Q: Particle diagram of KCl - solution in vessel 2



Key
● Any positive ion
○ Any negative ion
H ₂ O molecules are not shown.

Equal volumes of solutions in two different vessels are represented above. If the solution represented in vessel 1 is KCl(aq), then the solution represented in vessel 2 could be an aqueous solution of

- (A) KCl with the same molarity as the solution in vessel 1
- (B) KCl with twice the molarity of the solution in vessel 1
- (C) CaCl₂ with the same molarity as the solution in vessel 1
- * (D) CaCl₂ with twice the molarity of the solution in vessel 1

Topic
3.8 Representations of Solutions

2014 Practice Exam #10

Q: MCl gravimetric analysis - particle diagram AgNO_3

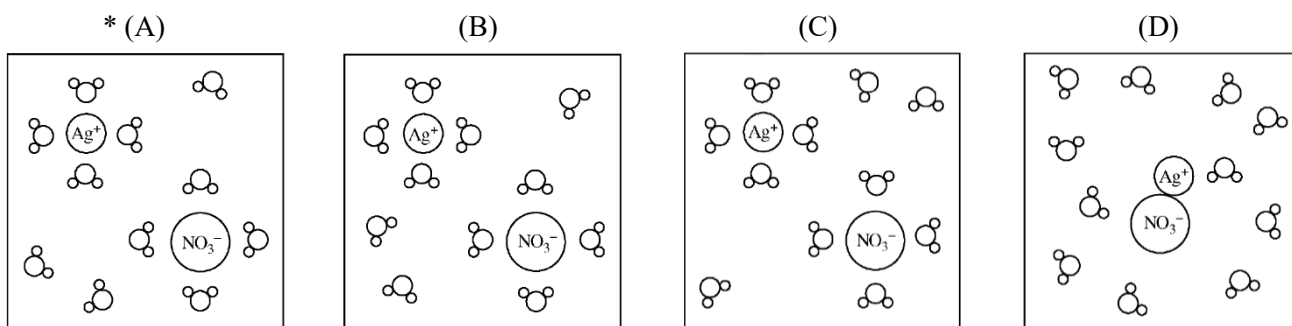
Questions X-Y refer to the following.

M^+ is an unknown metal cation with a +1 charge. A student dissolves the chloride of the unknown metal, MCl, in enough water to make 100.0 mL of solution. The student then mixes the solution with excess AgNO_3 solution, causing AgCl to precipitate. The student collects the precipitate by filtration, dries it, and records the data shown below. (The molar mass of AgCl is 143 g/mol.)

Mass of unknown chloride, MCl	0.74 g
Mass of filter paper	0.80 g
Mass of filter paper plus AgCl precipitate	2.23 g

Which of the following diagrams best represents the AgNO_3 solution before the reaction occurs?

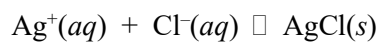
Note: water molecules are represented by the symbol .



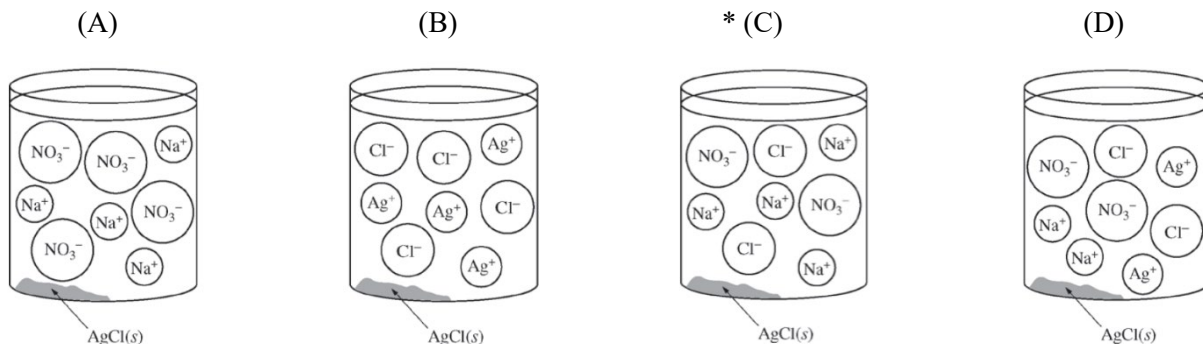
Topic
3.8 Representations of Solutions

2013 Practice Exam #28

Q: Particulate diagram - soln after AgCl precipitates



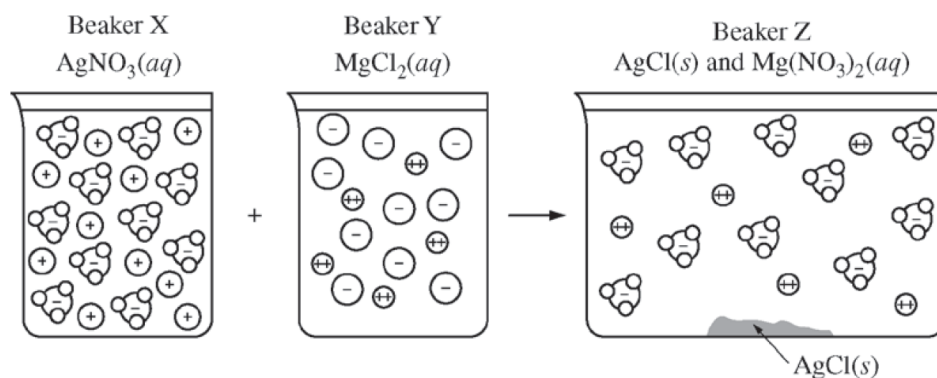
A student mixes dilute $\text{AgNO}_3(aq)$ with excess $\text{NaCl}(aq)$ to form $\text{AgCl}(s)$, as represented by the net ionic equation above. Which of the diagrams below best represents the ions that are present in significant concentrations in solution? (K_{sp} for AgCl is 1.8×10^{-10} .)



Topic
3.8 Representations of Solutions

2013 Practice Exam #56

Q: Set of solutions represented by AgCl particulate



Beaker X and beaker Y each contain 1.0 L of solution, as shown above. A student combines the solutions by pouring them into a larger, previously empty beaker Z and observes the formation of a white precipitate. Assuming that volumes are additive, which of the following sets of solutions could be represented by the diagram above?

	Beaker X	Beaker Y	Beaker Z
(A)	2.0 M AgNO_3	2.0 M MgCl_2	4.0 M $\text{Mg}(\text{NO}_3)_2$ and $\text{AgCl}(s)$
(B)	2.0 M AgNO_3	2.0 M MgCl_2	2.0 M $\text{Mg}(\text{NO}_3)_2$ and $\text{AgCl}(s)$
(C)	2.0 M AgNO_3	1.0 M MgCl_2	1.0 M $\text{Mg}(\text{NO}_3)_2$ and $\text{AgCl}(s)$
* (D)	2.0 M AgNO_3	1.0 M MgCl_2	0.50 M $\text{Mg}(\text{NO}_3)_2$ and $\text{AgCl}(s)$

Topic
3.9 Separation of Solutions and Mixtures

2022 Practice Exam (from AP Classroom)

Q: Basis of paper chromatography

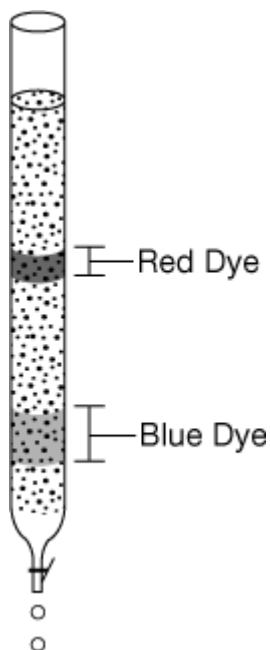
Which of the following questions about the components in a mixture could be investigated with a paper chromatography experiment?

- (A) Do the components have different densities?
- (B) Do the components have different molecular masses?
- * (C) Do the components have different molecular polarities?
- (D) Do the components have different average molecular speeds?

Topic
3.9 Separation of Solutions and Mixtures

2021 Practice Exam (from AP Classroom)

Q: Use different liquid in column



A student placed a sample of a food coloring that contains a mixture of a blue dye and a red dye at the top of a chromatography column filled with a nonpolar stationary phase. When water is poured through the column, two bands of colors are seen in the column, as shown in the diagram above.

Which of the following will most likely be observed if $\text{CH}_3\text{OH}(l)$ is used in the column instead of water? (Assume that both solvents flow through the column at the same rate.)

- (A) The dyes will not pass through the column because $\text{CH}_3\text{OH}(l)$ is a nonpolar solvent.
- * (B) The dyes will pass through the column at a slower rate because $\text{CH}_3\text{OH}(l)$ is a less polar solvent than water.
- (C) The dyes will pass through the column at a faster rate because $\text{CH}_3\text{OH}(l)$ has a greater molar mass than water.
- (D) No differences will be observed because the polarity of the solvent does not affect the separation of the dyes.

Topic
3.9 Separation of Solutions and Mixtures

2019 Practice Exam #6

Q: Separating components hexane and octane mixture

Compound	Formula	Boiling Point (°C)	Density (g/mL)
Hexane	C ₆ H ₁₄	69	0.66
Octane	C ₈ H ₁₈	126	0.70

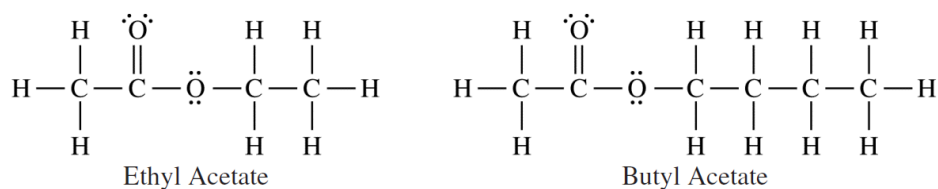
A student obtains a mixture of the liquids hexane and octane, which are miscible in all proportions. Which of the following techniques would be best for separating the two components of the mixture, and why?

- (A) Filtration, because the different densities of the liquids would allow one to pass through the filter paper while the other would not.
- (B) Paper chromatography, because the liquids would move along the stationary phase at different rates owing to the difference in polarity of their molecules.
- (C) Column chromatography, because the higher molar mass of octane would cause it to move down the column faster than hexane.
- * (D) Distillation, because the liquids would boil at different temperatures owing to the difference in strength of their intermolecular forces.

Topic
3.9 Separation of Solutions and Mixtures

2016 Practice Exam #28

Q: Distillation - ethyl acetate butyl acetate



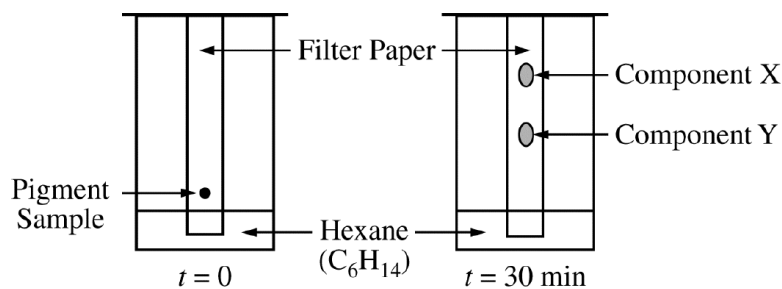
A mixture containing equal numbers of moles of ethyl acetate and butyl acetate was separated using distillation. Based on the diagrams shown above, which of the following identifies the substance that would be initially present in higher concentration in the distillate and correctly explains why that occurs?

- (A) Ethyl acetate, because it has fewer C–C bonds to break
- * (B) Ethyl acetate, because it has a shorter carbon chain and weaker London dispersion forces
- (C) Butyl acetate, because it has more C–C bonds to break
- (D) Butyl acetate, because it has a longer carbon chain and weaker dipole-dipole attractions

Topic
3.9 Separation of Solutions and Mixtures

2015 Practice Exam #49

Q: Paper chromatography - conclusion for dyes X and Y



In a paper chromatography experiment, a sample of a pigment is separated into two components, X and Y, as shown in the figure above. The surface of the paper is moderately polar. What can be concluded about X and Y based on the experimental results?

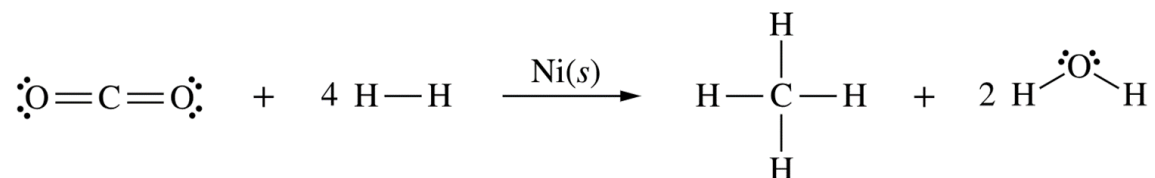
- (A) X has a larger molar mass than Y does.
- (B) Y has a larger molar mass than X does.
- (C) X is more polar than Y.
- * (D) Y is more polar than X.

Topic
3.10 Solubility

2023 Practice Exam (from AP Classroom)

Q: Solubility in EtOH

In the gas-phase reaction represented by the following equation, methane (CH₄) and water (H₂O) are produced from carbon dioxide (CO₂) and hydrogen (H₂) at high temperature and pressure.



Based on the Lewis diagrams, which of the products is more soluble in ethanol (C₂H₅OH)?

- (A) Methane, because it has more hydrogen atoms than water does, so it can form more hydrogen bonds with ethanol.
- (B) Methane, because it is a larger molecule than water, so its electron cloud is more polarizable.
- (C) Water, because water has a greater molar mass than methane does.
- * (D) Water, because water molecules can form hydrogen bonds with ethanol molecules, but methane molecules cannot.

Topic
3.10 Solubility

2022 Practice Exam (from AP Classroom)

Q: Solubility in water

Substance	Structural Formula	Molar Mass (g/mol)
Propylamine	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{N} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \end{array} $	59
Pentane	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} - \text{H} \\ & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	72
2-Propanol	$ \begin{array}{ccccccc} & & & \text{H} & & & \\ & & & & & & \\ & \text{H} & & \text{O} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \end{array} $	60
Propanoic acid	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{O} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{O} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & & \end{array} $	74

A student was given samples of four different unknown liquids. The unknown liquids are propylamine, pentane, 2-propanol, and propanoic acid. The structures and molar masses of the compounds are shown in the table above. On the basis of this information, the student designed some experiments to identify the samples.

The student mixed samples of each of the four compounds with water. Only one of the four did not dissolve in water. Based on the structures of the molecules and the strengths and types of their intermolecular forces, the compound that did not dissolve is most likely

(A) propylamine

* (B) pentane

(C) 2-propanol

(D) propanoic acid

Topic
3.10 Solubility

2021 Practice Exam (from AP Classroom)

Q: Layers of liquids

Compound	Structure	Boiling Point (°C)
Methanol	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	65
Ethanol	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	78
Propanal	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{:O:} \\ \quad \quad // \\ \text{H}-\text{C}-\text{C}-\text{C} \\ \quad \quad \backslash \\ \text{H} \quad \text{H} \quad \text{H} \end{array} $	49
Hexane	$ \begin{array}{cccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $	69

A 50 mL sample of $\text{C}_6\text{H}_{14}(l)$ is mixed with a 50 mL sample of $\text{H}_2\text{O}(l)$, and the mixture is shaken vigorously. The two liquids do not stay mixed but instead form two separate layers. The density of hexane is 0.66 g/mL, and the density of water is 1.00 g/mL. A 1.0 g sample of $\text{I}_2(s)$ is added to the mixture, which is shaken again. Which of the following best predicts what happens to the $\text{I}_2(s)$?

- (A) I_2 will be found mainly in the top layer because it will dissolve more in the $\text{H}_2\text{O}(l)$.
- (B) I_2 will be found mainly in the bottom layer because it will dissolve more in the $\text{H}_2\text{O}(l)$.
- * (C) I_2 will be found mainly in the top layer because it will dissolve more in the $\text{C}_6\text{H}_{14}(l)$.
- (D) I_2 will be found mainly in the bottom layer because it will dissolve more in the $\text{C}_6\text{H}_{14}(l)$.

Topic
3.10 Solubility

2019 Practice Exam #17

Q: Combustion rxn enthalpy - compound soluble in H₂O

Questions X-Y are based on the information in the table below.

Compound	Molar Mass	Balanced Equation for the Combustion of One Mole of the Compound	ΔH_{comb}° (kJ/mol _{rxn})
$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \\ \text{Ethane} \end{array} $	30. g/mol	$\text{C}_2\text{H}_6(g) + \frac{7}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$	-1560
$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \\ \text{Propanol} \end{array} $	60. g/mol	$\text{C}_3\text{H}_8\text{O}(l) + \frac{9}{2}\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2020
Unknown	?	$? + 5\text{O}_2(g) \rightarrow 4\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2240

Based on the structural formulas, which of the following identifies the compound that is more soluble in water and best helps to explain why?

- (A) Ethane, because the electron clouds of its molecules are more polarizable than those of propanol.
- (B) Ethane, because its molecules can fit into the spaces between water molecules more easily than those of propanol can.
- (C) Propanol, because its molecules have a greater mass than the molecules of ethane have.
- * (D) Propanol, because its molecules can form hydrogen bonds with water molecules but those of ethane cannot.

Topic
3.10 Solubility

2017 Practice Exam #21

Q: Given compound formula - most soluble in H₂O

On the basis of molecular structure and bond polarity, which of the following compounds is most likely to have the greatest solubility in water?

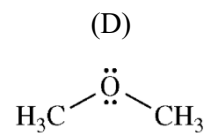
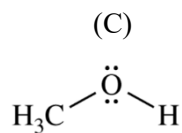
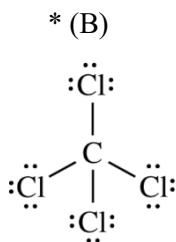
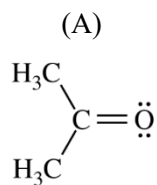
- (A) CH₄
- (B) CCl₄
- * (C) NH₃
- (D) PH₃

Topic
3.10 Solubility

2016 Practice Exam #17

Q: Lewis structures - least soluble in water

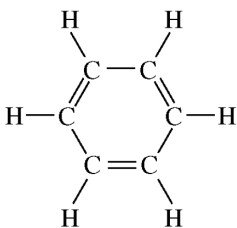
Which of the following molecules is least soluble in water?



Topic
3.10 Solubility

2015 Practice Exam #21

Q: IMFs between water and benzene, C₆H₆



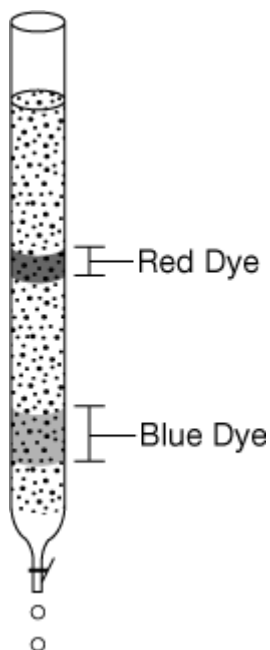
Benzene, C₆H₆, has the structure shown above. Considering the observation that benzene is only sparingly soluble in water, which of the following best describes the intermolecular forces of attraction between water and benzene?

- (A) Benzene is nonpolar, so there are no forces between water and benzene.
- (B) The H atoms in benzene form hydrogen bonds with the O atoms in water.
- (C) Benzene is hydrophobic, so there is a net repulsion between water and benzene.
- * (D) There are dipole-induced dipole and London dispersion interactions between water and benzene.

Topic
3.11 Spectroscopy and the Electromagnetic Spectrum

2021 Practice Exam (from AP Classroom)

Q: Investigate molecule vibrations



A student placed a sample of a food coloring that contains a mixture of a blue dye and a red dye at the top of a chromatography column filled with a nonpolar stationary phase. When water is poured through the column, two bands of colors are seen in the column, as shown in the diagram above.

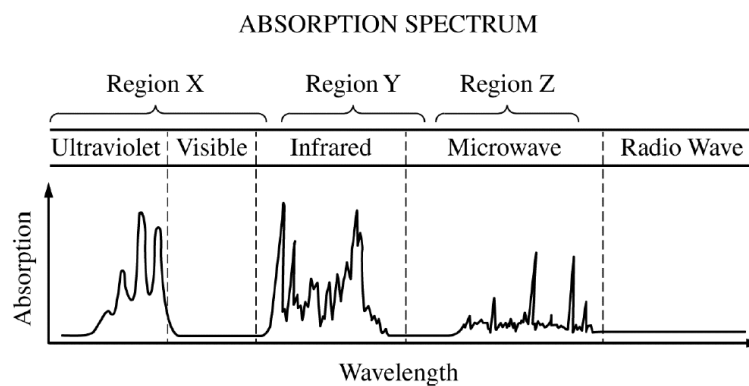
Which of the following techniques would be best to investigate molecular vibrations in molecules of the red dye?

- * (A) Infrared spectroscopy
- (B) UV / vis spectroscopy
- (C) Mass spectrometry
- (D) Gravimetric analysis

Topic
3.11 Spectroscopy and the Electromagnetic Spectrum

2015 Practice Exam #50

Q: Transitions observed for regions of EM spectrum



The diagram above represents the absorption spectrum for a pure molecular substance. Which of the following correctly indicates the type of transition observed for the substance in each of the regions of the absorption spectrum?

	Region X	Region Y	Region Z
(A)	Molecular vibration	Molecular rotation	Electronic transition
(B)	Electronic transition	Molecular rotation	Molecular vibration
(C)	Molecular rotation	Molecular vibration	Electronic transition
* (D)	Electronic transition	Molecular vibration	Molecular rotation

Topic
3.11 Spectroscopy and the Electromagnetic Spectrum

2013 Practice Exam #41

Q: Why N₂ absorbs UV but I₂ absorbs UV and visible

N₂ molecules absorb ultraviolet light but not visible light. I₂ molecules absorb both visible and ultraviolet light. Which of the following statements explains the observations?

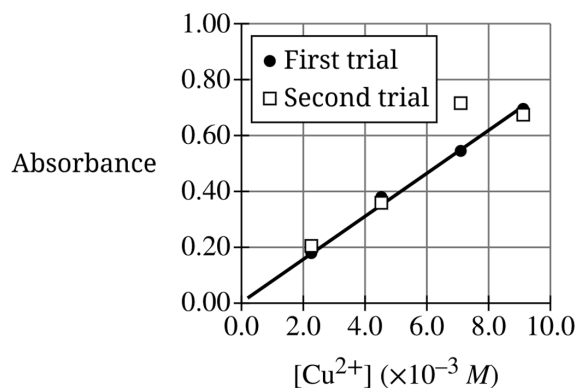
- (A) More energy is required to make N₂ molecules vibrate than is required to make I₂ molecules vibrate.
- (B) More energy is required to remove an electron from an I₂ molecule than is required to remove an electron from a N₂ molecule.
- * (C) Visible light does not produce transitions between electronic energy levels in the N₂ molecule but does produce transitions in the I₂ molecule.
- (D) The molecular mass of I₂ is greater than the molecular mass of N₂.

Topic
3.12 Properties of Photons

Topic
3.13 Beer–Lambert Law

2022 Practice Exam (from AP Classroom)

Q: Cuvette absorbance



A student prepared four solutions of known $[\text{Cu}^{2+}]$ and measured the absorbance of each solution using the same cuvette. The graph shows the data for two absorbance measurements done for each solution. Which of the following identifies the most likely error that affected the absorbance recorded for the solution with $[\text{Cu}^{2+}] \approx 7 \times 10^{-3} \text{ M}$ in the second trial?

- (A) The cuvette was rinsed with water between measurements.
- (B) A fingerprint was left on the side of the cuvette facing the detector.
- (C) The absorbance was measured at a wavelength where Cu^{2+} has a lower molar absorptivity.
- (D) The cuvette was not filled with the same volume of solution.

*

Topic
3.13 Beer–Lambert Law

2022 Practice Exam (from AP Classroom)

Q: Spectrophotometry absorbance too high

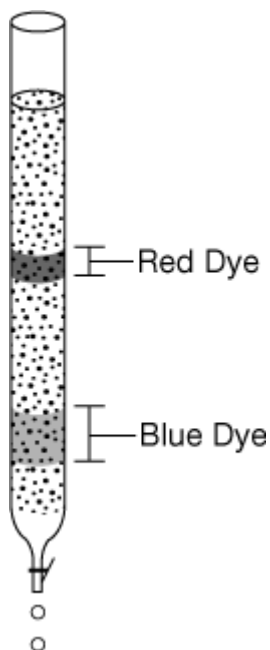
A student is given the task of making a calibration curve for $\text{CoCl}_2(aq)$ for use in a spectrophotometry experiment. The student pours a sample of $\text{CoCl}_2(aq)$ of known concentration into a cuvette with a 1.0 cm path length and tries to measure the absorbance at 500 nm, which is the wavelength of maximum absorbance. However, the absorbance is too high to give an accurate reading. Which of the following is the most appropriate next step for the student?

- (A) Switching to using a cuvette with a 1.5 cm path length
- (B) Repeating the experiment after warming the solution to 40°C
- * (C) Diluting a measured volume of the solution to a new known volume using distilled water
- (D) Pouring some solution out of the cuvette

Topic
3.13 Beer–Lambert Law

2021 Practice Exam (from AP Classroom)

Q: Spectrophotometry concentration



A student placed a sample of a food coloring that contains a mixture of a blue dye and a red dye at the top of a chromatography column filled with a nonpolar stationary phase. When water is poured through the column, two bands of colors are seen in the column, as shown in the diagram above.

A student collects a sample of the blue dye from the column in a cuvette. Which of the following is least useful to determine the concentration of the sample using a spectrophotometer set at 640 nm ?

- * (A) The volume of the sample
- (B) The path length of the cuvette
- (C) The absorbance of the dye at 640 nm
- (D) The molar absorptivity of the dye at 640 nm

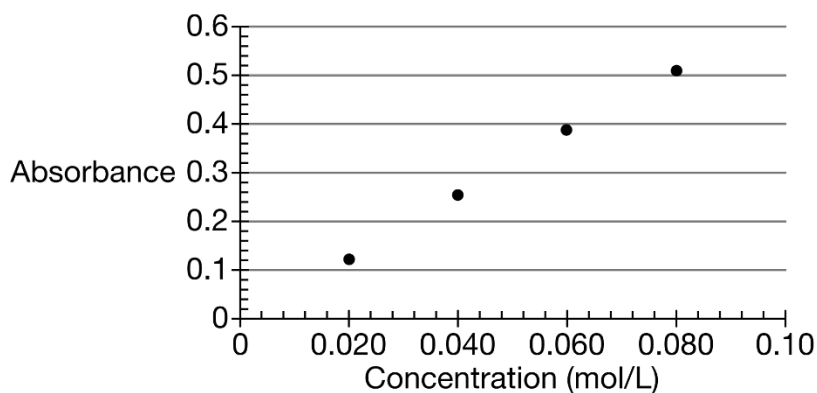
Topic
3.13 Beer–Lambert Law

2021 Practice Exam (from AP Classroom)

Q: Expected absorbance

An experiment was performed to investigate the reaction between Zn metal and $\text{Ni}^{2+}(aq)$ at different concentrations. Because the $\text{Ni}^{2+}(aq)$ ion is green, the extent of the reaction was determined using spectrophotometric analysis. Four 20.0 mL standard solutions of $\text{Ni}^{2+}(aq)$ were prepared by dissolving $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ (molar mass 240 g/mol) in water. The absorbance of each solution was measured; the results are shown both in the table below and in the following plot of the absorbance data.

Solution	$[\text{Ni}^{2+}]$	Absorbance
1	0.020	0.12
2	0.040	0.25
3	0.060	0.39
4	0.080	0.51



What is the expected absorbance of a standard solution made by dissolving 0.0070 mol of $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ in water to make 100. mL of solution?

(A) 0.0039

(B) 0.0080

(C) 0.045

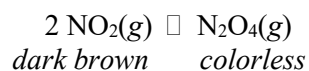
* (D) 0.45

Topic
3.13 Beer–Lambert Law

2018 Practice Exam #43

Q: NO₂ dimerization - experimental technique to study

Questions X-Y refer to the following information.



The dimerization of NO₂(g), an exothermic process, is represented by the equation above.

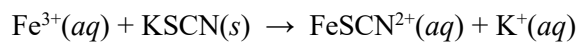
Which of the following experimental techniques will allow the most accurate determination of the concentration of NO₂(g) at equilibrium?

- (A) Paper chromatography
- (B) Gravimetric analysis
- (C) Titration
- * (D) Spectrophotometry

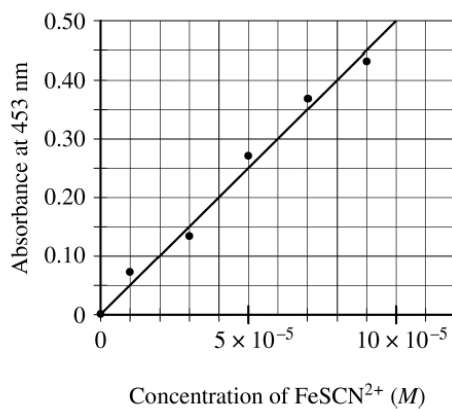
Topic
3.13 Beer–Lambert Law

2017 Practice Exam #5

Q: Moles of Fe^{3+} given Beer-Lambert plot absorbance



To determine the moles of $\text{Fe}^{3+}(aq)$ in a 100. mL sample of an unknown solution, excess $\text{KSCN}(s)$ is added to convert all the $\text{Fe}^{3+}(aq)$ into the dark red species $\text{FeSCN}^{2+}(aq)$, as represented by the equation above. The absorbance of $\text{FeSCN}^{2+}(aq)$ at different concentrations is shown in the graph below.



If the absorbance of the mixture is 0.20 at 453 nm, how many moles of $\text{Fe}^{3+}(aq)$ were present in the 100. mL sample? (Assume that any volume change due to adding the $\text{KSCN}(s)$ is negligible.)

- (A) 4×10^{-4} mol
- (B) 3×10^{-4} mol
- * (C) 4×10^{-6} mol
- (D) 3×10^{-6} mol

Topic
3.13 Beer-Lambert Law

2017 Practice Exam #11

Q: Cu + HNO₃ - error causes inconsistent absorbance

Questions X-Y refer to the following information.



Each student in a class placed a 2.00 g sample of a mixture of Cu and Al in a beaker and placed the beaker in a fume hood. The students slowly poured 15.0 mL of 15.8 M HNO₃(aq) into their beakers. The reaction between the copper in the mixture and the HNO₃(aq) is represented by the equation above. The students observed that a brown gas was released from the beakers and that the solutions turned blue, indicating the formation of Cu²⁺(aq). The solutions were then diluted with distilled water to known volumes.

[Cu ²⁺]	Absorbance
0.025	0.059
0.050	0.235
0.100	0.117
0.200	0.468
Unknown (from sample of mixture)	0.330

To determine the number of moles of Cu in the sample of the mixture, the students measured the absorbance of known concentrations of Cu(NO₃)₂(aq) using a spectrophotometer. A cuvette filled with some of the solution produced from the sample of the mixture was also tested. The data recorded by one student are shown in the table above. On the basis of the data provided, which of the following is a possible error that the student made?

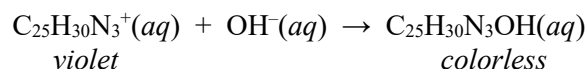
- (A) The Cu(NO₃)₂(aq) from the sample of the mixture was not diluted properly.
- (B) The spectrophotometer was calibrated with tap water instead of distilled water.
- * (C) The student labeled the cuvettes incorrectly, reversing the labels on two of the solutions of known concentration.
- (D) The spectrophotometer was originally set to an inappropriate wavelength, causing the absorbance to vary unpredictably.

Topic
3.13 Beer–Lambert Law

2016 Practice Exam #31

Not listed in the question bank

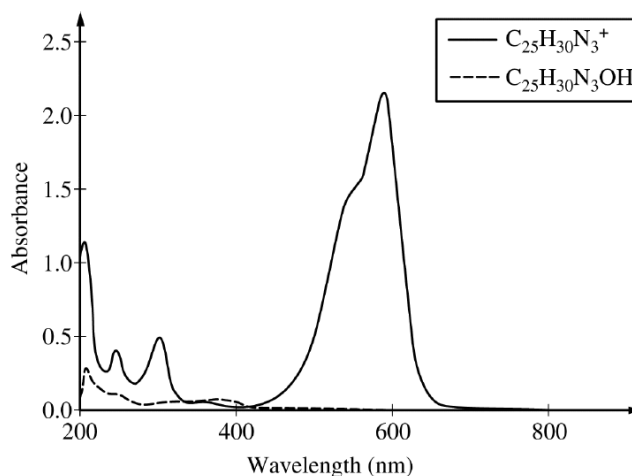
Questions X-Y refer to the investigation described below.



The reaction between $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ and $\text{OH}^-(aq)$, as represented above, is first order with respect to $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ in the presence of excess $\text{OH}^-(aq)$. A 10.0 mL sample of 0.10 M $\text{NaOH}(aq)$ is mixed with a 10.0 mL sample of 2.5×10^{-5} M $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$. A 5.0 mL sample of the mixture is quickly transferred to a clean cuvette and placed in a spectrophotometer, and the progress of the reaction is measured. The data are given in the table below.

Time (s)	0	30	60	90	120	150	180	210	240	270	300
Absorbance	0.62	0.54	0.47	0.41	0.36	0.31	0.27	0.23	0.20	0.17	0.15

To choose a wavelength to analyze the progress of the reaction, a student records the absorbance spectra of both $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ and $\text{C}_{25}\text{H}_{30}\text{N}_3\text{OH}(aq)$ in the range of 200–800 nm. The two spectra are presented in the graph below.



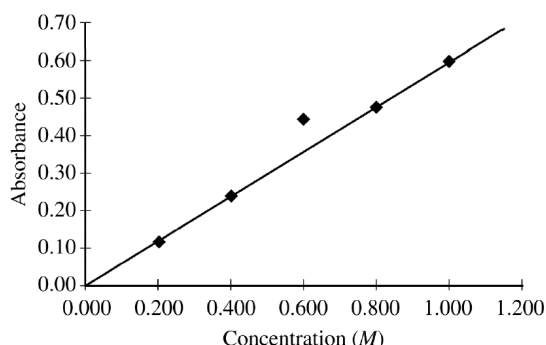
The student wants to use the spectrophotometer to measure $[\text{C}_{25}\text{H}_{30}\text{N}_3^+]$ with the greatest sensitivity as the reaction progresses. Which of the following indicates the best wavelength setting and explains why it is best?

- (A) 205 nm, because the colorless form of the molecule will absorb significantly at this wavelength
- (B) 205 nm, because both forms of the molecule will absorb significantly at this wavelength
- *(C) 590 nm, because only the violet form of the molecule will absorb significantly at this wavelength
- (D) 590 nm, because this wavelength falls in the violet region of the visible light spectrum

Topic
3.13 Beer–Lambert Law

2014 Practice Exam #27

Q: Explanation for higher absorbance in CuSO_4



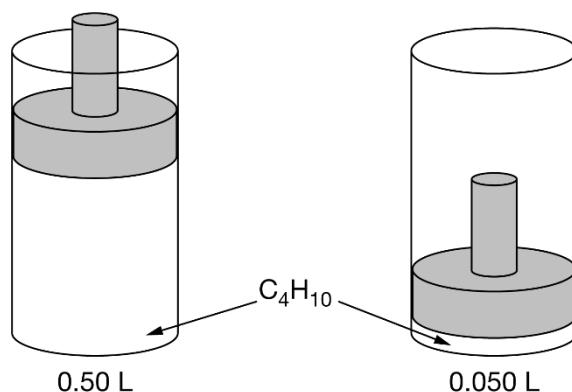
A student prepared five solutions of CuSO_4 with different concentrations, and then filled five cuvettes, each containing one of the solutions. The cuvettes were placed in a spectrophotometer set to the appropriate wavelength for maximum absorbance. The absorbance of each solution was measured and recorded. The student plotted absorbance versus concentration, as shown in the figure above. Which of the following is the most likely explanation for the variance of the data point for the 0.600 M CuSO_4 solution?

- (A) The cuvette into which the 0.600 M solution was placed had some water droplets inside.
- (B) The cuvette into which the 0.600 M solution was placed was filled slightly more than the other cuvettes.
- (C) The wavelength setting was accidentally moved away from that of maximum absorbance.
- * (D) The cuvette used for the 0.600 M solution had not been wiped clean before being put in the spectrophotometer.

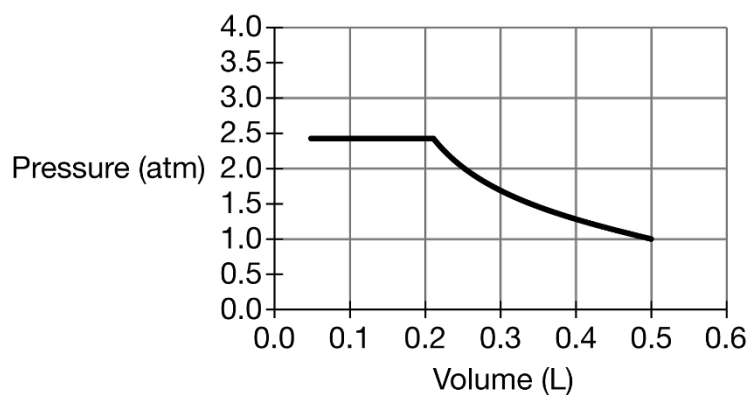
Topic
4.1 Introduction to Reactions

2021 Practice Exam (from AP Classroom)

Q: Reason for constant pressure



A sample of $C_4H_{10}(g)$ is placed in a rigid vessel with a movable piston. The volume of the gas is reduced by moving the piston downward while the temperature is maintained at $25^\circ C$, as shown above. The pressure of the gas versus its volume is plotted in the graph below.



Which of the following best accounts for the pressure in the vessel remaining constant as the volume decreases below 0.21 L?

- (A) The density of the $C_4H_{10}(g)$ increases.
- (B) The surface area of the interior of the vessel decreases.
- (C) The temperature of the $C_4H_{10}(g)$ decreases.
- * (D) Some $C_4H_{10}(g)$ condenses to form $C_4H_{10}(l)$.

Topic
4.1 Introduction to Reactions

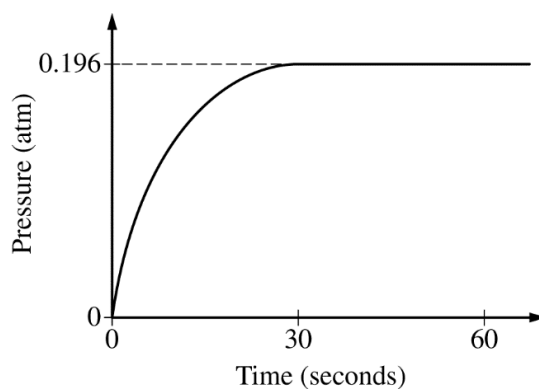
2018 Practice Exam #14

Q: CH₃OH vaporization - chemical or physical change

Questions X-Y refer to the following information.

Substance	Lewis Diagram	Boiling Point
CH ₃ OH	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	338 K
C ₂ H ₅ OH	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	351 K

Equimolar samples of CH₃OH(*l*) and C₂H₅OH(*l*) are placed in separate, previously evacuated, rigid 2.0 L vessels. Each vessel is attached to a pressure gauge, and the temperatures are kept at 300 K. In both vessels, liquid is observed to remain present at the bottom of the container at all times. The change in pressure inside the vessel containing CH₃OH(*l*) is shown below.



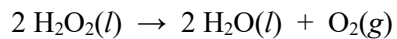
Which of the following best describes the change that takes place immediately after the CH₃OH(*l*) is introduced into the previously evacuated vessel?

- (A) A chemical change takes place because covalent bonds are broken.
- (B) A chemical change takes place because intermolecular attractions are overcome.
- (C) A physical change takes place because covalent bonds are broken.
- * (D) A physical change takes place because intermolecular attractions are overcome.

Topic
4.1 Introduction to Reactions

2017 Practice Exam #50

Q: H₂O₂ decomp - physical or chemical change



The exothermic process represented above is best classified as a

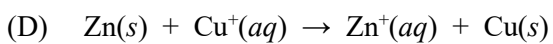
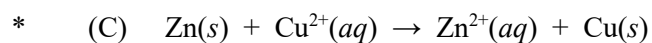
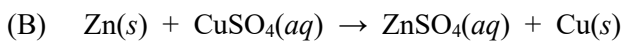
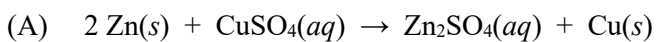
- (A) physical change because a new phase appears in the products
- (B) physical change because O₂(g) that was dissolved comes out of solution
- (C) chemical change because entropy increases as the process proceeds
- * (D) chemical change because covalent bonds are broken and new covalent bonds are formed

Topic
4.2 Net Ionic Equations

2022 Practice Exam (from AP Classroom)

Q: Zn plus CuSO₄

A student placed a piece of Zn(s) in a beaker containing CuSO₄(aq). After 45 minutes, the student observed a brown solid at the bottom of the beaker and that the solution had turned from blue to colorless. Which of the following balanced equations best represents only the species that react and the species that are produced in the reaction?



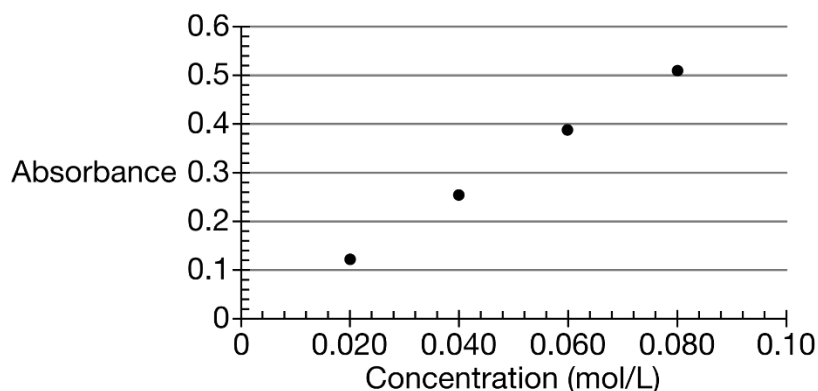
Topic
4.2 Net Ionic Equations

2021 Practice Exam (from AP Classroom)

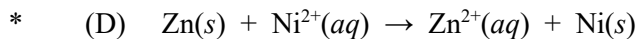
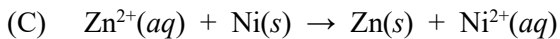
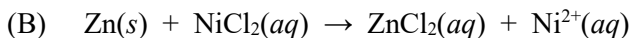
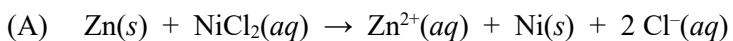
Q: Equation for reaction

An experiment was performed to investigate the reaction between Zn metal and $\text{Ni}^{2+}(aq)$ at different concentrations. Because the $\text{Ni}^{2+}(aq)$ ion is green, the extent of the reaction was determined using spectrophotometric analysis. Four 20.0 mL standard solutions of $\text{Ni}^{2+}(aq)$ were prepared by dissolving $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ (molar mass 240 g/mol) in water. The absorbance of each solution was measured; the results are shown both in the table below and in the following plot of the absorbance data.

Solution	$[\text{Ni}^{2+}]$	Absorbance
1	0.020	0.12
2	0.040	0.25
3	0.060	0.39
4	0.080	0.51



Which of the following equations best represents the reacting species in the reaction between Zn metal and $\text{NiCl}_2(aq)$?



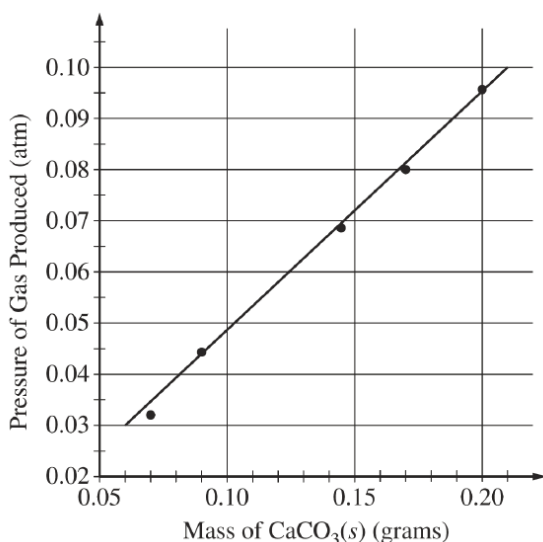
Topic
4.2 Net Ionic Equations

2019 Practice Exam #35

Q: CaCO_3 in eggshells - equation for reacting species

Questions X-Y refer to the following information.

An experiment is performed to measure the mass percent of $\text{CaCO}_3(s)$ in eggshells. Five different samples of $\text{CaCO}_3(s)$ of known mass react with an excess of $2.0\text{ M HCl}(aq)$ in identical sealed, rigid reaction vessels. The pressure of the gas produced is measured with a pressure gauge attached to the reaction vessel. Since the reaction is exothermic, the reaction system is cooled to its original temperature before the pressure is recorded. The experimental data are used to create the calibration line below.



The experiment is repeated with an eggshell sample, and the experimental data are recorded in the table below.

Mass of eggshell sample	0.200 g
Pressure prior to reaction	0.800 atm
Pressure at completion of reaction	0.870 atm

Which of the following equations best represents the species that react and the species that are produced when $\text{CaCO}_3(s)$ and $\text{HCl}(aq)$ are combined?

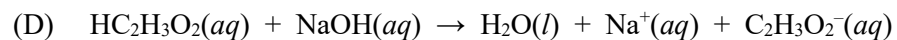
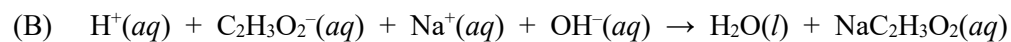
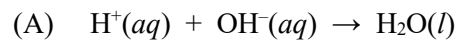
- (A) $2\text{H}^+(aq) + \text{CaCO}_3(s) \rightarrow \text{Ca}^{2+}(aq) + \text{CO}_3^{2-}(aq) + \text{H}_2(g)$
- * (B) $2\text{H}^+(aq) + \text{CaCO}_3(s) \rightarrow \text{Ca}^{2+}(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g)$
- (C) $2\text{H}^+(aq) + \text{CaCO}_3(s) \rightarrow \text{Ca}^{2+}(aq) + 2\text{OH}^-(aq) + \text{CO}(g)$
- (D) $2\text{HCl}(aq) + \text{CaCO}_3(s) \rightarrow \text{Ca}^{2+}(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g) + 2\text{Cl}^-(aq)$

Topic
4.2 Net Ionic Equations

2018 Practice Exam #7

Q: Net ionic rxn - HC₂H₃O₂ titrated with NaOH

A 20. mL sample of 0.50 M HC₂H₃O₂(aq) is titrated with 0.50 M NaOH(aq). Which of the following best represents the species that react and the species produced in the reaction?

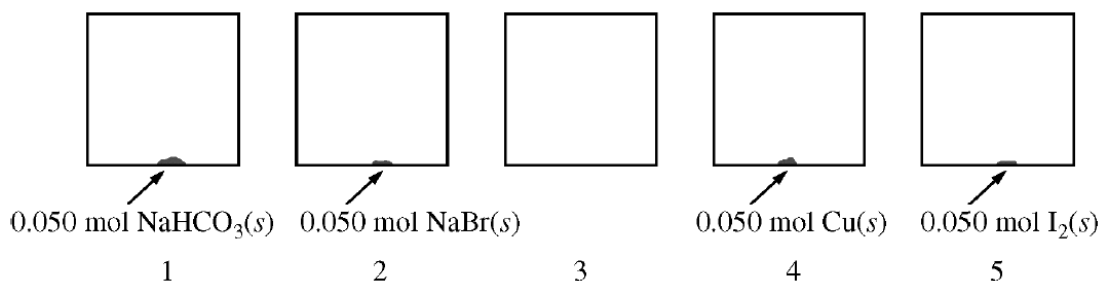


Topic
4.2 Net Ionic Equations

2015 Practice Exam #7

Q: 5 vessels - rxn that accounts for higher pressure

Questions X-Y refer to the following information.



At 27°C , five identical rigid 2.0 L vessels are filled with $\text{N}_2(g)$ and sealed. Four of the five vessels also contain a 0.050 mol sample of $\text{NaHCO}_3(s)$, $\text{NaBr}(s)$, $\text{Cu}(s)$, or $\text{I}_2(s)$, as shown in the diagram above. The volume taken up by the solids is negligible, and the initial pressure of $\text{N}_2(g)$ in each vessel is 720 mm Hg. All five vessels are heated to 127°C and allowed to reach a constant pressure.

At 127°C , the pressure in vessel 1 is found to be higher than that in vessel 2. Which of the following reactions best accounts for the observation?

- (A) $\text{NaHCO}_3(s) \rightarrow \text{Na}(s) + \text{HCO}_3(s)$
- (B) $\text{NaHCO}_3(s) \rightarrow \text{NaH}(s) + \text{CO}_3(s)$
- * (C) $2 \text{NaHCO}_3(s) \rightarrow \text{Na}_2\text{CO}_3(s) + \text{CO}_2(g) + \text{H}_2\text{O}(g)$
- (D) $2 \text{NaHCO}_3(s) + \text{N}_2(g) \rightarrow 2 \text{NaNO}_3(s) + \text{C}_2\text{H}_2(g)$

Topic
4.2 Net Ionic Equations

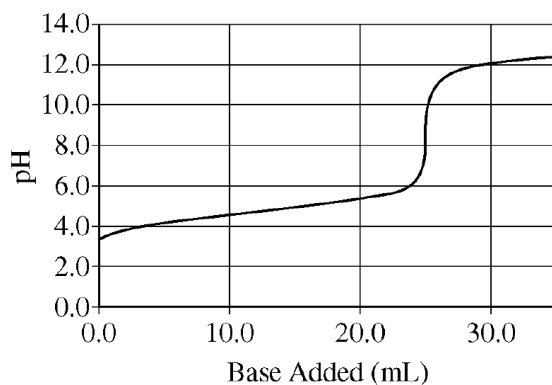
2015 Practice Exam #20

Q: $\text{Li} + \text{H}_2\text{O}$ - net ionic equation for reaction

Questions X-Y refer to the following information.

A 0.35 g sample of $\text{Li}(s)$ is placed in an Erlenmeyer flask containing 100 mL of water at 25°C . A balloon is placed over the mouth of the flask to collect the hydrogen gas that is generated.

After all of the $\text{Li}(s)$ has reacted with $\text{H}_2\text{O}(l)$, the solution in the flask is added to a clean, dry buret and used to titrate an aqueous solution of a monoprotic acid. The pH curve for this titration is shown in the diagram below.



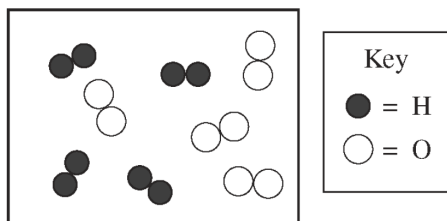
Which of the following is the balanced net-ionic equation for the reaction between $\text{Li}(s)$ and water?

- (A) $2 \text{Li}(s) + 2 \text{H}^+(aq) + 2 \text{OH}^-(aq) \rightarrow 2 \text{Li}^+(aq) + 2 \text{OH}^-(aq) + \text{H}_2(g)$
- * (B) $2 \text{Li}(s) + 2 \text{H}_2\text{O}(l) \rightarrow 2 \text{Li}^+(aq) + 2 \text{OH}^-(aq) + \text{H}_2(g)$
- (C) $2 \text{Li}(s) + 2 \text{H}_2\text{O}(l) \rightarrow 2 \text{LiOH}(s) + \text{H}_2(g)$
- (D) $2 \text{Li}(s) + 2 \text{H}_2\text{O}(l) \rightarrow 2 \text{LiH}(s) + \text{H}_2(g)$

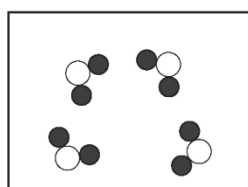
Topic
4.3 Representations of Reactions

2019 Practice Exam #22

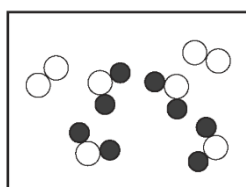
Q: Particulate diagram - products of 4 H₂ and 4 O₂



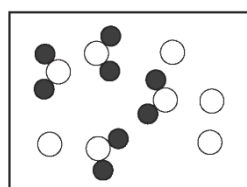
A mixture of H₂(g) and O₂(g) is placed in a container as represented above. The H₂(g) and O₂(g) react to form H₂O(g). Which of the following best represents the container after the reaction has gone to completion?



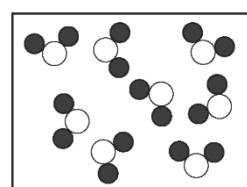
(A)



*(B)



(C)



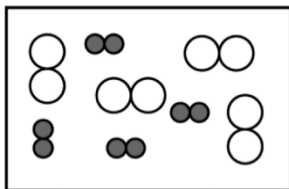
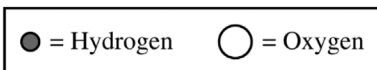
(D)

Topic
4.3 Representations of Reactions

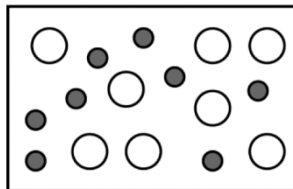
2018 Practice Exam #1

Q: Particle diagram when 4 molecules H_2O_2 decompose

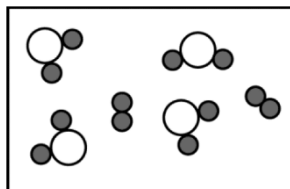
Which of the following particle diagrams best represents the products when four molecules of $\text{H}_2\text{O}_2(l)$ decompose into water and oxygen gas at room temperature?



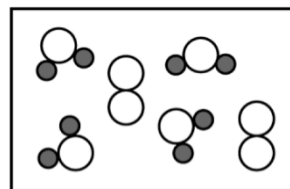
(A)



(B)



(C)

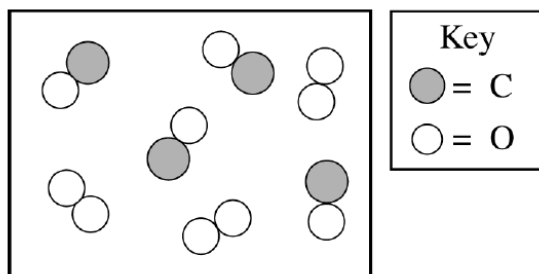


* (D)

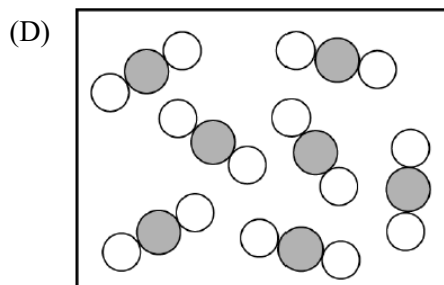
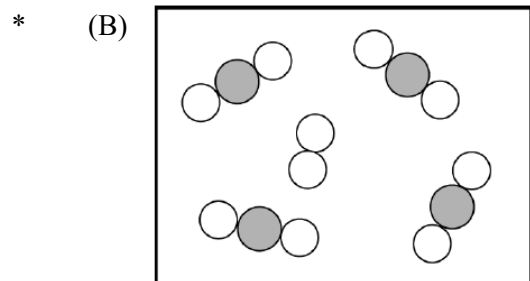
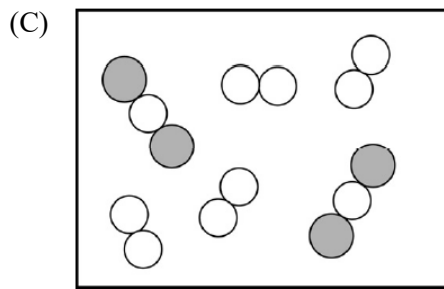
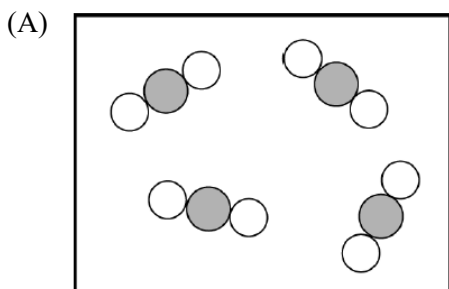
Topic
4.3 Representations of Reactions

2017 Practice Exam #9

Q: Particle diagram after rxn - 4 CO + 3 O₂ molecules



A mixture of CO(g) and O₂(g) is placed in a container, as shown above. A reaction occurs, forming CO₂(g). Which of the following best represents the contents of the box after the reaction has proceeded as completely as possible?

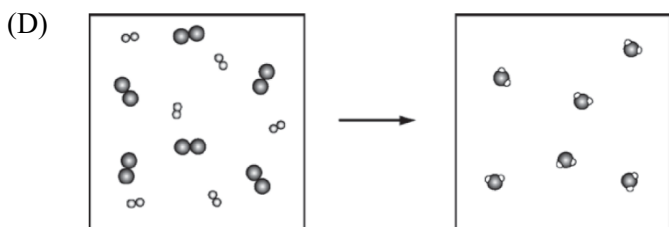
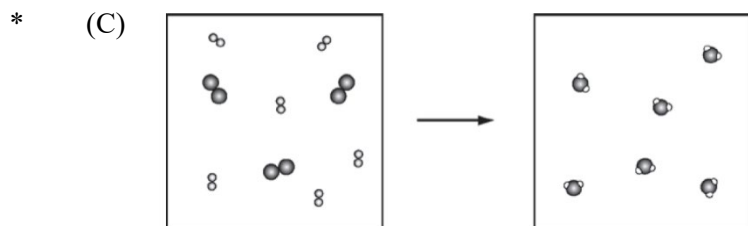
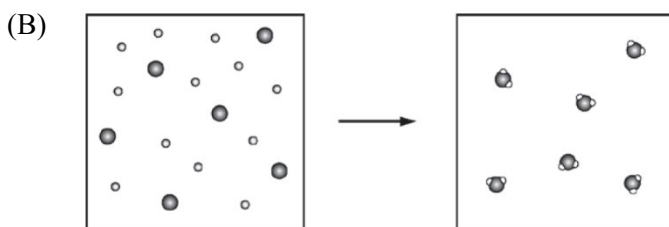
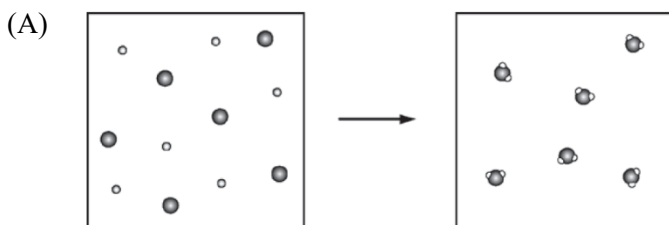


Topic
4.3 Representations of Reactions

2013 Practice Exam #13

Q: Particulate diagram - H₂ and O₂ form water vapor

Which of the following particulate diagrams best shows the formation of water vapor from hydrogen gas and oxygen gas in a rigid container at 125°C?



Topic
4.4 Physical and Chemical Changes

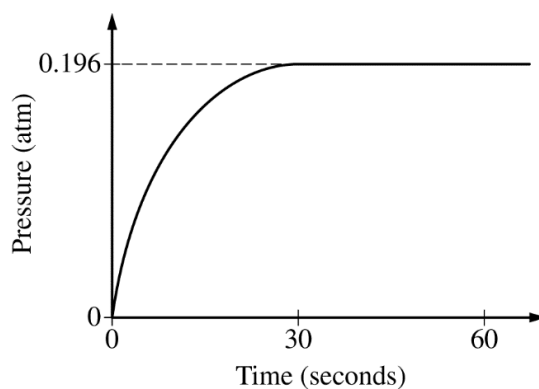
2018 Practice Exam #14

Q: CH₃OH vaporization - chemical or physical change

Questions X-Y refer to the following information.

Substance	Lewis Diagram	Boiling Point
CH ₃ OH	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	338 K
C ₂ H ₅ OH	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	351 K

Equimolar samples of CH₃OH(*l*) and C₂H₅OH(*l*) are placed in separate, previously evacuated, rigid 2.0 L vessels. Each vessel is attached to a pressure gauge, and the temperatures are kept at 300 K. In both vessels, liquid is observed to remain present at the bottom of the container at all times. The change in pressure inside the vessel containing CH₃OH(*l*) is shown below.



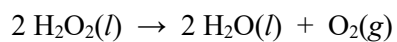
Which of the following best describes the change that takes place immediately after the CH₃OH(*l*) is introduced into the previously evacuated vessel?

- (A) A chemical change takes place because covalent bonds are broken.
- (B) A chemical change takes place because intermolecular attractions are overcome.
- (C) A physical change takes place because covalent bonds are broken.
- * (D) A physical change takes place because intermolecular attractions are overcome.

Topic
4.4 Physical and Chemical Changes

2017 Practice Exam #50

Q: H₂O₂ decomp - physical or chemical change



The exothermic process represented above is best classified as a

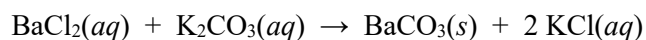
- (A) physical change because a new phase appears in the products
- (B) physical change because O₂(g) that was dissolved comes out of solution
- (C) chemical change because entropy increases as the process proceeds
- * (D) chemical change because covalent bonds are broken and new covalent bonds are formed

Topic
4.5 Stoichiometry

2023 Practice Exam (from AP Classroom)

Q: Barium concentration in original sample

Students are asked to design an experiment to determine the molarity of a $\text{BaCl}_2(aq)$ solution. After examining the K_{sp} values of some barium-containing compounds, the students decide to use $0.100\text{ M K}_2\text{CO}_3(aq)$ to precipitate the barium ions. An excess of $\text{K}_2\text{CO}_3(aq)$ is added to a 50.0 mL sample of the $\text{BaCl}_2(aq)$ solution, and the reaction represented by the following equation occurs.



The $\text{BaCO}_3(s)$ is filtered, dried, and weighed. The data are recorded in the following table.

Volume of $\text{BaCl}_2(aq)$	Volume of $0.100\text{ M K}_2\text{CO}_3(aq)$	Mass of $\text{BaCO}_3(s)$
50.0 mL	$150.\text{ mL}$	1.97 g

The molar masses of BaCl_2 and BaCO_3 are 208 g/mol and 197 g/mol , respectively.

On the basis of the experimental data, what was $[\text{Ba}^{2+}]$ in the original 50.0 mL sample of the solution?

(A) 0.05 M

(B) 0.10 M

* (C) 0.20 M

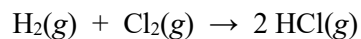
(D) 0.40 M

Topic
4.5 Stoichiometry

2023 Practice Exam (from AP Classroom)

Q: How pressure affected by reaction

Gaseous hydrogen and gaseous chlorine can react to form hydrogen chloride gas, as represented by the following equation.



Equimolar amounts of H_2 and Cl_2 are placed in an evacuated reaction vessel at 500 K. Which of the following statements correctly predicts how the pressure will be affected as the reaction proceeds at a constant temperature and explains why?

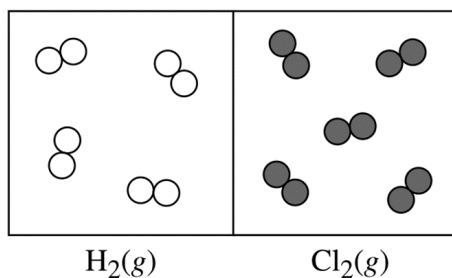
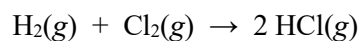
- * (A) The pressure will remain constant because the number of gas particles is constant.
- (B) The pressure will be halved because one substance is produced from two substances.
- (C) The pressure will increase because the coefficient of HCl in the balanced chemical equation is greater than that of the reactants.
- (D) The pressure will decrease because the average speed of the gaseous product molecules is less than the average speed of the gaseous reactant molecules.

Topic
4.5 Stoichiometry

2023 Practice Exam (from AP Classroom)

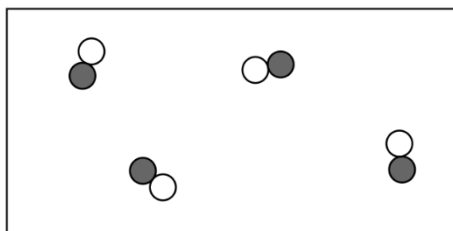
Q: Particle diagram after reaction

Gaseous hydrogen and gaseous chlorine can react to form hydrogen chloride gas, as represented by the following equation.

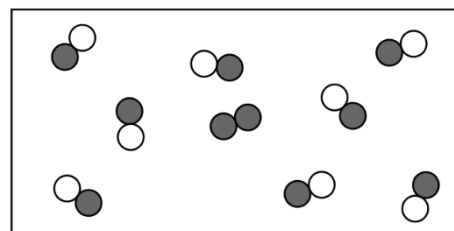


The diagrams show particulate representations for samples of gaseous H_2 and Cl_2 separated by a barrier. After the barrier is removed, the gases react. Which of the following diagrams best represents the mixture if the reaction goes to completion?

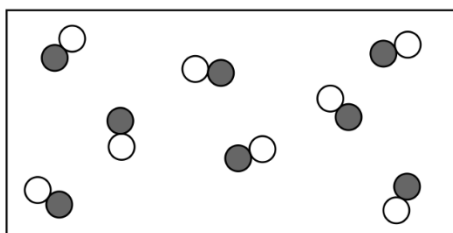
(A)



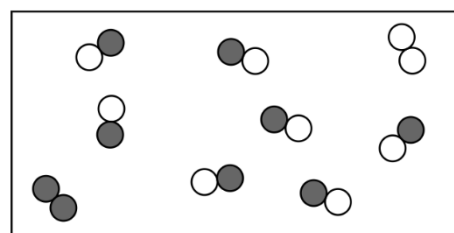
* (C)



(B)



(D)

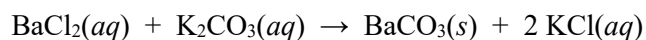


Topic
4.5 Stoichiometry

2023 Practice Exam (from AP Classroom)

Q: Species with highest concentration

Students are asked to design an experiment to determine the molarity of a $\text{BaCl}_2(aq)$ solution. After examining the K_{sp} values of some barium-containing compounds, the students decide to use $0.100\text{ M K}_2\text{CO}_3(aq)$ to precipitate the barium ions. An excess of $\text{K}_2\text{CO}_3(aq)$ is added to a 50.0 mL sample of the $\text{BaCl}_2(aq)$ solution, and the reaction represented by the following equation occurs.



The $\text{BaCO}_3(s)$ is filtered, dried, and weighed. The data are recorded in the following table.

Volume of $\text{BaCl}_2(aq)$	Volume of $0.100\text{ M K}_2\text{CO}_3(aq)$	Mass of $\text{BaCO}_3(s)$
50.0 mL	$150.\text{ mL}$	1.97 g

The molar masses of BaCl_2 and BaCO_3 are 208 g/mol and 197 g/mol , respectively.

Of the following species, which is present in the highest concentration in the filtrate?

(A) $\text{H}^+(aq)$

* (B) $\text{K}^+(aq)$

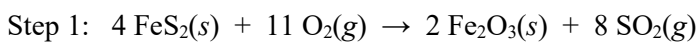
(C) $\text{Cl}^-(aq)$

(D) $\text{CO}_3^{2-}(aq)$

Topic
4.5 Stoichiometry

2022 Practice Exam (from AP Classroom)

Q: Mass of FeS₂ from two reaction



Extraction of Fe(s) from pyrite, FeS₂, is a two-step process, as represented above. The maximum amount of Fe(s) that could be extracted from 120 grams of FeS₂ (molar mass 120 g/mol) is approximately

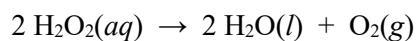
- (A) 28 grams
- * (B) 56 grams
- (C) 84 grams
- (D) 112 grams

Topic
4.5 Stoichiometry

2022 Practice Exam (from AP Classroom)

Q: Moles of product

The following balanced equation represents the decomposition of hydrogen peroxide, H_2O_2 .



A student carries out an experiment in which a sample of $\text{H}_2\text{O}_2(aq)$ decomposes in the presence of $\text{MnO}_2(s)$. The student measures the volume of $\text{O}_2(g)$ produced by the reaction at regular intervals while the temperature is held constant. The student's data are given in the following table.

Time (s)	Volume of $\text{O}_2(g)$ Collected (mL)
0	0
60	42
120	64
180	76
240	82
300	86
360	88
420	89

If 6.0×10^{-3} mol of H_2O_2 was consumed in the experiment, how many total moles of products were produced?

(A) 6.0×10^{-3} mol

* (B) 9.0×10^{-3} mol

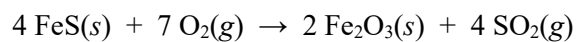
(C) 12×10^{-3} mol

(D) 18×10^{-3} mol

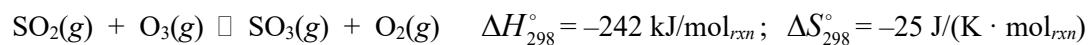
Topic
4.5 Stoichiometry

2021 Practice Exam (from AP Classroom)

Q: Limiting reactant



Due to the presence of $\text{FeS}(s)$ as an impurity, the combustion of some types of coal results in the formation of $\text{SO}_2(g)$, as represented by the equation above. Also, $\text{SO}_2(g)$ can react with $\text{O}_3(g)$ to form $\text{SO}_3(g)$, as represented by the equation below.



Which of the following statements is correct when 2.0 mol of $\text{FeS}(s)$ reacts with 4.0 mol of $\text{O}_2(g)$?

- (A) $\text{O}_2(g)$ is the limiting reactant and 2.0 mol of $\text{SO}_2(g)$ is formed.
- (B) $\text{O}_2(g)$ is the limiting reactant and 4.0 mol of $\text{SO}_2(g)$ is formed.
- (C) $\text{FeS}(s)$ is the limiting reactant and 4.0 mol of $\text{SO}_2(g)$ is formed.
- * (D) $\text{FeS}(s)$ is the limiting reactant and 0.5 mol of $\text{O}_2(g)$ remains unreacted.

Topic
4.5 Stoichiometry

2021 Practice Exam (from AP Classroom)

Q: Hydrated compound

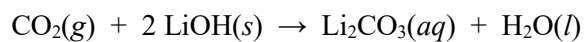
A student finds the mass of a pure sample of a metal chloride hydrate. The student heats the sample several times, reaching a constant mass that contains 0.100 mole of anhydrous metal chloride. Which of the following questions about the hydrated metal chloride substance is most likely to be answered by the results of the experiment?

- * (A) How many moles of water are in one mole of the substance?
- (B) How many moles of the metal cation are in one mole of the substance?
- (C) What is the identity of the metal cation in the formula of the substance?
- (D) What is the melting point of the substance?

Topic
4.5 Stoichiometry

2019 Practice Exam #12

Q: Mass of LiOH needed to absorb CO₂ from astronaut



In a one-person spacecraft, an astronaut exhales 880 g of CO₂(g) (molar mass 44 g/mol) per day. To prevent the buildup of CO₂(g) in the spacecraft, a device containing LiOH(s) is used to remove the CO₂(g), as represented by the equation above. What mass of LiOH(s) (molar mass 24 g/mol) is needed to react with all of the CO₂(g) produced by an astronaut in one day?

(A) 40. g

(B) 240 g

(C) 480 g

* (D) 960 g

Topic
4.5 Stoichiometry

2019 Practice Exam #15

Q: Combustion rxn enthalpy - unknown compound formula

Questions X-Y are based on the information in the table below.

Compound	Molar Mass	Balanced Equation for the Combustion of One Mole of the Compound	ΔH_{comb}° (kJ/mol _{rxn})
$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \\ \text{Ethane} \end{array} $	30. g/mol	$\text{C}_2\text{H}_6(g) + \frac{7}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$	-1560
$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \\ \text{Propanol} \end{array} $	60. g/mol	$\text{C}_3\text{H}_8\text{O}(l) + \frac{9}{2}\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2020
Unknown	?	$? + 5\text{O}_2(g) \rightarrow 4\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2240

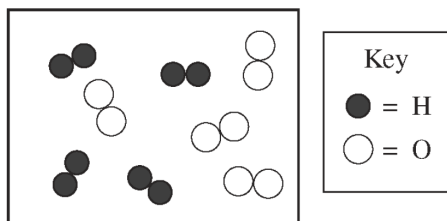
Which of the following is the molecular formula of the unknown compound?

- (A) C_4H_8
- (B) $\text{C}_4\text{H}_8\text{O}$
- (C) $\text{C}_4\text{H}_4\text{O}_2$
- * (D) $\text{C}_4\text{H}_8\text{O}_2$

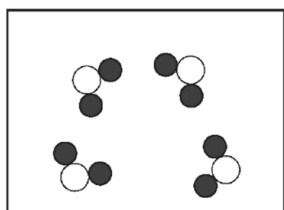
Topic
4.5 Stoichiometry

2019 Practice Exam #22

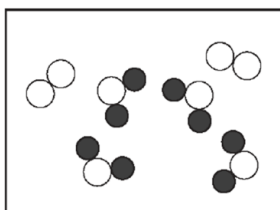
Q: Particulate diagram - products of 4 H₂ and 4 O₂



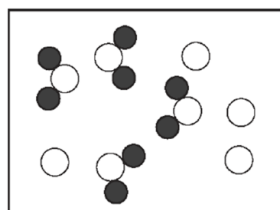
A mixture of H₂(g) and O₂(g) is placed in a container as represented above. The H₂(g) and O₂(g) react to form H₂O(g). Which of the following best represents the container after the reaction has gone to completion?



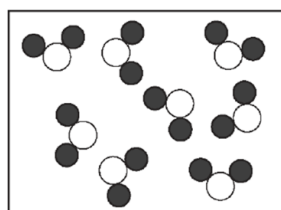
(A)



* (B)



(C)

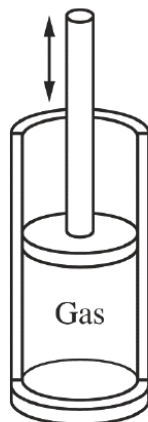


(D)

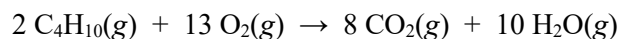
Topic
4.5 Stoichiometry

2019 Practice Exam #25

Q: Volume after reaction of C₄H₁₀ and O₂



A mixture of two gases, 0.01 mol of C₄H₁₀(g) and 0.065 mol of O₂(g), is pumped into a cylinder with a movable piston, as shown above. The mixture, originally at 200°C and 1.0 atm, is sparked and the reaction represented below occurs.



Which of the following is true after the product gases return to the original temperature and pressure, and why will the change occur? (Assume all gases behave ideally.)

- * (A) The piston will be higher than its original position, because the cylinder will contain a greater number of gas molecules.
- (B) The position of the piston will be unchanged, because the total mass of the gases in the cylinder does not change.
- (C) The position of the piston will be unchanged, because the temperature and pressure of the contents of the cylinder remain the same.
- (D) The piston will be lower than its original position, because the product molecules are smaller than the reactant molecules.

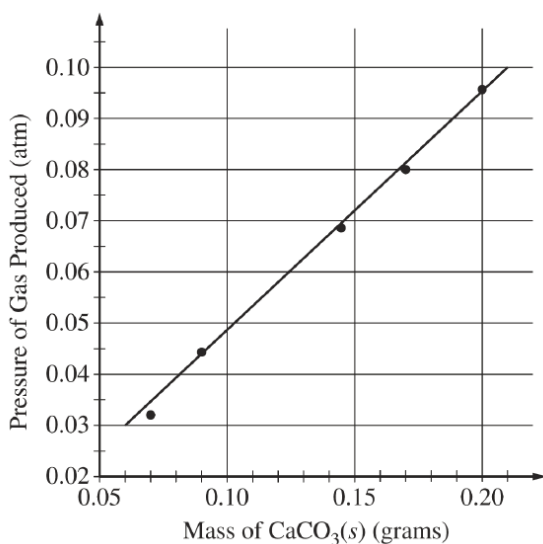
Topic
4.5 Stoichiometry

2019 Practice Exam #37

Q: CaCO_3 in eggshells - concentration of HCl

Questions X-Y refer to the following information.

An experiment is performed to measure the mass percent of $\text{CaCO}_3(s)$ in eggshells. Five different samples of $\text{CaCO}_3(s)$ of known mass react with an excess of $2.0\text{ M HCl}(aq)$ in identical sealed, rigid reaction vessels. The pressure of the gas produced is measured with a pressure gauge attached to the reaction vessel. Since the reaction is exothermic, the reaction system is cooled to its original temperature before the pressure is recorded. The experimental data are used to create the calibration line below.



The experiment is repeated with an eggshell sample, and the experimental data are recorded in the table below.

Mass of eggshell sample	0.200 g
Pressure prior to reaction	0.800 atm
Pressure at completion of reaction	0.870 atm

Another sample of eggshell reacts completely with 4.0 mL of an $\text{HCl}(aq)$ solution of unknown concentration. If the reaction produced 0.095 atm of gas, the concentration of the $\text{HCl}(aq)$ solution was at least

- (A) 0.0020 M
- (B) 0.050 M
- (C) 0.50 M

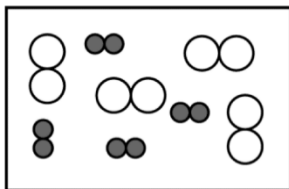
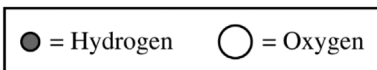
* (D) 1.0 M

Topic
4.5 Stoichiometry

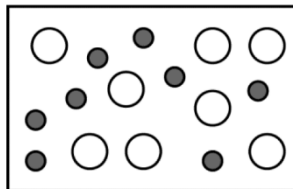
2018 Practice Exam #1

Q: Particle diagram when 4 molecules H_2O_2 decompose

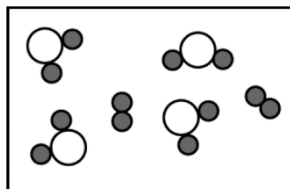
Which of the following particle diagrams best represents the products when four molecules of $\text{H}_2\text{O}_2(l)$ decompose into water and oxygen gas at room temperature?



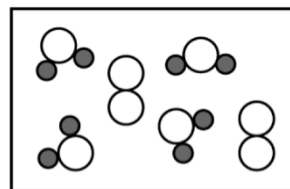
(A)



(B)



(C)



* (D)

Topic
4.5 Stoichiometry

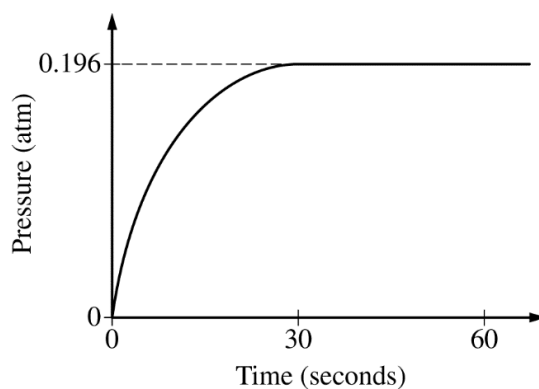
2018 Practice Exam #16

Q: CH₃OH vaporization - Pressure with half the mass

Questions X-Y refer to the following information.

Substance	Lewis Diagram	Boiling Point
CH ₃ OH	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	338 K
C ₂ H ₅ OH	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	351 K

Equimolar samples of CH₃OH(*l*) and C₂H₅OH(*l*) are placed in separate, previously evacuated, rigid 2.0 L vessels. Each vessel is attached to a pressure gauge, and the temperatures are kept at 300 K. In both vessels, liquid is observed to remain present at the bottom of the container at all times. The change in pressure inside the vessel containing CH₃OH(*l*) is shown below.



The temperature of the CH₃OH is increased from 300 K to 400 K to vaporize all the liquid, which increases the pressure in the vessel to 0.30 atm. The experiment is repeated under identical conditions but this time using half the mass of CH₃OH that was used originally. What will be the pressure in the vessel at 400 K?

- * (A) 0.15 atm
- (B) 0.30 atm
- (C) 0.40 atm
- (D) 0.60 atm

Topic
4.5 Stoichiometry

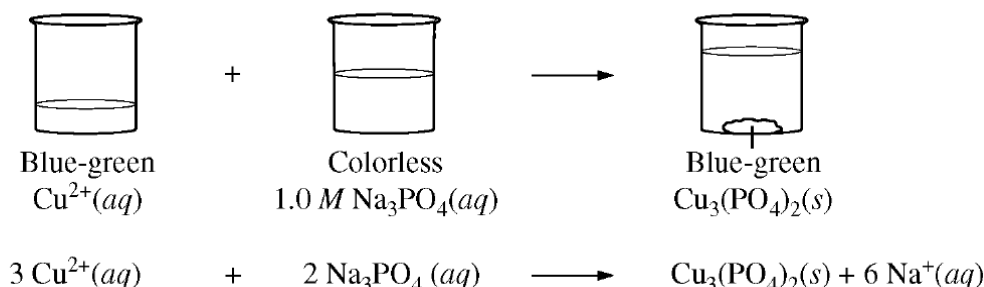
2018 Practice Exam #22

Q: Cu recovery - approximate Cu^{2+} conc. in soln

Questions X-Y refer to the following information.

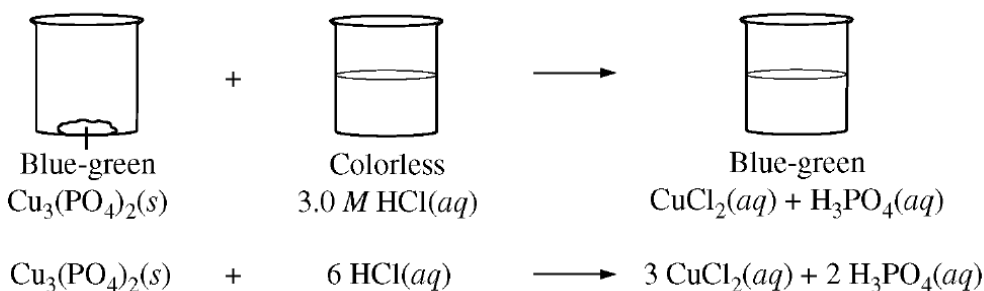
A group of students was asked to recover $\text{Cu}(s)$ from a blue-green aqueous solution containing an unknown concentration of $\text{Cu}^{2+}(aq)$. The students took a 100.0 mL sample of the solution and added an excess of 1.0 M $\text{Na}_3\text{PO}_4(aq)$, causing the $\text{Cu}^{2+}(aq)$ to precipitate as $\text{Cu}_3(\text{PO}_4)_2(s)$, as shown in step 1 below.

Step 1



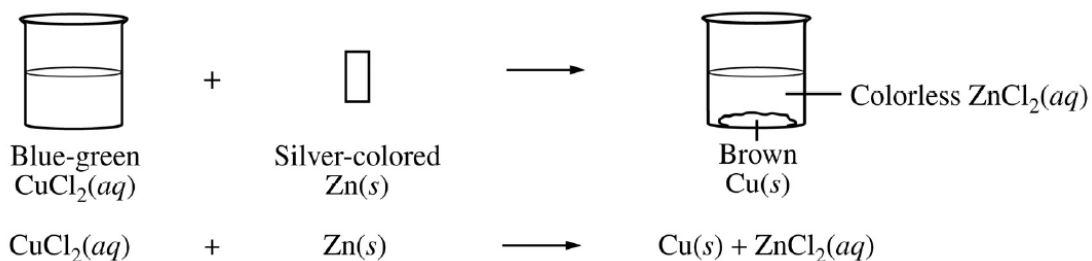
The $\text{Cu}_3(\text{PO}_4)_2(s)$ was filtered, dried, and weighed. Then the $\text{Cu}_3(\text{PO}_4)_2(s)$ was dissolved in a 3.0 M $\text{HCl}(aq)$ solution, as shown in step 2 below.

Step 2



The students added a strip of $\text{Zn}(s)$ to the solution to recover the $\text{Cu}(s)$, as shown in step 3 below.

Step 3



Finally, the $\text{Cu}(s)$ was filtered, dried, and weighed.

(This question is continued on the next page.)

Topic
4.5 Stoichiometry

2018 Practice Exam #22

Q: Cu recovery - approximate Cu^{2+} conc. in soln

(This question is continued from the previous page.)

If 3.8 g of $\text{Cu}_3(\text{PO}_4)_2(s)$ was recovered from step 1, what was the approximate $[\text{Cu}^{2+}]$ in the original solution?
(The molar mass of $\text{Cu}_3(\text{PO}_4)_2$ is 381 g/mol.)

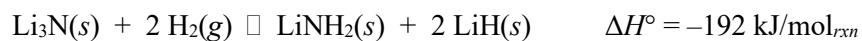
- (A) 0.10 *M*
- * (B) 0.30 *M*
- (C) 1.0 *M*
- (D) 3.0 *M*

Topic
4.5 Stoichiometry

2018 Practice Exam #33

Q: H₂ storage - percent yield when 70.g Li₃N reacts

Questions X-Y refer to the following information.



Because pure H₂ is a hazardous substance, safer and more cost effective techniques to store it as a solid for shipping purposes have been developed. One such method is the reaction represented above, which occurs at 200°C.

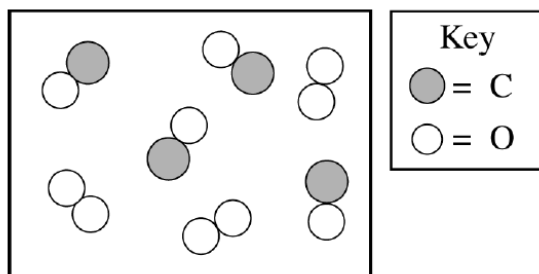
When 70. g of Li₃N(s) (molar mass 35 g/mol) reacts with excess H₂(g), 8.0 g of LiH(s) is produced. The percent yield is closest to

- (A) 17%
- * (B) 25%
- (C) 50.0%
- (D) 100%

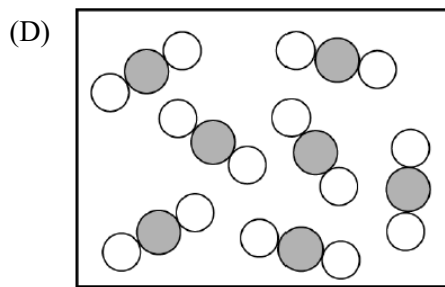
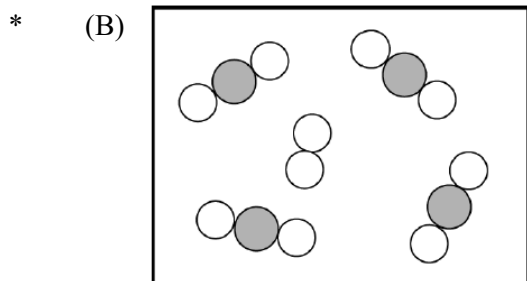
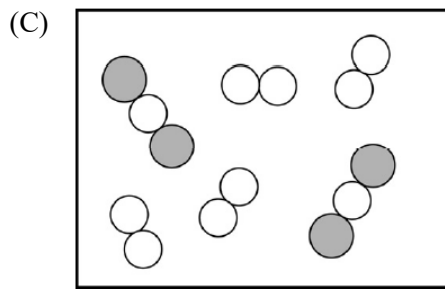
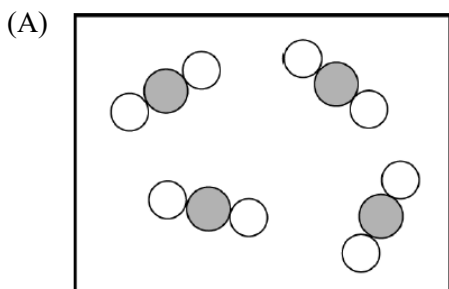
Topic
4.5 Stoichiometry

2017 Practice Exam #9

Q: Particle diagram after rxn - 4 CO + 3 O₂ molecules



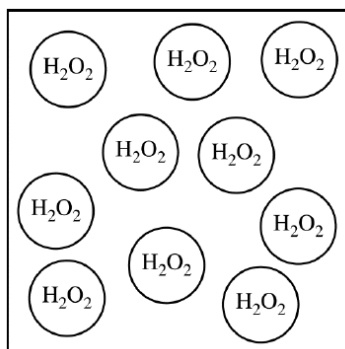
A mixture of CO(g) and O₂(g) is placed in a container, as shown above. A reaction occurs, forming CO₂(g). Which of the following best represents the contents of the box after the reaction has proceeded as completely as possible?



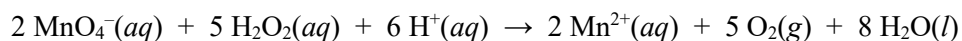
Topic
4.5 Stoichiometry

2017 Practice Exam #35

Q: Particle diagram of H₂O₂ MnO₄⁻ titration - halfway



A particle view of a sample of H₂O₂(aq) is shown above. The H₂O₂(aq) is titrated with KMnO₄(aq), as represented by the equation below.



Which of the following particle views best represents the mixture when the titration is halfway to the equivalence point? (H₂O molecules and H⁺ ions are not shown.)

- (A)
- (B)
- * (C)
- (D)

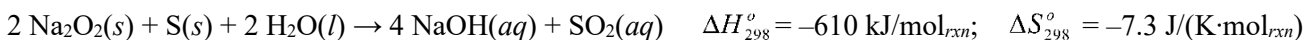
Topic
4.5 Stoichiometry

2016 Practice Exam #37

Q: Na₂O₂ + S - limiting reactant and heat released

Questions X-Y refer to the following information.

When water is added to a mixture of Na₂O₂(s) and S(s), a redox reaction occurs, as represented by the equation below.



Two trials are run, using excess water. In the first trial, 7.8 g of Na₂O₂(s) (molar mass 78 g/mol) is mixed with 3.2 g of S(s). In the second trial, 7.8 g of Na₂O₂(s) is mixed with 6.4 g of S(s). The Na₂O₂(s) and S(s) react as completely as possible. Both trials yield the same amount of SO₂(aq). Which of the following identifies the limiting reactant and the heat released, *q*, for the two trials at 298 K?

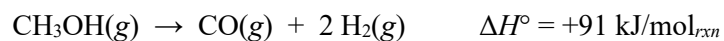
	Limiting Reactant	<i>q</i>
(A)	S	30. kJ
(B)	S	61 kJ
* (C)	Na ₂ O ₂	30. kJ
(D)	Na ₂ O ₂	61 kJ

Topic
4.5 Stoichiometry

2016 Practice Exam #45

Q: CH₃OH decomp - compare pressure after reaction

Questions X-Y refer to the following.



The reaction represented above goes essentially to completion. The reaction takes place in a rigid, insulated vessel that is initially at 600 K.

A sample of CH₃OH(g) is placed in the previously evacuated vessel with a pressure of P_1 at 600 K. What is the final pressure in the vessel after the reaction is complete and the contents of the vessel are returned to 600 K?

(A) $\frac{P_1}{9}$

(B) $\frac{P_1}{3}$

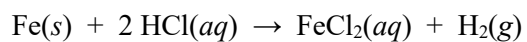
(C) P_1

* (D) $3P_1$

Topic
4.5 Stoichiometry

2016 Practice Exam #50

Q: Amount of products - 0.56g Fe + 30.0mL 1.00 M HCl



When a student adds 30.0 mL of 1.00 *M* HCl to 0.56 g of powdered Fe, a reaction occurs according to the equation above. When the reaction is complete at 273 K and 1.0 atm, which of the following is true?

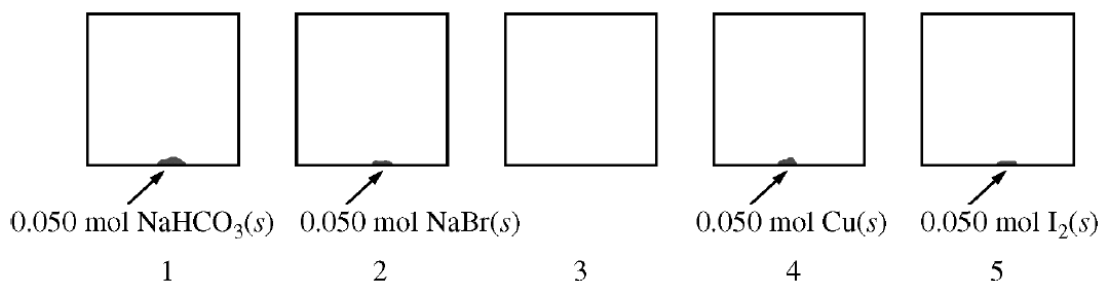
- (A) HCl is in excess, and 0.100 mol of HCl remains unreacted.
- (B) HCl is in excess, and 0.020 mol of HCl remains unreacted.
- (C) 0.015 mol of FeCl₂ has been produced.
- * (D) 0.22 L of H₂ has been produced.

Topic
4.5 Stoichiometry

2015 Practice Exam #8

Q: 5 vessels - mass of vaporized I₂ to solid

Questions X-Y refer to the following information.



At 27°C, five identical rigid 2.0 L vessels are filled with N₂(g) and sealed. Four of the five vessels also contain a 0.050 mol sample of NaHCO₃(s), NaBr(s), Cu(s), or I₂(s), as shown in the diagram above. The volume taken up by the solids is negligible, and the initial pressure of N₂(g) in each vessel is 720 mm Hg. All five vessels are heated to 127°C and allowed to reach a constant pressure.

At 127°C, the entire sample of I₂ is observed to have vaporized. How does the mass of vessel 5 at 127°C compare to its mass at 27°C?

- (A) The mass is less, since the I₂ is in the vapor phase.
- * (B) The mass is the same, since the number of each type of atom in the vessel is constant.
- (C) The mass is greater, since the I₂ will react with N₂ to form NI₃, which has a greater molar mass.
- (D) The mass is greater, since the pressure is greater and the particles have a higher average kinetic energy.

Topic
4.5 Stoichiometry

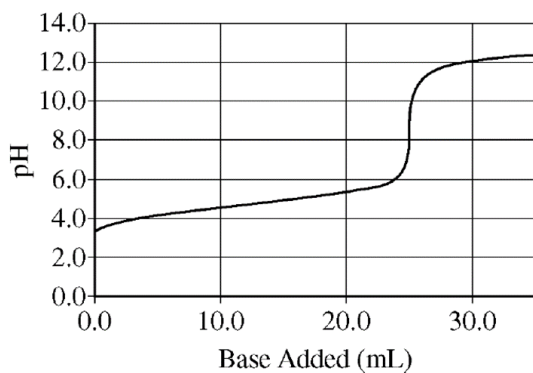
2015 Practice Exam #18

Q: $\text{Li} + \text{H}_2\text{O}$ - volume of gas produced with K vs Li

Questions X-Y refer to the following information.

A 0.35 g sample of $\text{Li}(s)$ is placed in an Erlenmeyer flask containing 100 mL of water at 25°C . A balloon is placed over the mouth of the flask to collect the hydrogen gas that is generated.

After all of the $\text{Li}(s)$ has reacted with $\text{H}_2\text{O}(l)$, the solution in the flask is added to a clean, dry buret and used to titrate an aqueous solution of a monoprotic acid. The pH curve for this titration is shown in the diagram below.



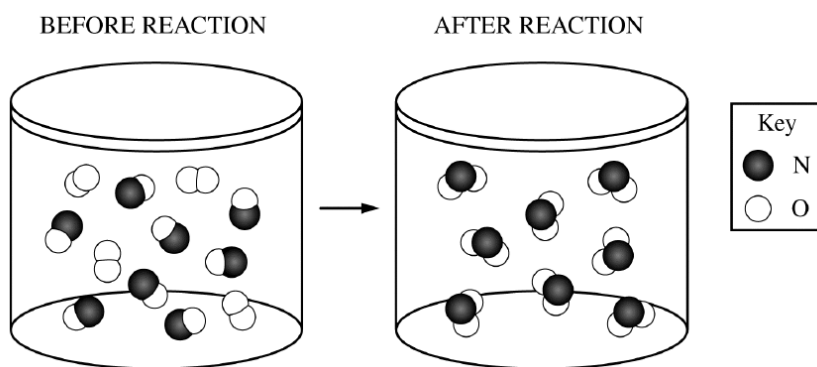
What will be the effect on the amount of gas produced if the experiment is repeated using 0.35 g of $\text{K}(s)$ instead of 0.35 g of $\text{Li}(s)$?

- (A) No gas will be produced when $\text{K}(s)$ is used.
- * (B) Some gas will be produced but less than the amount of gas produced with $\text{Li}(s)$.
- (C) Equal quantities of gas will be produced with the two metals.
- (D) More gas will be produced with $\text{K}(s)$ than with $\text{Li}(s)$.

Topic
4.5 Stoichiometry

2015 Practice Exam #24

Q: Particulate of $\text{NO} + \text{O}_2$ - pressure as rxn proceeds



The reaction between $\text{NO}(g)$ and $\text{O}_2(g)$ to produce $\text{NO}_2(g)$ in a rigid reaction vessel is represented in the diagram above. The pressure inside the container is recorded using a pressure gauge. Which of the following statements correctly predicts the change in pressure as the reaction goes to completion at constant temperature, and provides the correct explanation?

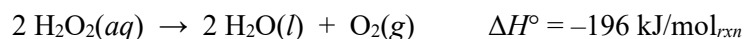
- (A) The pressure will increase because the product molecules have a greater mass than either of the reactant molecules.
- * (B) The pressure will decrease because there are fewer molecules of product than reactants.
- (C) The pressure will decrease because the product molecules have a lower average speed than the reactant molecules.
- (D) The pressure will not change because the total mass of the product molecules is the same as the total mass of the reactant molecules.

Topic
4.5 Stoichiometry

2015 Practice Exam #26

Q: H₂O₂ decomp - pressure in 10.0 L flask after 400 s

Questions X-Y refer to the following information.



The decomposition of H₂O₂(aq) is represented by the equation above. A student monitored the decomposition of a 1.0 L sample of H₂O₂(aq) at a constant temperature of 300. K and recorded the concentration of H₂O₂ as a function of time. The results are given in the table below.

Time (s)	[H ₂ O ₂]
0	2.7
200.	2.1
400.	1.7
600.	1.4

The O₂(g) produced from the decomposition of the 1.0 L sample of H₂O₂(aq) is collected in a previously evacuated 10.0 L flask at 300. K. What is the approximate pressure in the flask after 400. s? (For estimation purposes, assume that 1.0 mole of gas in 1.0 L exerts a pressure of 24 atm at 300. K.)

- * (A) 1.2 atm
- (B) 2.4 atm
- (C) 12 atm
- (D) 24 atm

Topic
4.5 Stoichiometry

2015 Practice Exam #32

Q: Empirical formula - C H N from combustion analysis

A sample of a compound that contains only the elements C, H, and N is completely burned in O_2 to produce 44.0 g of CO_2 , 45.0 g of H_2O , and some NO_2 . A possible empirical formula of the compound is

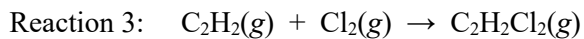
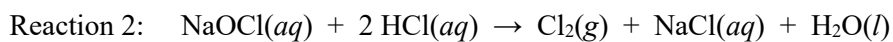
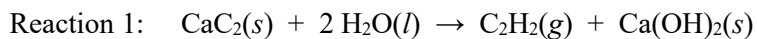
- (A) CH_2N
- * (B) CH_5N
- (C) C_2H_5N
- (D) $C_3H_3N_2$

Topic
4.5 Stoichiometry

2015 Practice Exam #35

Q: CaC_2 rxn - conc of NaOCl if 0.010 mol Cl_2 produced

Questions X-Y refer to the reactions represented below, which are involved in a demonstration commonly known as "underwater fireworks."



Reaction 2 occurs when an excess of 6 *M* $\text{HCl}(aq)$ solution is added to 100. mL of $\text{NaOCl}(aq)$ of unknown concentration. If the reaction goes to completion and 0.010 mol of $\text{Cl}_2(g)$ is produced, then what was the molarity of the $\text{NaOCl}(aq)$ solution?

(A) 0.0010 *M*

(B) 0.010 *M*

* (C) 0.10 *M*

(D) 1.0 *M*

Topic
4.5 Stoichiometry

2015 Practice Exam #39

Q: Combustion of which compound yields greatest g CO₂

If equal masses of the following compounds undergo complete combustion, which will yield the greatest mass of CO₂ ?

- * (A) Benzene, C₆H₆
- (B) Cyclohexane, C₆H₁₂
- (C) Glucose, C₆H₁₂O₆
- (D) Methane, CH₄

Topic
4.5 Stoichiometry

2014 Practice Exam #8

Q: MCl gravimetric analysis - identify metal chloride

Questions X-Y refer to the following.

M^+ is an unknown metal cation with a +1 charge. A student dissolves the chloride of the unknown metal, MCl, in enough water to make 100.0 mL of solution. The student then mixes the solution with excess $AgNO_3$ solution, causing AgCl to precipitate. The student collects the precipitate by filtration, dries it, and records the data shown below. (The molar mass of AgCl is 143 g/mol.)

Mass of unknown chloride, MCl	0.74 g
Mass of filter paper	0.80 g
Mass of filter paper plus AgCl precipitate	2.23 g

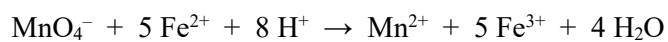
What is the identity of the metal chloride?

- (A) NaCl
- * (B) KCl
- (C) CuCl
- (D) LiCl

Topic
4.5 Stoichiometry

2014 Practice Exam #26

Q: Number of MnO_4^- ions reacting in redox reaction



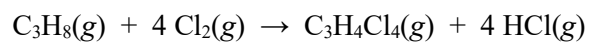
In the reaction represented above, the number of MnO_4^- ions that react must be equal to which of the following?

- * (A) One-fifth the number of Fe^{2+} ions that are consumed
- (B) Eight times the number of H^+ ions that are consumed
- (C) Five times the number of Fe^{3+} ions that are produced
- (D) One-half the number of H_2O molecules that are produced

Topic
4.5 Stoichiometry

2014 Practice Exam #48

Q: Mol HCl produced from 6.0 mol C₃H₈ and 20. mol Cl₂



A 6.0 mol sample of C₃H₈(g) and a 20. mol sample of Cl₂(g) are placed in a previously evacuated vessel, where they react according to the equation above. After one of the reactants has been totally consumed, how many moles of HCl(g) have been produced?

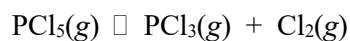
- (A) 4.0 mol
- (B) 8.0 mol
- * (C) 20. mol
- (D) 24 mol

Topic
4.5 Stoichiometry

2013 Practice Exam #31

Q: PCl_5 equil. - total P if rxn goes to completion

Questions X-Y refer to the following.



$\text{PCl}_5(g)$ decomposes into $\text{PCl}_3(g)$ and $\text{Cl}_2(g)$ according to the equation above. A pure sample of $\text{PCl}_5(g)$ is placed in a rigid, evacuated 1.00 L container. The initial pressure of the $\text{PCl}_5(g)$ is 1.00 atm. The temperature is held constant until the $\text{PCl}_5(g)$ reaches equilibrium with its decomposition products. The figures below show the initial and equilibrium conditions of the system.

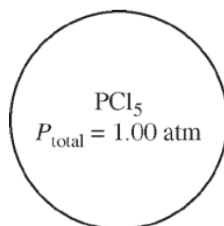


Figure 1: Initial



Figure 2: Equilibrium

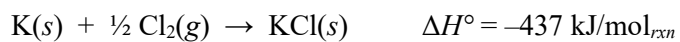
If the decomposition reaction were to go to completion, the total pressure in the container would be

- (A) 1.4 atm
- * (B) 2.0 atm
- (C) 2.8 atm
- (D) 3.0 atm

Topic
4.5 Stoichiometry

2013 Practice Exam #35

Q: KCl enthalpy - remains after equal masses react



The elements K and Cl react directly to form the compound KCl according to the equation above. Refer to the information above and the table below to answer the questions that follow.

Process	ΔH° (kJ/mol _{rxn})
$\text{K}(s) \rightarrow \text{K}(g)$	v
$\text{K}(g) \rightarrow \text{K}^+(g) + e^-$	w
$\text{Cl}_2(g) \rightarrow 2 \text{Cl}(g)$	x
$\text{Cl}(g) + e^- \rightarrow \text{Cl}^-(g)$	y
$\text{K}^+(g) + \text{Cl}^-(g) \rightarrow \text{KCl}(s)$	z

What remains in the reaction vessel after equal masses of K(s) and Cl₂(g) have reacted until either one or both of the reactants have been completely consumed?

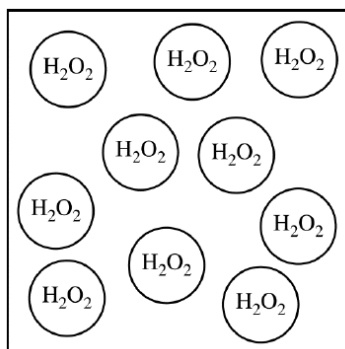
- (A) KCl only
- (B) KCl and K only
- (C) KCl and Cl₂ only
- (D) KCl, K, and Cl₂

*

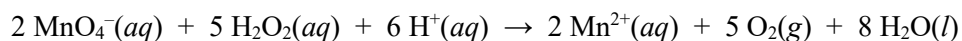
Topic
4.6 Introduction to Titration

2017 Practice Exam #35

Q: Particle diagram of H_2O_2 MnO_4^- titration - halfway



A particle view of a sample of $\text{H}_2\text{O}_2(\text{aq})$ is shown above. The $\text{H}_2\text{O}_2(\text{aq})$ is titrated with $\text{KMnO}_4(\text{aq})$, as represented by the equation below.



Which of the following particle views best represents the mixture when the titration is halfway to the equivalence point? (H_2O molecules and H^+ ions are not shown.)

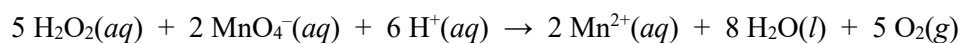
- (A)
- (B)
- * (C)
- (D)

Topic
4.6 Introduction to Titration

2014 Practice Exam #34

Q: H₂O₂ titration - pH of soln as titration proceeds

Questions X-Y refer to the following.



In a titration experiment, H₂O₂(aq) reacts with MnO₄⁻(aq) as represented by the equation above. The dark purple KMnO₄ solution is added from a buret to a colorless, acidified solution of H₂O₂(aq) in an Erlenmeyer flask. (Note: At the end point of the titration, the solution is a pale pink color.)

Which of the following best describes what happens to the pH of the H₂O₂ solution as the titration proceeds?

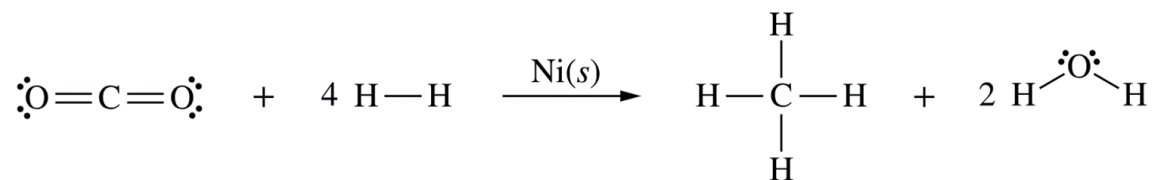
- (A) The +2 charge on the manganese ions maintains the acidity of the solution.
- (B) The production of water dilutes the solution, making it basic.
- * (C) As H⁺ ions are consumed, the solution becomes less acidic and the pH increases.
- (D) As H⁺ ions are consumed, the solution becomes less acidic and the pH decreases.

Topic
4.7 Types of Chemical Reactions

2023 Practice Exam (from AP Classroom)

Q: Redox of reaction

In the gas-phase reaction represented by the following equation, methane (CH₄) and water (H₂O) are produced from carbon dioxide (CO₂) and hydrogen (H₂) at high temperature and pressure.



Which of the following is a correct statement about oxidation and reduction during the reaction?

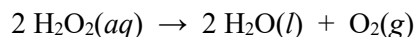
- * (A) Hydrogen is oxidized, and carbon is reduced.
- (B) Carbon is oxidized, and oxygen is reduced.
- (C) Oxygen is oxidized, and hydrogen is reduced.
- (D) It is not an oxidation-reduction reaction.

Topic
4.7 Types of Chemical Reactions

2022 Practice Exam (from AP Classroom)

Q: Change in oxidation numbers

The following balanced equation represents the decomposition of hydrogen peroxide, H_2O_2 .



A student carries out an experiment in which a sample of $\text{H}_2\text{O}_2(aq)$ decomposes in the presence of $\text{MnO}_2(s)$. The student measures the volume of $\text{O}_2(g)$ produced by the reaction at regular intervals while the temperature is held constant. The student's data are given in the following table.

Time (s)	Volume of $\text{O}_2(g)$ Collected (mL)
0	0
60	42
120	64
180	76
240	82
300	86
360	88
420	89

The student claims that the reaction is an oxidation-reduction reaction. Which of the following statements correctly describes a change in oxidation number as the decomposition reaction proceeds?

- (A) The oxidation number of hydrogen changes from +2 to +1.
- (B) The oxidation number of hydrogen changes from +1 to +2.
- (C) The oxidation number of oxygen changes from -2 to -1.
- * (D) The oxidation number of oxygen changes from -1 to 0.

Topic
4.7 Types of Chemical Reactions

2022 Practice Exam (from AP Classroom)

Q: Error in mass of precipitate

A 10.0 g sample of $\text{Pb}(\text{NO}_3)_2(s)$ is dissolved in distilled water and an excess of 1.0 M $\text{HCl}(aq)$ is added. The $\text{PbCl}_2(s)$ formed is filtered and placed in an oven to dry. The final mass of the precipitate is significantly greater than predicted. Which of the following could account for the discrepancy?

- (A) The sample of $\text{Pb}(\text{NO}_3)_2(s)$ was wet.
- (B) The K_{sp} of $\text{PbCl}_2(s)$ is extremely small.
- * (C) The precipitate was not dried to a constant mass.
- (D) A 3.0 M $\text{HCl}(aq)$ solution was used instead of a 1.0 M $\text{HCl}(aq)$ solution.

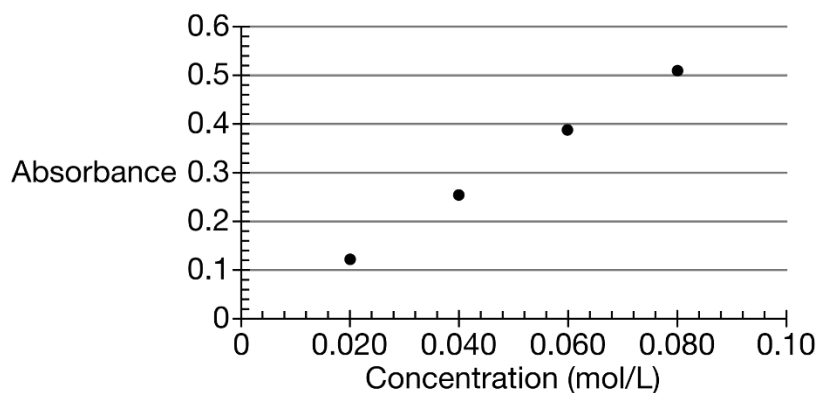
Topic
4.7 Types of Chemical Reactions

2021 Practice Exam (from AP Classroom)

Q: Species being oxidized

An experiment was performed to investigate the reaction between Zn metal and $\text{Ni}^{2+}(aq)$ at different concentrations. Because the $\text{Ni}^{2+}(aq)$ ion is green, the extent of the reaction was determined using spectrophotometric analysis. Four 20.0 mL standard solutions of $\text{Ni}^{2+}(aq)$ were prepared by dissolving $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ (molar mass 240 g/mol) in water. The absorbance of each solution was measured; the results are shown both in the table below and in the following plot of the absorbance data.

Solution	$[\text{Ni}^{2+}]$	Absorbance
1	0.020	0.12
2	0.040	0.25
3	0.060	0.39
4	0.080	0.51



Which species is being oxidized in the reaction between Zn metal and $\text{NiCl}_2(aq)$?

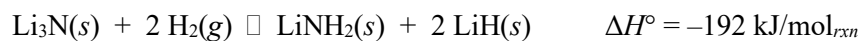
- * (A) Zn
- (B) Zn^{2+}
- (C) Ni
- (D) Ni^{2+}

Topic
4.7 Types of Chemical Reactions

2018 Practice Exam #34

Q: H₂ storage - are H atoms oxidized or reduced

Questions X-Y refer to the following information.



Because pure H₂ is a hazardous substance, safer and more cost effective techniques to store it as a solid for shipping purposes have been developed. One such method is the reaction represented above, which occurs at 200°C.

Which of the following happens to H atoms in the forward reaction?

- (A) H atoms are oxidized only.
- (B) H atoms are reduced only.
- * (C) H atoms are both oxidized and reduced.
- (D) H atoms are neither oxidized nor reduced.

Topic
4.7 Types of Chemical Reactions

2017 Practice Exam #10

Q: Cu + HNO₃ - reaction type

Questions X-Y refer to the following information.



Each student in a class placed a 2.00 g sample of a mixture of Cu and Al in a beaker and placed the beaker in a fume hood. The students slowly poured 15.0 mL of 15.8 M HNO₃(aq) into their beakers. The reaction between the copper in the mixture and the HNO₃(aq) is represented by the equation above. The students observed that a brown gas was released from the beakers and that the solutions turned blue, indicating the formation of Cu²⁺(aq). The solutions were then diluted with distilled water to known volumes.

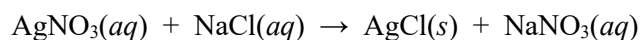
Which of the following is true about the reaction?

- (A) It is a Brønsted-Lowry acid-base reaction, because the solution is neutral at the end.
- (B) It is a Brønsted-Lowry acid-base reaction, because HNO₃(aq) is a strong acid.
- (C) It is a redox reaction, because Cu(s) is oxidized and H⁺(aq) is reduced.
- * (D) It is a redox reaction, because Cu(s) is oxidized and the nitrogen atom in NO₃⁻(aq) is reduced.

Topic
4.7 Types of Chemical Reactions

2016 Practice Exam #21

Not listed in the question bank



A student performed an analysis to determine the amount of $\text{AgNO}_3(aq)$ in a solution. Excess $\text{NaCl}(aq)$ was added to the solution, and the $\text{Ag}^+(aq)$ precipitated as $\text{AgCl}(s)$. The precipitate was collected by gravity filtration and dried in an oven. Three trials were performed, and in each case, according to the instructor, the mass of precipitate recovered was 5 percent higher than the actual mass of $\text{AgCl}(s)$ that should have formed. Which of the following could account for the error?

- (A) The pores in the filter paper were too large.
- (B) Not all of the precipitate was transferred to the filter paper.
- (C) The $\text{NaCl}(aq)$ solution was too concentrated.
- * (D) The precipitate was not rinsed with deionized water before drying.

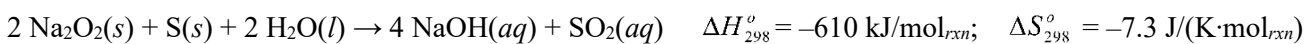
Topic
4.7 Types of Chemical Reactions

2016 Practice Exam #38

Q: $\text{Na}_2\text{O}_2 + \text{S}$ - element that is reduced in reaction

Questions X-Y refer to the following information.

When water is added to a mixture of $\text{Na}_2\text{O}_2(s)$ and $\text{S}(s)$, a redox reaction occurs, as represented by the equation below.



Atoms of which element are reduced in the reaction?

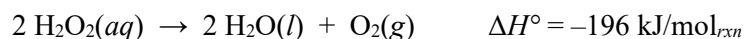
- (A) S; each atom loses four electrons
- (B) Na in Na_2O_2 ; each atom loses one electron
- * (C) O in Na_2O_2 ; each atom gains one electron
- (D) O in H_2O ; each atom gains one electron

Topic
4.7 Types of Chemical Reactions

2015 Practice Exam #25

Q: H₂O₂ decomp - element being oxidized and reduced

Questions X-Y refer to the following information.



The decomposition of H₂O₂(aq) is represented by the equation above. A student monitored the decomposition of a 1.0 L sample of H₂O₂(aq) at a constant temperature of 300. K and recorded the concentration of H₂O₂ as a function of time. The results are given in the table below.

Time (s)	[H ₂ O ₂]
0	2.7
200.	2.1
400.	1.7
600.	1.4

Which of the following identifies the element(s) being oxidized and reduced in the reaction?

- (A) Hydrogen is oxidized and oxygen is reduced.
- (B) Oxygen is oxidized and hydrogen is reduced.
- * (C) Oxygen is both oxidized and reduced.
- (D) No elements are oxidized or reduced; the reaction is not a redox reaction.

Topic
4.7 Types of Chemical Reactions

2015 Practice Exam #31

Q: Analyze Ag content in jewelry - step after HNO_3

To gravimetrically analyze the silver content of a piece of jewelry made from an alloy of Ag and Cu, a student dissolves a small preweighed sample in $\text{HNO}_3(aq)$. $\text{Ag}^+(aq)$ and $\text{Cu}^{2+}(aq)$ ions form in the solution. Which of the following should be the next step in the analytical process?

- (A) Centrifuging the solution to isolate the heavier ions
- (B) Evaporating the solution to recover the dissolved nitrates
- (C) Adding enough base solution to bring the pH up to 7.0
- * (D) Adding a solution containing an anion that forms an insoluble salt with only one of the metal ions

Topic
4.7 Types of Chemical Reactions

2014 Practice Exam #9

Q: MCl gravimetric analysis - what happens to NO_3^-

Questions X-Y refer to the following.

M^+ is an unknown metal cation with a +1 charge. A student dissolves the chloride of the unknown metal, MCl, in enough water to make 100.0 mL of solution. The student then mixes the solution with excess AgNO_3 solution, causing AgCl to precipitate. The student collects the precipitate by filtration, dries it, and records the data shown below. (The molar mass of AgCl is 143 g/mol.)

Mass of unknown chloride, MCl	0.74 g
Mass of filter paper	0.80 g
Mass of filter paper plus AgCl precipitate	2.23 g

During the course of the experiment, which of the following happens to the NO_3^- ions?

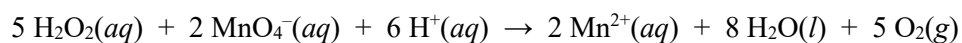
- (A) They are oxidized by Cl^- ions.
- (B) They are reduced to NO_2^- ions.
- (C) They are decomposed by reacting with M^+ ions.
- * (D) They remain dissolved in the filtrate solution.

Topic
4.7 Types of Chemical Reactions

2014 Practice Exam #33

Q: H₂O₂ titration - change in oxidation number

Questions X-Y refer to the following.



In a titration experiment, H₂O₂(aq) reacts with MnO₄⁻(aq) as represented by the equation above. The dark purple KMnO₄ solution is added from a buret to a colorless, acidified solution of H₂O₂(aq) in an Erlenmeyer flask. (Note: At the end point of the titration, the solution is a pale pink color.)

Which element is being oxidized during the titration, and what is the element's change in oxidation number?

- * (A) Oxygen, which changes from -1 to 0
- (B) Oxygen, which changes from 0 to -2
- (C) Manganese, which changes from -1 to +2
- (D) Manganese, which changes from +7 to +2

Topic
4.7 Types of Chemical Reactions

2013 Practice Exam #4

Q: Which has more effective reducing ability than Zn

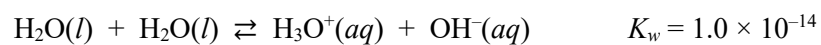
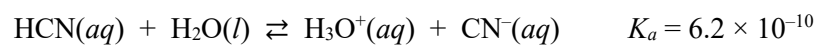
$\text{Zn}(s)$ is used to reduce other compounds in chemical reactions. If a chemist needs a substance that is more effective in its reducing ability, which of the following species would be the best choice?

- * (A) Na
- (B) H^+
- (C) K^+
- (D) Cl^-

Topic
4.8 Introduction to Acid-Base Reactions

2023 Practice Exam (from AP Classroom)

Q: Acid and base strength from equations



Based on the chemical equations given, which of the following statements is correct?

- (A) HCN is a weaker acid than H₂O.
- (B) CN⁻ is a stronger acid than HCN.
- * (C) CN⁻ is a stronger base than H₂O.
- (D) H₂O is a weaker base than HCN.

Topic
4.8 Introduction to Acid-Base Reactions

2022 Practice Exam (from AP Classroom)

Q: Conjugate acid base pair

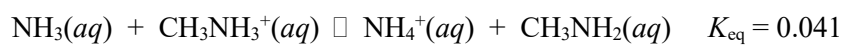
Which of the following correctly identifies a Bronsted-Lowry conjugate acid-base in a solution prepared by mixing together $\text{HNO}_2(aq)$ and $\text{NH}_3(aq)$?

- (A) The acid is $\text{HNO}_2(aq)$, and the conjugate base is $\text{NH}_3(aq)$.
- * (B) The acid is $\text{HNO}_2(aq)$, and the conjugate base is $\text{NO}_2^-(aq)$.
- (C) The acid is $\text{NH}_4^+(aq)$, and the conjugate base is $\text{NO}_2^-(aq)$.
- (D) The acid is $\text{NH}_3(aq)$, and the conjugate base is $\text{NH}_4^+(aq)$.

Topic
4.8 Introduction to Acid-Base Reactions

2021 Practice Exam (from AP Classroom)

Q: Strongest base in reaction



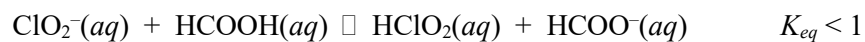
Which of the following species is the strongest base in the reaction represented above?

- (A) $\text{NH}_3(aq)$
- (B) $\text{CH}_3\text{NH}_3^+(aq)$
- (C) $\text{NH}_4^+(aq)$
- * (D) $\text{CH}_3\text{NH}_2(aq)$

Topic
4.8 Introduction to Acid-Base Reactions

2017 Practice Exam #46

Q: Relative strengths of acids-bases given small K



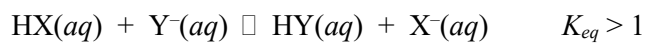
What are the relative strengths of the acids and bases in the reaction represented by the equation above?

	<u>Acid Strength</u>	<u>Base Strength</u>
(A)	$\text{HClO}_2 < \text{HCOOH}$	$\text{ClO}_2^- < \text{HCOO}^-$
(B)	$\text{HClO}_2 < \text{HCOOH}$	$\text{ClO}_2^- > \text{HCOO}^-$
(C)	$\text{HClO}_2 > \text{HCOOH}$	$\text{ClO}_2^- > \text{HCOO}^-$
* (D)	$\text{HClO}_2 > \text{HCOOH}$	$\text{ClO}_2^- < \text{HCOO}^-$

Topic
4.8 Introduction to Acid-Base Reactions

2016 Practice Exam #20

Q: $\text{HX} + \text{Y}^-$ - strongest acid given large K



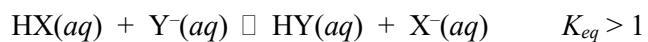
Based on the information given above, which of the following is the strongest acid?

- * (A) $\text{HX}(aq)$
- (B) $\text{Y}^-(aq)$
- (C) $\text{HY}(aq)$
- (D) $\text{X}^-(aq)$

Topic
4.8 Introduction to Acid-Base Reactions

2015 Practice Exam #45

Q: Given K, which species is the strongest base



A solution of a salt of a weak acid HY is added to a solution of another weak acid HX. Based on the information given above, which of the following species is the strongest base?

- (A) $\text{HX}(aq)$
- * (B) $\text{Y}^-(aq)$
- (C) $\text{HY}(aq)$
- (D) $\text{X}^-(aq)$

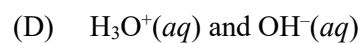
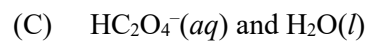
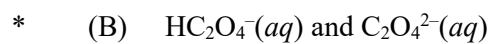
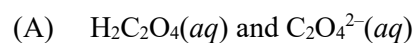
Topic
4.8 Introduction to Acid-Base Reactions

2013 Practice Exam #11

Q: Oxalic acid - identify conjugate acid-base pair



All the reactions represented above occur in an aqueous solution of oxalic acid. Which of the following represent a Brønsted-Lowry conjugate acid-base pair?

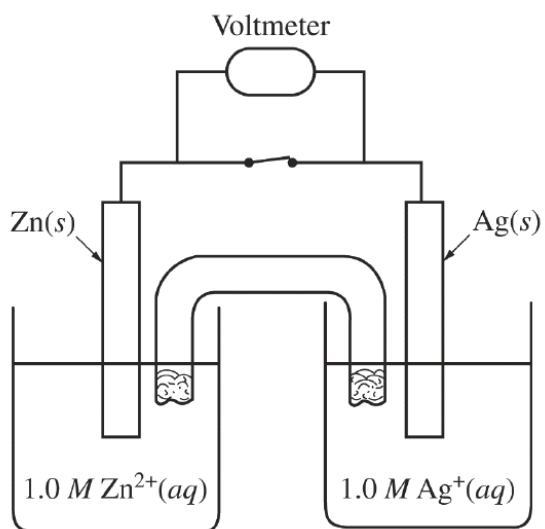


Topic
4.9 Oxidation-Reduction (Redox) Reactions

2019 Practice Exam #10

Q: Standard Zn-Ag Galvanic cell - overall reaction

Questions X-Y refer to the following information.



Standard reduction potentials for the half-reactions associated with the electrochemical cell shown above are given in the table below.

Half-Reaction	E° (V)
$\text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s)$	+ 0.80
$\text{Zn}^{2+}(aq) + 2 e^- \rightarrow \text{Zn}(s)$	- 0.76

Which of the following is the net ionic equation for the overall reaction that occurs as the cell operates?

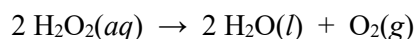
- (A) $\text{Ag}(s) + \text{Zn}^{2+}(aq) \rightarrow \text{Ag}^{2+}(aq) + \text{Zn}(s)$
- (B) $\text{Ag}^+(aq) + \text{Zn}^{2+}(aq) + 3 e^- \rightarrow \text{AgZn}(s)$
- (C) $\text{Ag}^+(aq) + \text{Zn}(s) \rightarrow \text{Ag}(s) + \text{Zn}^{2+}(aq) + e^-$
- * (D) $2 \text{Ag}^+(aq) + \text{Zn}(s) \rightarrow 2 \text{Ag}(s) + \text{Zn}^{2+}(aq)$

Topic
5.1 Reaction Rates

2022 Practice Exam (from AP Classroom)

Q: Rate of decomposition

The following balanced equation represents the decomposition of hydrogen peroxide, H_2O_2 .



A student carries out an experiment in which a sample of $\text{H}_2\text{O}_2(aq)$ decomposes in the presence of $\text{MnO}_2(s)$. The student measures the volume of $\text{O}_2(g)$ produced by the reaction at regular intervals while the temperature is held constant. The student's data are given in the following table.

Time (s)	Volume of $\text{O}_2(g)$ Collected (mL)
0	0
60	42
120	64
180	76
240	82
300	86
360	88
420	89

Based on the student's data, which of the following statements correctly describes how the rate of O_2 production changes during the experiment?

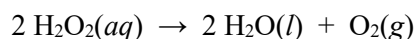
- (A) The rate is constant at first and then increases over time.
- * (B) The rate decreases throughout the experiment.
- (C) The rate increases throughout the experiment.
- (D) The rate is constant throughout the experiment.

Topic
5.1 Reaction Rates

2022 Practice Exam (from AP Classroom)

Q: Volume of product

The following balanced equation represents the decomposition of hydrogen peroxide, H_2O_2 .



A student carries out an experiment in which a sample of $\text{H}_2\text{O}_2(aq)$ decomposes in the presence of $\text{MnO}_2(s)$. The student measures the volume of $\text{O}_2(g)$ produced by the reaction at regular intervals while the temperature is held constant. The student's data are given in the following table.

Time (s)	Volume of $\text{O}_2(g)$ Collected (mL)
0	0
60	42
120	64
180	76
240	82
300	86
360	88
420	89

A second experiment is done under identical conditions using a higher concentration of $\text{H}_2\text{O}_2(aq)$ in the presence of the same mass of $\text{MnO}_2(s)$. The volume of gas collected during the first 60 seconds will most likely be

- (A) less than 42 mL
- (B) equal to 42 mL
- * (C) greater than 42 mL
- (D) impossible to predict without knowing the actual concentration of H_2O_2 used in the two experiments

Topic
5.1 Reaction Rates

2021 Practice Exam (from AP Classroom)

Q: Conditions for fastest reaction rate

Two solid reactants of varying particle size are combined in a vessel. Assuming that the same mass of each reactant is used in each case, which of the following represents the conditions that will result in the fastest reaction rate?

(A) 
Temperature = 950° C

(B) 
Temperature = 500° C

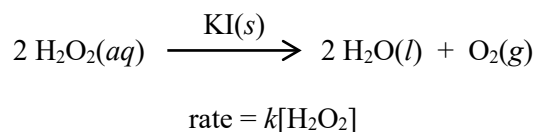
(C) 
Temperature = 500° C

* (D) 
Temperature = 950° C

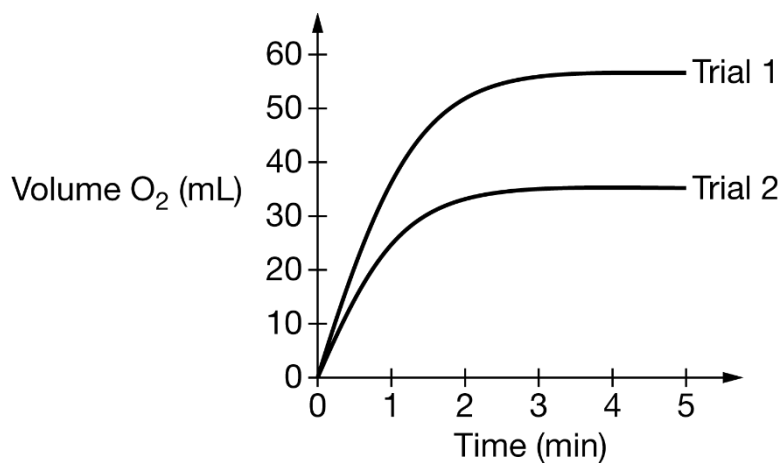
Topic
5.1 Reaction Rates

2021 Practice Exam (from AP Classroom)

Q: Kinetics experiment data



A student performed an experiment to study the factors that affect the rate of the first-order catalytic decomposition of $\text{H}_2\text{O}_2(aq)$, represented above.



The student monitored the volume of $\text{O}_2(g)$ produced over time as the reaction proceeded. The data from two trials are plotted in the graph above. Which of the following best explains the results of trial 2 compared with those of trial 1?

- (A) The reaction temperature in trial 2 was higher than it was in trial 1.
- (B) The volume of the reaction vessel was larger in trial 2 than it was in trial 1.
- (C) The student used a smaller amount of $\text{KI}(s)$ in trial 2 compared with that used in trial 1.
- * (D) The concentration of $\text{H}_2\text{O}_2(aq)$ was lower in trial 2 than it was in trial 1.

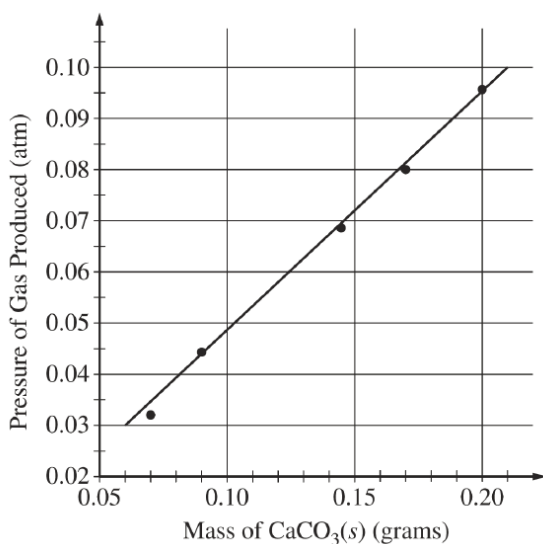
Topic
5.1 Reaction Rates

2019 Practice Exam #38

Q: CaCO_3 in eggshells - modification to increase rate

Questions X-Y refer to the following information.

An experiment is performed to measure the mass percent of $\text{CaCO}_3(s)$ in eggshells. Five different samples of $\text{CaCO}_3(s)$ of known mass react with an excess of $2.0\text{ M HCl}(aq)$ in identical sealed, rigid reaction vessels. The pressure of the gas produced is measured with a pressure gauge attached to the reaction vessel. Since the reaction is exothermic, the reaction system is cooled to its original temperature before the pressure is recorded. The experimental data are used to create the calibration line below.



The experiment is repeated with an eggshell sample, and the experimental data are recorded in the table below.

Mass of eggshell sample	0.200 g
Pressure prior to reaction	0.800 atm
Pressure at completion of reaction	0.870 atm

Which of the following modifications will increase the rate of the reaction the most?

- (A) Using $2.0\text{ M CH}_3\text{COOH}(aq)$ instead of $2.0\text{ M HCl}(aq)$
- (B) Cooling the $\text{HCl}(aq)$ to a lower temperature than it was in the original experiment
- (C) Reducing the volume of the reaction vessel

* (D) Using eggshells that are more finely powdered than those used in the original experiment

Topic
5.1 Reaction Rates

2017 Practice Exam #13

Q: Cu + HNO₃ - explanation for slower reaction rate

Questions X-Y refer to the following information.



Each student in a class placed a 2.00 g sample of a mixture of Cu and Al in a beaker and placed the beaker in a fume hood. The students slowly poured 15.0 mL of 15.8 M HNO₃(aq) into their beakers. The reaction between the copper in the mixture and the HNO₃(aq) is represented by the equation above. The students observed that a brown gas was released from the beakers and that the solutions turned blue, indicating the formation of Cu²⁺(aq). The solutions were then diluted with distilled water to known volumes.

In one student's experiment the reaction proceeded at a much slower rate than it did in the other students' experiments. Which of the following could explain the slower reaction rate?

- (A) In the student's sample the metal pieces were much smaller than those in the other students' samples.
- (B) The student heated the reaction mixture as the HNO₃(aq) was added.
- * (C) The student used a 1.5 M solution of HNO₃(aq) instead of a 15.8 M solution of HNO₃(aq).
- (D) The student used a 3.00 g sample of the mixture instead of the 2.00 g sample that was used by the other students.

Topic
5.1 Reaction Rates

2016 Practice Exam #2

Q: Explain why rate increases with higher temperature

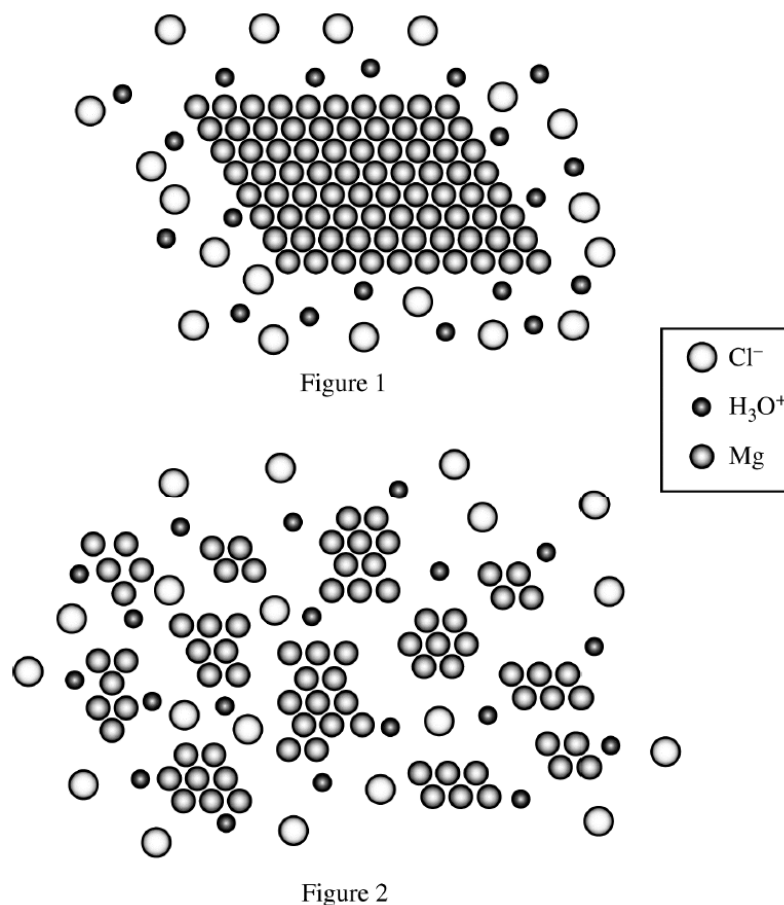
Which of the following best helps explain why an increase in temperature increases the rate of a chemical reaction?

- (A) At higher temperatures, reactions have a lower activation energy.
- (B) At higher temperatures, reactions have a higher activation energy.
- (C) At higher temperatures, every collision results in the formation of product.
- * (D) At higher temperatures, high-energy collisions happen more frequently.

Topic
5.1 Reaction Rates

2016 Practice Exam #10

Q: Particulate - Mg + HCl rxn rate and surface area



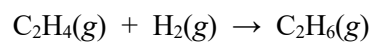
Two samples of $\text{Mg}(s)$ of equal mass were placed in equal amounts of $\text{HCl}(aq)$ contained in two separate reaction vessels. Particle representations of the mixing of $\text{Mg}(s)$ and $\text{HCl}(aq)$ in the two reaction vessels are shown in Figure 1 and Figure 2 above. Water molecules are not included in the particle representations. Which of the reactions will initially proceed faster, and why?

- (A) The reaction in Figure 1, because the atoms of Mg are more concentrated than those in Figure 2
- (B) The reaction in Figure 1, because the $\text{Mg}(s)$ in Figure 1 has a larger mass than the $\text{Mg}(s)$ in Figure 2
- * (C) The reaction in Figure 2, because more Mg atoms are exposed to $\text{HCl}(aq)$ in Figure 2 than in Figure 1
- (D) The reaction in Figure 2, because the $\text{Mg}(s)$ in Figure 2 has less surface area than the $\text{Mg}(s)$ in Figure 1

Topic
5.1 Reaction Rates

2016 Practice Exam #16

Q: C₂H₆ formation - what increases rxn rate



Which of the following will most likely increase the rate of the reaction represented above?

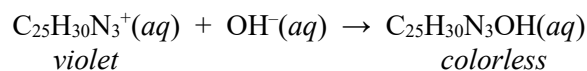
- (A) Decreasing the temperature of the reaction system
- * (B) Adding a heterogeneous catalyst to the reaction system
- (C) Increasing the volume of the reaction vessel using a piston
- (D) Removing some H₂(g) from the reaction system

Topic
5.1 Reaction Rates

2016 Practice Exam #30

Not listed in the question bank

Questions X-Y refer to the investigation described below.



The reaction between $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ and $\text{OH}^-(aq)$, as represented above, is first order with respect to $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ in the presence of excess $\text{OH}^-(aq)$. A 10.0 mL sample of 0.10 M $\text{NaOH}(aq)$ is mixed with a 10.0 mL sample of $2.5 \times 10^{-5} \text{ M } \text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$. A 5.0 mL sample of the mixture is quickly transferred to a clean cuvette and placed in a spectrophotometer, and the progress of the reaction is measured. The data are given in the table below.

Time (s)	0	30	60	90	120	150	180	210	240	270	300
Absorbance	0.62	0.54	0.47	0.41	0.36	0.31	0.27	0.23	0.20	0.17	0.15

What would be the effect on the reaction rate if the solution of $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ is diluted by a factor of two?

- (A) It would be higher.
- * (B) It would be lower.
- (C) It would not change.
- (D) It would initially be higher but then rapidly decrease.

Topic
5.1 Reaction Rates

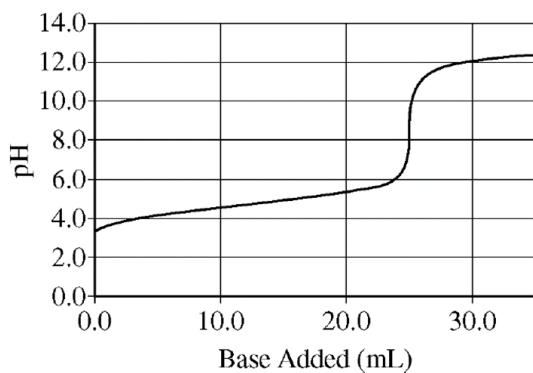
2015 Practice Exam #17

Q: $\text{Li} + \text{H}_2\text{O}$ - increase rxn rate between Li and H_2O

Questions X-Y refer to the following information.

A 0.35 g sample of $\text{Li}(s)$ is placed in an Erlenmeyer flask containing 100 mL of water at 25°C . A balloon is placed over the mouth of the flask to collect the hydrogen gas that is generated.

After all of the $\text{Li}(s)$ has reacted with $\text{H}_2\text{O}(l)$, the solution in the flask is added to a clean, dry buret and used to titrate an aqueous solution of a monoprotic acid. The pH curve for this titration is shown in the diagram below.



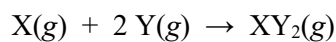
Which of the following changes will most likely increase the rate of reaction between $\text{Li}(s)$ and water?

- (A) Using 125 mL of water instead of 100 mL
- (B) Using a 0.25 g sample of $\text{Li}(s)$ instead of a 0.35 g sample
- * (C) Using a 0.35 g sample of $\text{Li}(s)$ cut into small pieces
- (D) Decreasing the water temperature before adding the $\text{Li}(s)$

Topic
5.1 Reaction Rates

2015 Practice Exam #48

Q: Relative rates of X and Y given initial rate data



In order to determine the order of the reaction represented above, the initial rate of formation of XY_2 is measured using different initial values of $[\text{X}]$ and $[\text{Y}]$. The results of the experiment are shown in the table below.

Trial	$[\text{X}]$ (M)	$[\text{Y}]$ (M)	Initial Rate of Formation of XY_2 (M s^{-1})
1	0.50	0.50	8.0×10^{-3}
2	1.00	0.50	3.2×10^{-2}
3	1.00	1.00	6.4×10^{-2}

In trial 2 which of the reactants would be consumed more rapidly, and why?

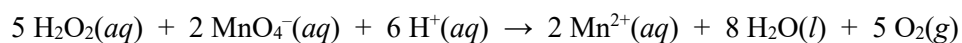
- (A) X, because it has a higher molar concentration.
- (B) X, because the reaction is second order with respect to X.
- (C) Y, because the reaction is second order with respect to Y.
- * (D) Y, because the rate of disappearance will be double that of X.

Topic
5.1 Reaction Rates

2014 Practice Exam #32

Q: H₂O₂ titration - rate of disappearance of MnO₄⁻

Questions X-Y refer to the following.



In a titration experiment, H₂O₂(aq) reacts with MnO₄⁻(aq) as represented by the equation above. The dark purple KMnO₄ solution is added from a buret to a colorless, acidified solution of H₂O₂(aq) in an Erlenmeyer flask. (Note: At the end point of the titration, the solution is a pale pink color.)

At a certain time during the titration, the rate of appearance of O₂(g) was $1.0 \times 10^{-3} \text{ mol/(L}\cdot\text{s)}$. What was the rate of disappearance of MnO₄⁻(aq) at the same time?

(A) $6.0 \times 10^{-3} \text{ mol/(L}\cdot\text{s)}$

(B) $4.0 \times 10^{-3} \text{ mol/(L}\cdot\text{s)}$

(C) $6.0 \times 10^{-4} \text{ mol/(L}\cdot\text{s)}$

* (D) $4.0 \times 10^{-4} \text{ mol/(L}\cdot\text{s)}$

Topic
5.1 Reaction Rates

2013 Practice Exam #6

Q: Which will increase rxn rate of chalk and acid

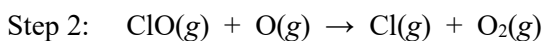
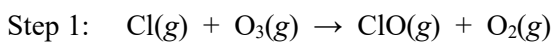
A kinetics experiment is set up to collect the gas that is generated when a sample of chalk, consisting primarily of solid CaCO_3 , is added to a solution of ethanoic acid, CH_3COOH . The rate of reaction between CaCO_3 and CH_3COOH is determined by measuring the volume of gas generated at 25°C and 1 atm as a function of time. Which of the following experimental conditions is most likely to increase the rate of gas production?

- (A) Decreasing the volume of ethanoic acid solution used in the experiment
- (B) Decreasing the concentration of the ethanoic acid solution used in the experiment
- (C) Decreasing the temperature at which the experiment is performed
- * (D) Decreasing the particle size of the CaCO_3 by grinding it into a fine powder

Topic
5.1 Reaction Rates

2013 Practice Exam #53

Q: Evidence for mechanism of ozone destruction



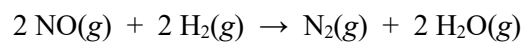
A proposed mechanism for destruction of ozone gas in the stratosphere is represented above. Which of the following is evidence that the mechanism is occurring?

- * (A) The presence of Cl(g) increases the rate of the overall reaction.
- (B) The presence of Cl(g) decreases the rate of the overall reaction.
- (C) The presence of Cl(g) increases the equilibrium constant of the overall reaction.
- (D) The presence of Cl(g) decreases the equilibrium constant of the overall reaction.

Topic
5.2 Introduction to the Rate Law

2023 Practice Exam (from AP Classroom)

Q: Kinetics of NO



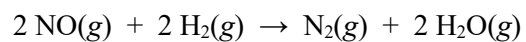
The rate law for the reaction shown is $\text{rate} = k[\text{NO}]^2[\text{H}_2]$. What is the overall order of the reaction?

- (A) First order
- (B) Second order
- * (C) Third order
- (D) Fourth order

Topic
5.2 Introduction to the Rate Law

2023 Practice Exam (from AP Classroom)

Q: Rate from concentration



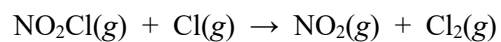
The rate law for the reaction shown is $rate = k[\text{NO}]^2[\text{H}_2]$. What happens to the rate of the reaction when the concentration of $\text{NO}(g)$ is doubled and concentration of $\text{H}_2(g)$ is halved?

- (A) The rate is halved.
- (B) The rate is the same.
- * (C) The rate is doubled.
- (D) The rate is quadrupled.

Topic
5.2 Introduction to the Rate Law

2023 Practice Exam (from AP Classroom)

Q: Single step reaction



The single-step reaction represented above takes place in a sealed container. Which of the following will reduce the value of k , the rate constant for the reaction?

- * (A) Decreasing the temperature
- (B) Increasing the temperature
- (C) Decreasing the size of the sealed container
- (D) Increasing the size of the sealed container

Topic
5.3 Concentration Changes Over Time

2023 Practice Exam (from AP Classroom)

Q: Rate constant from half life

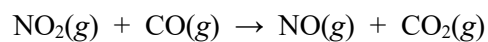
A 100. g sample of a substance decomposes so that 25 g of the original substance remains after 40. seconds. If the decomposition is first order, which of the following is the rate constant, k , of the decomposition reaction?

- (A) 0.017 s^{-1}
- * (B) 0.035 s^{-1}
- (C) 1.4 s^{-1}
- (D) $20. \text{ s}^{-1}$

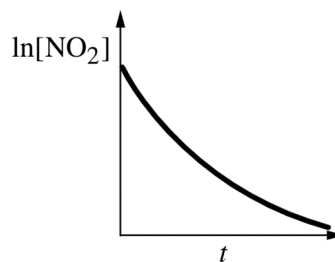
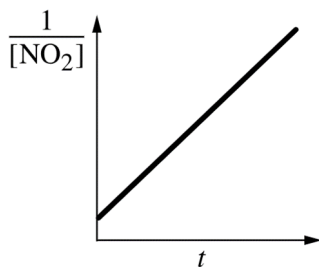
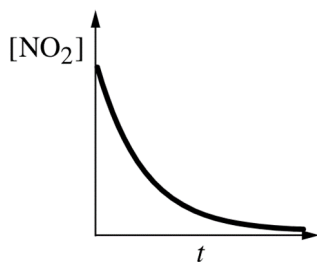
Topic
5.3 Concentration Changes Over Time

2023 Practice Exam (from AP Classroom)

Q: Rate law of NO₂ from graphs



A group of students studied the rate of the reaction represented above at a fixed temperature. During the reaction, the concentration of CO was in large excess. The graphs shown below were created using the data collected by the students. Based on the graphs, which of the following is the rate law?



(A) rate = k

(B) rate = $[\text{NO}_2]$

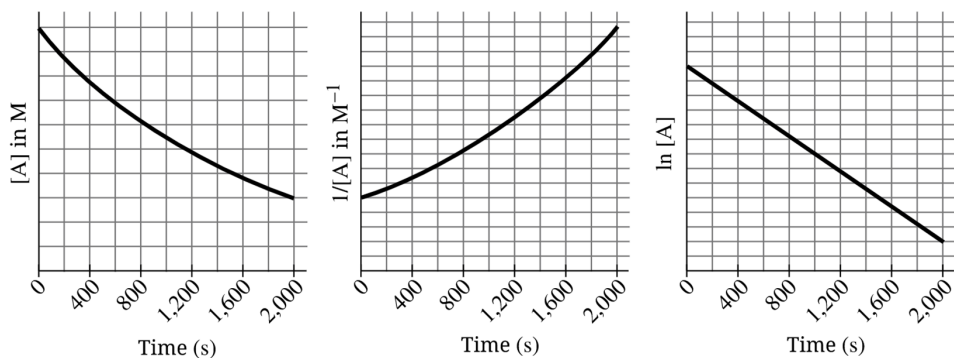
(C) rate = $k[\text{NO}_2]$

* (D) rate = $k[\text{NO}_2]^2$

Topic
5.3 Concentration Changes Over Time

2022 Practice Exam (from AP Classroom)'

Q: Rate law from graphs



A student recorded the rate of decomposition of compound A as a function of time at 45°C. The experimental data are shown above. What is the rate law for the decomposition of A at this temperature?

- (A) $\text{rate} = k$
- * (B) $\text{rate} = k[A]$
- (C) $\text{rate} = k[A]^2$
- (D) The rate law cannot be determined without additional experimentation.

Topic
5.3 Concentration Changes Over Time

2019 Practice Exam #13

Q: Rate law of NO₂ from conc natural log inverse data

Time (s)	[NO ₂] (mol/L)	ln [NO ₂]	$\frac{1}{[\text{NO}_2]}$ (L/mol)
0	0.500	-0.693	2.00
100	0.364	-1.01	2.75
200	0.286	-1.25	3.50
300	0.235	-1.45	4.25

The data from a study of the decomposition of NO₂(g) to form NO(g) and O₂(g) are given in the table above. Which of the following rate laws is consistent with the data?

(A) Rate = $k [\text{NO}_2]$

* (B) Rate = $k [\text{NO}_2]^2$

(C) Rate = $k \frac{1}{[\text{NO}_2]}$

(D) Rate = $k \frac{1}{[\text{NO}_2]^2}$

Topic
5.3 Concentration Changes Over Time

2019 Practice Exam #23

Q: Determine rate constant from pesticide half-life

After a certain pesticide compound is applied to crops, its decomposition is a first-order reaction with a half-life of 56 days. What is the rate constant, k , for the decomposition reaction?

- * (A) 0.012 day^{-1}
- (B) 0.018 day^{-1}
- (C) 56 day^{-1}
- (D) 81 day^{-1}

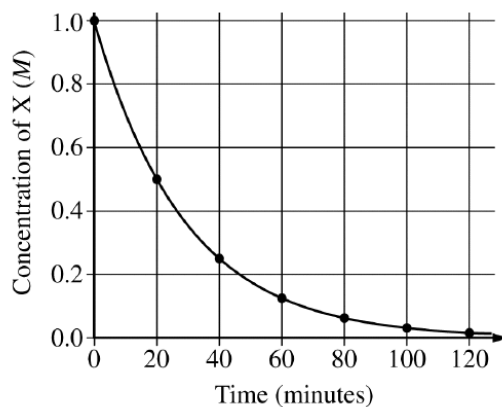
Topic
5.3 Concentration Changes Over Time

2018 Practice Exam #40

Q: How to find rate constant from conc. vs time graph



A student studied the kinetics of the reaction represented above by measuring the concentration of the reactant, X, over time. The data are plotted in the graph below.



Which of the following procedures will allow the student to determine the rate constant, k , for the reaction?

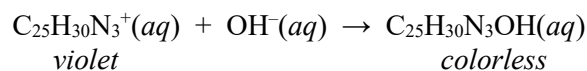
- * (A) Plot $\ln [X]$ versus time and determine the magnitude of the slope.
- (B) Plot $\frac{1}{[X]}$ versus time and determine the magnitude of the slope.
- (C) Run another trial of the experiment with a different initial concentration, plot the data on the same graph, and see where the curves intersect.
- (D) Run another trial of the experiment at a different temperature, plot the data on the same graph, and see where the curves have the same slope.

Topic
5.3 Concentration Changes Over Time

2016 Practice Exam #29

Q: Time needed for 75 percent of $\text{C}_{25}\text{H}_{30}\text{N}_3^+$ to react

Questions X-Y refer to the investigation described below.



The reaction between $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ and $\text{OH}^-(aq)$, as represented above, is first order with respect to $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ in the presence of excess $\text{OH}^-(aq)$. A 10.0 mL sample of 0.10 M $\text{NaOH}(aq)$ is mixed with a 10.0 mL sample of $2.5 \times 10^{-5} \text{ M } \text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$. A 5.0 mL sample of the mixture is quickly transferred to a clean cuvette and placed in a spectrophotometer, and the progress of the reaction is measured. The data are given in the table below.

Time (s)	0	30	60	90	120	150	180	210	240	270	300
Absorbance	0.62	0.54	0.47	0.41	0.36	0.31	0.27	0.23	0.20	0.17	0.15

Approximately how long did it take for 75 percent of the initial amount of $\text{C}_{25}\text{H}_{30}\text{N}_3^+(aq)$ to react?

(A) 75 s

(B) 225 s

* (C) 300 s

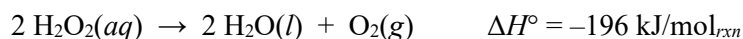
(D) 600 s

Topic
5.3 Concentration Changes Over Time

2015 Practice Exam #27

Q: H₂O₂ decomp - reaction order from conc. vs time

Questions X-Y refer to the following information.



The decomposition of H₂O₂(aq) is represented by the equation above. A student monitored the decomposition of a 1.0 L sample of H₂O₂(aq) at a constant temperature of 300. K and recorded the concentration of H₂O₂ as a function of time. The results are given in the table below.

Time (s)	[H ₂ O ₂]
0	2.7
200.	2.1
400.	1.7
600.	1.4

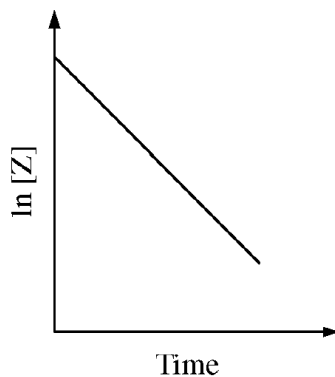
Which of the following statements is a correct interpretation of the data regarding how the order of the reaction can be determined?

- (A) The reaction must be first order because there is only one reactant species.
- * (B) The reaction is first order if the plot of $\ln[\text{H}_2\text{O}_2]$ versus time is a straight line.
- (C) The reaction is first order if the plot of $1/[\text{H}_2\text{O}_2]$ versus time is a straight line.
- (D) The reaction is second order because 2 is the coefficient of H₂O₂ in the chemical equation.

Topic
5.3 Concentration Changes Over Time

2014 Practice Exam #43

Q: Rxn order given linear plot of $\ln(Z)$ vs time



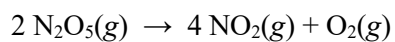
Consider the reaction represented by the equation $2 X + 2 Z \rightarrow X_2Z_2$. During a reaction in which a large excess of reactant X was present, the concentration of reactant Z was monitored over time. A plot of the natural logarithm of the concentration of Z versus time is shown in the figure above. The order of the reaction with respect to reactant Z is

- (A) zero order
- * (B) first order
- (C) second order
- (D) third order

Topic
5.3 Concentration Changes Over Time

2013 Practice Exam #57

Q: N₂O₅ decomposition - rate order from pressure data



A sample of N₂O₅ was placed in an evacuated container, and the reaction represented above occurred. The value of $P_{\text{N}_2\text{O}_5}$, the partial pressure of N₂O₅(g), was measured during the reaction and recorded in the table below.

Time (min)	$P_{\text{N}_2\text{O}_5}$ (atm)	$\ln(P_{\text{N}_2\text{O}_5})$	$\frac{1}{P_{\text{N}_2\text{O}_5}}$ (atm ⁻¹)
0	150	5.0	0.0067
100	75	4.3	0.013
200	38	3.6	0.027
300	19	2.9	0.053

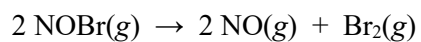
Which of the following correctly describes the reaction?

- (A) The decomposition of N₂O₅ is a zero-order reaction.
- * (B) The decomposition of N₂O₅ is a first-order reaction.
- (C) The decomposition of N₂O₅ is a second-order reaction.
- (D) The overall reaction order is 3.

Topic
5.4 Elementary Reactions

2018 Practice Exam #12

Q: Rate law for elementary step - NOBr



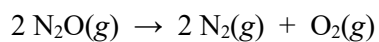
The equation above represents an elementary step in a chemical reaction. Which of the following is the correct expression for the rate law of the elementary step?

- (A) $\text{Rate} = k[\text{NOBr}]^{1/2}$
- (B) $\text{Rate} = k[\text{NOBr}]$
- * (C) $\text{Rate} = k[\text{NOBr}]^2$
- (D) $\text{Rate} = k[\text{NO}]^2[\text{Br}_2]$

Topic
5.5 Collision Model

2022 Practice Exam (from AP Classroom)

Q: Explain why rate increases



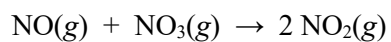
The rate law for the reaction represented above is experimentally determined to be $\text{rate} = k[\text{N}_2\text{O}]$. Which of the following best explains why increasing the initial concentration of $\text{N}_2\text{O}(g)$ at a constant temperature increases the reaction rate?

- * (A) Molecular collisions become more frequent.
- (B) There is a higher probability of effective molecular collisions.
- (C) The rate constant for the reaction increases.
- (D) The reaction mechanism changes to one that has a lower activation energy.

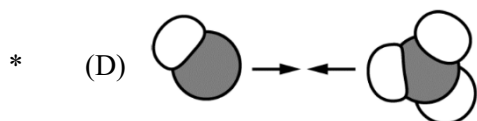
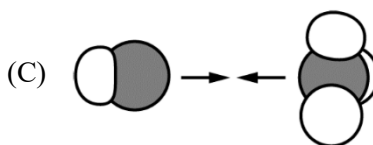
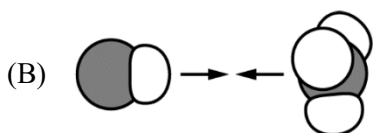
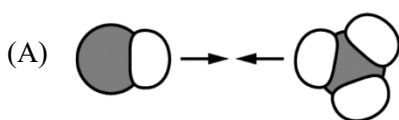
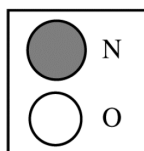
Topic
5.5 Collision Model

2018 Practice Exam #47

Q: Most effective particle collision NO and NO₃



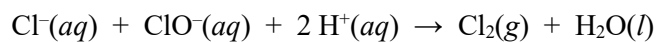
The reaction between NO(g) and NO₃(g) is represented by the equation above. Which of the following orientations of collision between NO(g) and NO₃(g) is most likely to be effective?



Topic
5.5 Collision Model

2017 Practice Exam #29

Q: Effect of increasing H⁺ conc on reaction kinetics



What effect will increasing [H⁺] at constant temperature have on the reaction represented above?

- (A) The activation energy of the reaction will increase.
- (B) The activation energy of the reaction will decrease.
- * (C) The frequency of collisions between H⁺(aq) ions and ClO⁻(aq) ions will increase.
- (D) The value of the rate constant will increase.

Topic
5.5 Collision Model

2016 Practice Exam #2

Q: Explain why rate increases with higher temperature

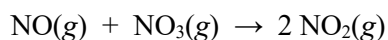
Which of the following best helps explain why an increase in temperature increases the rate of a chemical reaction?

- (A) At higher temperatures, reactions have a lower activation energy.
- (B) At higher temperatures, reactions have a higher activation energy.
- (C) At higher temperatures, every collision results in the formation of product.
- * (D) At higher temperatures, high-energy collisions happen more frequently.

Topic
5.5 Collision Model

2014 Practice Exam #50

Q: Rate for elementary step slower than calculated



$$\text{rate} = k[\text{NO}][\text{NO}_3]$$

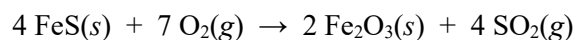
The reaction represented above occurs in a single step that involves the collision between a particle of NO and a particle of NO₃. A scientist correctly calculates the rate of collisions between NO and NO₃ that have sufficient energy to overcome the activation energy. The observed reaction rate is only a small fraction of the calculated collision rate. Which of the following best explains the discrepancy?

- (A) The energy of collisions between two reactant particles is frequently absorbed by collision with a third particle.
- * (B) The two reactant particles must collide with a particular orientation in order to react.
- (C) The activation energy for a reaction is dependent on the concentrations of the reactant particles.
- (D) The activation energy for a reaction is dependent on the temperature.

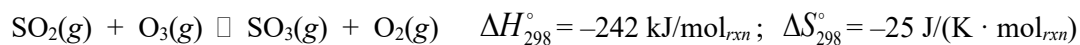
Topic
5.6 Reaction Energy Profile

2021 Practice Exam (from AP Classroom)

Q: Activation energy on graph

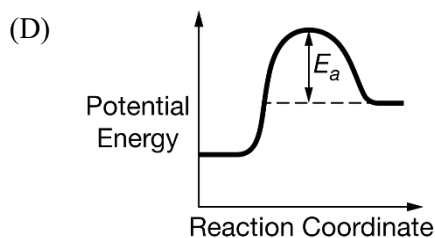
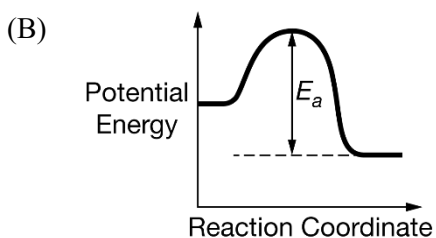
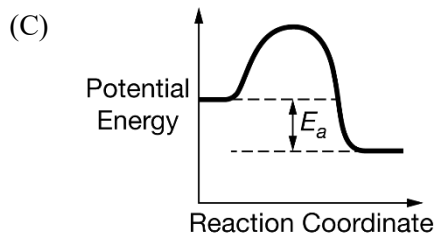
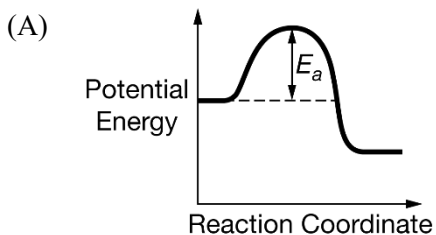


Due to the presence of $\text{FeS}(s)$ as an impurity, the combustion of some types of coal results in the formation of $\text{SO}_2(g)$, as represented by the equation above. Also, $\text{SO}_2(g)$ can react with $\text{O}_3(g)$ to form $\text{SO}_3(g)$, as represented by the equation below.



Which of the following diagrams shows the correctly labeled activation energy, E_a , for the reaction between $\text{SO}_2(g)$ and $\text{O}_3(g)$?

*



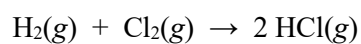
Topic
5.6 Reaction Energy Profile

2016 Practice Exam #40

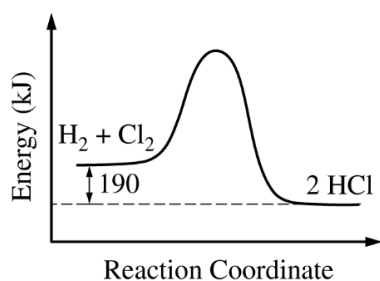
Q: Rxn energy profile for HCl formation - bond energy

Bond	Bond Energy (kJ/mol)
H-H	430
Cl-Cl	240
H-Cl	430

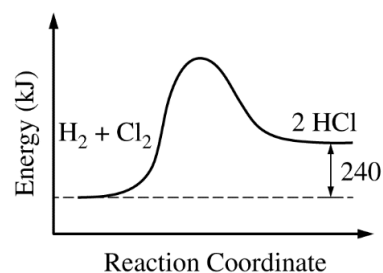
Based on the bond energies shown in the table above, which of the following diagrams best represents the change in energy as the reaction represented below proceeds?



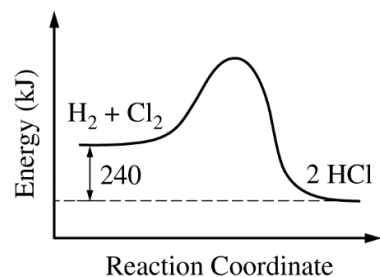
* (A)



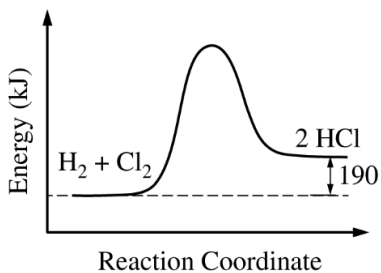
(C)



(B)



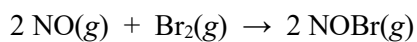
(D)



Topic
5.7 Introduction to Reaction Mechanisms

2023 Practice Exam (from AP Classroom)

Q: Observation to support mechanism



The two mechanisms in the table below have been proposed for the reaction represented above.

Mechanism 1	Mechanism 2
Step 1: $\text{NO}(g) + \text{NO}(g) \rightarrow \text{N}_2\text{O}_2(g)$ <i>slow</i>	Step 1: $\text{NO}(g) + \text{Br}_2(g) \rightarrow \text{NOBr}_2(g)$ <i>slow</i>
Step 2: $\text{N}_2\text{O}_2(g) + \text{Br}_2(g) \rightarrow 2 \text{NOBr}(g)$ <i>fast</i>	Step 2: $\text{NOBr}_2(g) + \text{NO}(g) \rightarrow 2 \text{NOBr}(g)$ <i>fast</i>

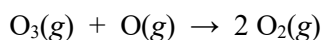
Which of the following observations would support mechanism 1 but not mechanism 2?

- (A) The reaction rate is independent of $[\text{NO}]$.
- * (B) The reaction rate is independent of $[\text{Br}_2]$.
- (C) The reaction is exothermic.
- (D) The reaction is second order overall.

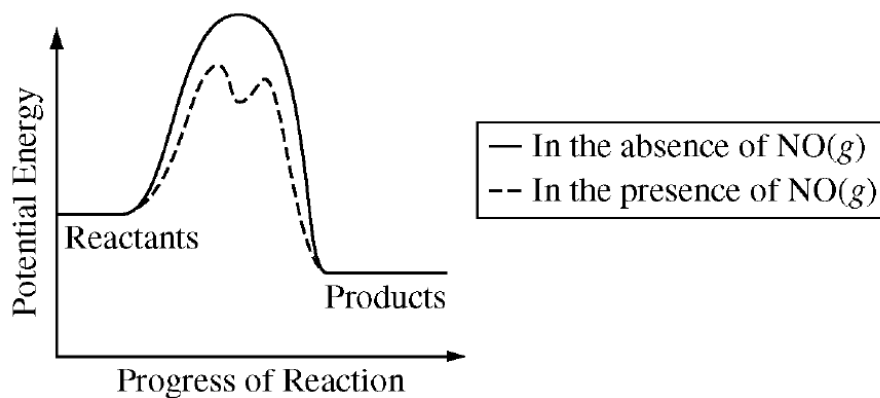
Topic
5.7 Introduction to Reaction Mechanisms

2017 Practice Exam #32

Q: Mechanism consistent with rxn energy profile of O₃



The decomposition of O₃(g) in the upper atmosphere is represented by the equation above. The potential energy diagram for the decomposition of O₃(g) in the presence and absence of NO(g) is given below.



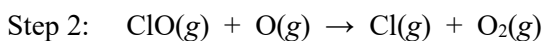
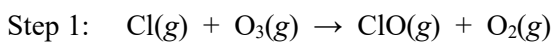
Which of the following mechanisms for the catalyzed reaction is consistent with the equation and diagram above?

- (A) $2 \text{O}_3(\text{g}) + 2 \text{NO}(\text{g}) \rightarrow 4 \text{O}_2(\text{g}) + \text{N}_2(\text{g})$ *slow*
- * (B) $\text{O}_3(\text{g}) + \text{NO}(\text{g}) \rightarrow \text{NO}_2(\text{g}) + \text{O}_2(\text{g})$ *slow*
 $\text{NO}_2(\text{g}) + \text{O}(\text{g}) \rightarrow \text{NO}(\text{g}) + \text{O}_2(\text{g})$ *fast*
- (C) $\text{NO}_2(\text{g}) + \text{O}_3(\text{g}) \rightarrow \text{NO}(\text{g}) + 2 \text{O}_2(\text{g})$ *slow*
 $\text{NO}(\text{g}) + \text{O}(\text{g}) \rightarrow \text{NO}_2(\text{g})$ *fast*
- (D) $\text{NO}_2(\text{g}) + \text{O}(\text{g}) \rightarrow \text{NO}_3(\text{g})$ *slow*
 $\text{NO}_3(\text{g}) + \text{O}_3(\text{g}) \rightarrow \text{NO}_2(\text{g}) + 2 \text{O}_2(\text{g})$ *fast*

Topic
5.7 Introduction to Reaction Mechanisms

2013 Practice Exam #53

Q: Evidence for mechanism of ozone destruction



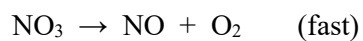
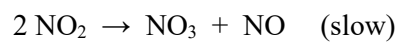
A proposed mechanism for destruction of ozone gas in the stratosphere is represented above. Which of the following is evidence that the mechanism is occurring?

- * (A) The presence of Cl(g) increases the rate of the overall reaction.
- (B) The presence of Cl(g) decreases the rate of the overall reaction.
- (C) The presence of Cl(g) increases the equilibrium constant of the overall reaction.
- (D) The presence of Cl(g) decreases the equilibrium constant of the overall reaction.

Topic
5.8 Reaction Mechanism and Rate Law

2022 Practice Exam (from AP Classroom)

Q: Rate law from mechanism



A proposed two-step mechanism for the reaction $2 \text{NO}_2 \rightarrow 2 \text{NO} + \text{O}_2$ is represented. Which of the following rate laws is consistent with the mechanism?

(A) $\text{rate} = k[\text{NO}_2]$

* (B) $\text{rate} = k[\text{NO}_2]^2$

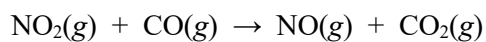
(C) $\text{rate} = k[\text{NO}_2]^2[\text{NO}_3]$

(D) $\text{rate} = k \frac{[\text{NO}]^2[\text{O}_2]}{[\text{NO}_2]^2}$

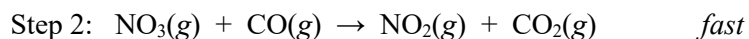
Topic
5.8 Reaction Mechanism and Rate Law

2017 Practice Exam #28

Q: NO₂ + CO - rate law consistent with mechanism



The reaction between NO₂(g) and CO(g) is represented above. The elementary steps of a proposed reaction mechanism are represented below.



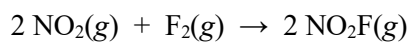
Which of the following is the rate law for the overall reaction that is consistent with the proposed mechanism?

- (A) Rate = $k [\text{NO}_2][\text{CO}]$
- * (B) Rate = $k [\text{NO}_2]^2$
- (C) Rate = $k [\text{NO}_3][\text{CO}]$
- (D) Rate = $k [\text{NO}_2][\text{NO}_3][\text{CO}]$

Topic
5.8 Reaction Mechanism and Rate Law

2016 Practice Exam #26

Q: Identify slow first elementary step given rate law



The rate law for the reaction represented by the equation above is $\text{rate} = k [\text{NO}_2][\text{F}_2]$. Which of the following could be the first elementary step of a two-step mechanism for the reaction if the first step is slow and the second step is fast?

- (A) $\text{F}_2(g) \rightarrow 2 \text{F}(g)$
- * (B) $\text{NO}_2(g) + \text{F}_2(g) \rightarrow \text{NO}_2\text{F}(g) + \text{F}(g)$
- (C) $\text{NO}_2(g) + \text{F}(g) \rightarrow \text{NO}_2\text{F}(g)$
- (D) $2 \text{NO}_2(g) + \text{F}_2(g) \rightarrow 2 \text{NO}_2\text{F}(g)$

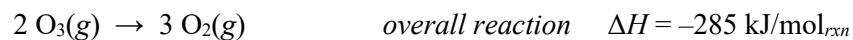
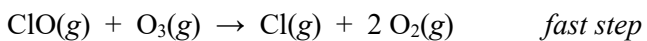
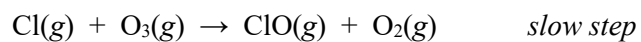
Topic
5.8 Reaction Mechanism and Rate Law

2015 Practice Exam #42

Q: Cl + O₃ mechanism - overall rate law

Questions X-Y refer to the following information.

When free Cl(g) atoms encounter O₃(g) molecules in the upper atmosphere, the following reaction mechanism is proposed to occur.



Which of the following rate laws for the overall reaction corresponds to the proposed mechanism?

(A) $\text{Rate} = k[\text{O}_3]^2$

* (B) $\text{Rate} = k[\text{Cl}][\text{O}_3]$

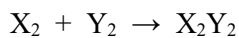
(C) $\text{Rate} = k[\text{ClO}][\text{O}_3]^2$

(D) $\text{Rate} = k \frac{[\text{O}_2]^3}{[\text{O}_3]^2}$

Topic
5.8 Reaction Mechanism and Rate Law

2014 Practice Exam #28

Q: 2 mechanisms - which is consistent with rate law



$$\text{rate} = k[\text{X}_2]$$

A reaction and its experimentally determined rate law are represented above. A chemist proposes two different possible mechanisms for the reaction, which are given below.

<u>Mechanism 1</u>		<u>Mechanism 2</u>	
$\text{X}_2 \rightarrow 2 \text{X}$	(<i>slow</i>)	$\text{X}_2 \rightarrow 2 \text{X}$	(<i>slow</i>)
$\text{X} + \text{Y}_2 \rightarrow \text{XY}_2$	(<i>fast</i>)	$\text{X} + \text{Y}_2 \rightarrow \text{XY} + \text{Y}$	(<i>fast</i>)
$\text{X} + \text{XY}_2 \rightarrow \text{X}_2\text{Y}_2$	(<i>fast</i>)	$\text{X} + \text{XY} \rightarrow \text{X}_2\text{Y}$	(<i>fast</i>)
		$\text{X}_2\text{Y} + \text{Y} \rightarrow \text{X}_2\text{Y}_2$	(<i>fast</i>)

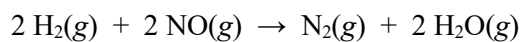
Based on the information above, which of the following is true?

- (A) Only mechanism 1 is consistent with the rate law.
- (B) Only mechanism 2 is consistent with the rate law.
- * (C) Both mechanism 1 and mechanism 2 are consistent with the rate law.
- (D) Neither mechanism 1 nor mechanism 2 is consistent with the rate law.

Topic
5.9 Pre-Equilibrium Approximation

2021 Practice Exam (from AP Classroom)

Q: Mechanism consistent with rate law



The experimental rate law for the reaction represented above is $\text{rate} = k[\text{H}_2][\text{NO}]^2$. Which of the following proposed mechanisms is consistent with the rate law?

- (A) Step 1: $2 \text{NO} \rightarrow \text{N}_2\text{O}_2$ *fast*
 Step 2: $\text{H}_2 + \text{N}_2\text{O}_2 \rightleftharpoons \text{N}_2\text{O} + \text{H}_2\text{O}$ *fast*
 Step 3: $\text{H}_2 + \text{N}_2\text{O} \rightarrow \text{N}_2 + \text{H}_2\text{O}$ *slow*

- * (B) Step 1: $2 \text{NO} \rightleftharpoons \text{N}_2\text{O}_2$ *fast*
 Step 2: $\text{H}_2 + \text{N}_2\text{O}_2 \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O}$ *slow*
 Step 3: $\text{H}_2 + \text{N}_2\text{O} \rightarrow \text{N}_2 + \text{H}_2\text{O}$ *fast*

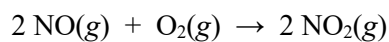
- (C) Step 1: $2 \text{NO} \rightarrow \text{N}_2 + \text{O}_2$ *slow*
 Step 2: $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}_2$ *fast*
 Step 3: $\text{H}_2 + \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O}$ *fast*

- (D) Step 1: $2 \text{NO} \rightarrow \text{N}_2 + \text{O}_2$ *fast*
 Step 2: $\text{H}_2 + \text{O}_2 \rightleftharpoons \text{H}_2\text{O}_2$ *fast*
 Step 3: $\text{H}_2 + \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O}$ *slow*

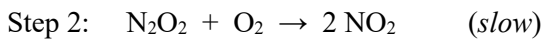
Topic
5.9 Pre-Equilibrium Approximation

2013 Practice Exam #24

Q: Given mechanism for NO₂ - which statement is true



Consider the following mechanism for the reaction represented above.



Which of the following statements is true?

- (A) Step 1 represents a unimolecular reaction.
- (B) Increasing the concentration of NO will decrease the overall rate of the reaction.
- (C) Raising the temperature will have no effect on the numerical value of the rate constant.
- * (D) The rate law that is consistent with the mechanism is $rate = k[\text{NO}]^2[\text{O}_2]$.

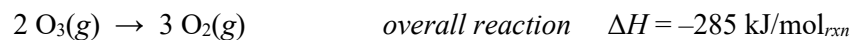
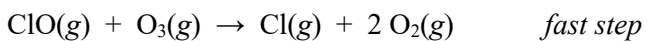
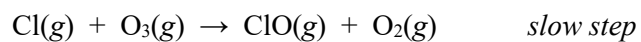
Topic
5.10 Multistep Reaction Energy Profile

2015 Practice Exam #43

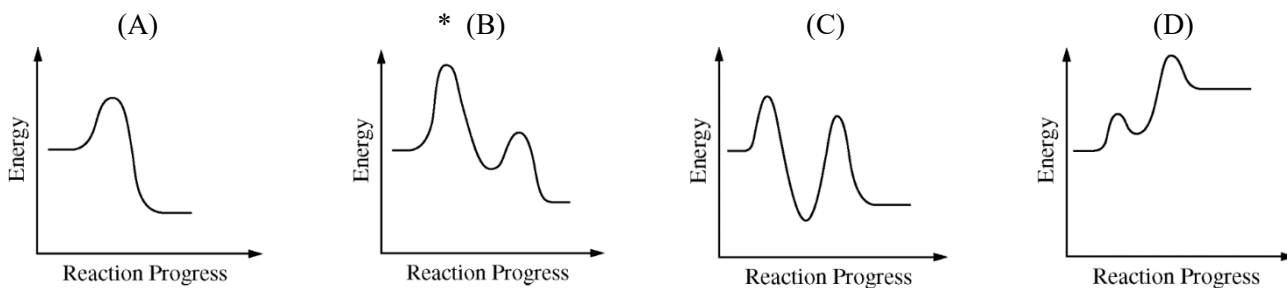
Q: Cl + O₃ mechanism - reaction energy profile

Questions X-Y refer to the following information.

When free Cl(g) atoms encounter O₃(g) molecules in the upper atmosphere, the following reaction mechanism is proposed to occur.



Which of the following reaction energy profiles best corresponds to the proposed mechanism?

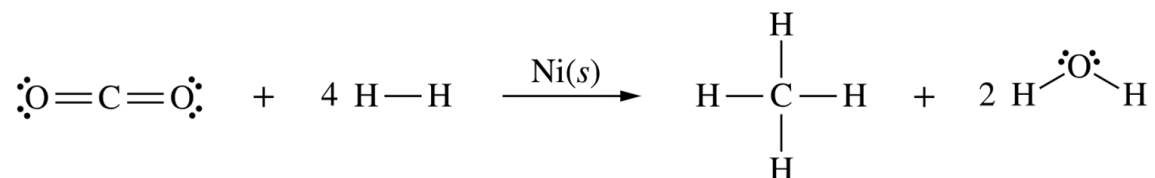


Topic
5.11 Catalysis

2023 Practice Exam (from AP Classroom)

Q: Effect of Ni catalyst

In the gas-phase reaction represented by the following equation, methane (CH₄) and water (H₂O) are produced from carbon dioxide (CO₂) and hydrogen (H₂) at high temperature and pressure.



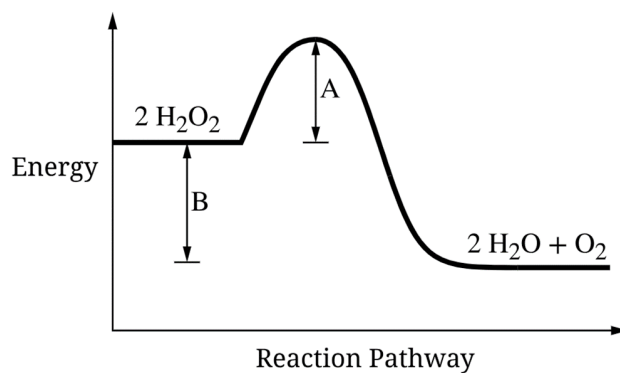
The reaction is catalyzed by solid nickel. Which of the following describes the effect of the catalyst on the reaction?

- (A) The presence of the catalyst results in an overall reaction that releases less energy.
- * (B) The presence of the catalyst results in a reaction pathway that requires a lower activation energy.
- (C) The presence of the catalyst results in an overall reaction that requires more energy.
- (D) The presence of the catalyst results in a reaction pathway that requires a greater activation energy.

Topic
5.11 Catalysis

2023 Practice Exam (from AP Classroom)

Q: Energy diagram with catalyst



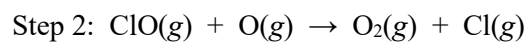
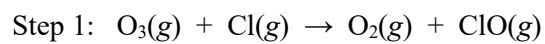
The potential energy diagram for the uncatalyzed decomposition of $\text{H}_2\text{O}_2(l)$ is shown above. The arrows labeled A and B represent different amounts of energy. When $\text{I}^-(aq)$ is used as a catalyst, how do the magnitudes of A and B in the new reaction energy diagram compare to the uncatalyzed diagram shown above?

	Energy A	Energy B
(A)	Larger	Larger
(B)	Smaller	Smaller
* (C)	Smaller	Unchanged
(D)	Unchanged	Smaller

Topic
5.11 Catalysis

2022 Practice Exam (from AP Classroom)

Q: Catalyst in mechanism



A proposed mechanism for the destruction of $\text{O}_3(g)$ in the upper atmosphere is represented above. Which of the following is the catalyst in the proposed mechanism?

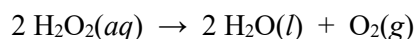
- (A) $\text{O}(g)$
- * (B) $\text{Cl}(g)$
- (C) $\text{ClO}(g)$
- (D) $\text{O}_2(g)$

Topic
5.11 Catalysis

2022 Practice Exam (from AP Classroom)

Q: Reason for slower rate

The following balanced equation represents the decomposition of hydrogen peroxide, H_2O_2 .



A student carries out an experiment in which a sample of $\text{H}_2\text{O}_2(aq)$ decomposes in the presence of $\text{MnO}_2(s)$. The student measures the volume of $\text{O}_2(g)$ produced by the reaction at regular intervals while the temperature is held constant. The student's data are given in the following table.

Time (s)	Volume of $\text{O}_2(g)$ Collected (mL)
0	0
60	42
120	64
180	76
240	82
300	86
360	88
420	89

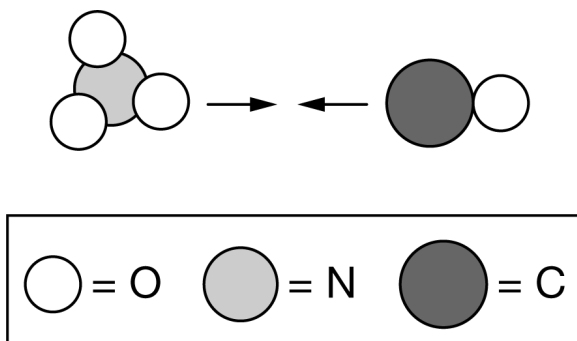
The student observes that under the same conditions, the reaction occurs at a much slower rate when $\text{MnO}_2(s)$ is not used. Which of the following statements best explains this observation?

- (A) $\text{MnO}_2(s)$ changes the reaction from endothermic to exothermic.
- (B) $\text{MnO}_2(s)$ shifts the equilibrium position of the reaction from reactant favored to product favored.
- (C) $\text{MnO}_2(s)$ releases heat in order to start the reaction.
- * (D) $\text{MnO}_2(s)$ provides a reaction pathway with a lower activation energy.

Topic
5.11 Catalysis

2021 Practice Exam (from AP Classroom)

Q: How catalyst increases reaction rate



The slowest step in a reaction mechanism requires the collision represented above to occur. Which of the following most likely indicates how the addition of a solid catalyst could increase the rate of the reaction?

- (A) The catalyst could change the reaction from second order to third order.
- (B) The catalyst could increase the particles' speed, thereby increasing the value of the rate constant, k .
- (C) The catalyst could decrease the particles' speed, making it less likely that the particles will rebound without reacting when they collide.
- * (D) The catalyst could adsorb one of the particles, making a successful (reaction-producing) collision with the other particle more likely.

Topic
5.11 Catalysis

2019 Practice Exam #8

Q: Mechanism of enzyme catalyst

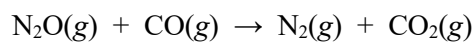
To catalyze a biochemical reaction, an enzyme typically

- (A) drives the reaction to completion by consuming byproducts of the reaction
- * (B) binds temporarily to reactant molecules to lower the activation energy of the reaction
- (C) dissociates into additional reactant molecules, thereby increasing the reaction rate
- (D) decomposes and releases energy to increase the number of successful collisions between reactant molecules

Topic
5.11 Catalysis

2018 Practice Exam #48

Q: N₂O and CO rxn rate increases in presence of Pd



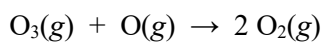
The rate of the reaction represented above increases significantly in the presence of Pd(s). Which of the following best explains this observation?

- (A) Pd increases the activation energy of the reaction.
- (B) Pd absorbs the heat produced in the reaction.
- * (C) One of the reactants binds on the surface of Pd, which introduces an alternative reaction pathway with a lower activation energy.
- (D) One of the products binds on the surface of Pd, which increases the reaction rate by decreasing the concentration of products in the mixture.

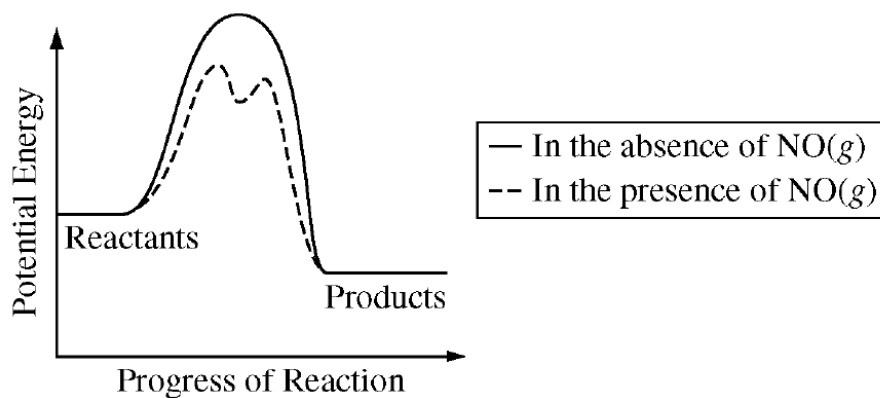
Topic
5.11 Catalysis

2017 Practice Exam #32

Q: Mechanism consistent with rxn energy profile of O₃



The decomposition of O₃(g) in the upper atmosphere is represented by the equation above. The potential energy diagram for the decomposition of O₃(g) in the presence and absence of NO(g) is given below.



Which of the following mechanisms for the catalyzed reaction is consistent with the equation and diagram above?

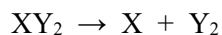
- (A) $2 \text{O}_3(\text{g}) + 2 \text{NO}(\text{g}) \rightarrow 4 \text{O}_2(\text{g}) + \text{N}_2(\text{g})$ *slow*
- * (B) $\text{O}_3(\text{g}) + \text{NO}(\text{g}) \rightarrow \text{NO}_2(\text{g}) + \text{O}_2(\text{g})$ *slow*
 $\text{NO}_2(\text{g}) + \text{O}(\text{g}) \rightarrow \text{NO}(\text{g}) + \text{O}_2(\text{g})$ *fast*
- (C) $\text{NO}_2(\text{g}) + \text{O}_3(\text{g}) \rightarrow \text{NO}(\text{g}) + 2 \text{O}_2(\text{g})$ *slow*
 $\text{NO}(\text{g}) + \text{O}(\text{g}) \rightarrow \text{NO}_2(\text{g})$ *fast*
- (D) $\text{NO}_2(\text{g}) + \text{O}(\text{g}) \rightarrow \text{NO}_3(\text{g})$ *slow*
 $\text{NO}_3(\text{g}) + \text{O}_3(\text{g}) \rightarrow \text{NO}_2(\text{g}) + 2 \text{O}_2(\text{g})$ *fast*

Topic
5.11 Catalysis

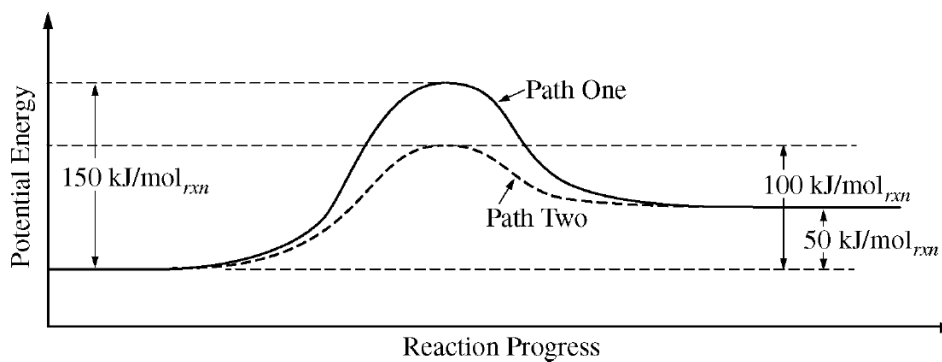
2014 Practice Exam #44

Q: Rxn energy profile - account for lower Path 2

Questions X-Y relate to the following information.



The equation above represents the decomposition of a compound XY_2 . The diagram below shows two reaction profiles (path one and path two) for the decomposition of XY_2 .



Which of the following most likely accounts for the difference between reaction path one and reaction path two?

- (A) A higher temperature in path one
- (B) A higher temperature in path two
- (C) The presence of a catalyst in path one
- * (D) The presence of a catalyst in path two

Topic
6.1 Endothermic and Exothermic Processes

2021 Practice Exam (from AP Classroom)

Q: Observations from mixing liquids

Compound	Structure	Boiling Point (°C)
Methanol	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	65
Ethanol	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	78
Propanal	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{:O:} \\ \quad \quad // \\ \text{H}-\text{C}-\text{C}-\text{C} \\ \quad \quad \backslash \\ \text{H} \quad \text{H} \quad \text{H} \end{array} $	49
Hexane	$ \begin{array}{cccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $	69

When a 50. mL sample of $\text{C}_2\text{H}_5\text{OH}$ is mixed with a 50. mL sample of H_2O , the resulting mixture has a volume of 95 mL, and the container is warm to the touch. Which of the following best describes these observations?

- (A) A chemical reaction occurs, as evidenced by the volume of the resultant mixture being less than the total volume of the initial components.
- (B) A chemical change occurs, as evidenced by the formation of new covalent bonds, releasing more energy than is absorbed by the breaking of the existing covalent bonds.

- * (C) A physical change occurs, and the solvation process is exothermic.
- (D) A physical change occurs, and the solvation process is endothermic.

Topic
6.1 Endothermic and Exothermic Processes

2014 Practice Exam #5

Q: Why enthalpy of dissolution is positive for CaF_2

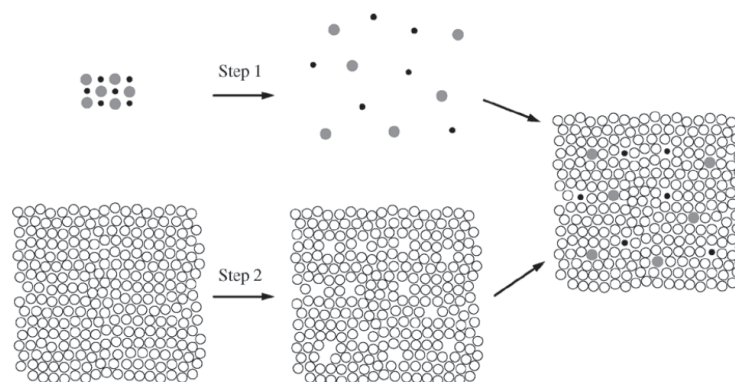
Which of the following best helps to explain why the value of ΔH° for the dissolving of CaF_2 in water is positive?

- (A) $\text{CaF}_2(s)$ is insoluble in water.
- (B) $\text{CaF}_2(s)$ dissolves in water to form $\text{CaF}_2(aq)$ particles.
- * (C) Ca^{2+} ions have very strong ion-ion interactions with F^- ions in the crystal lattice.
- (D) Ca^{2+} ions have very strong ion-dipole interactions with water molecules in the solution.

Topic
6.1 Endothermic and Exothermic Processes

2013 Practice Exam #27

Q: Energy changes - ionic solute dissolution in H₂O



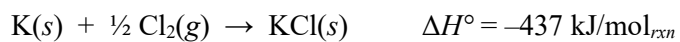
The dissolution of an ionic solute in a polar solvent can be imagined as occurring in three steps, as shown in the figure above. In step 1, the separation between ions in the solute is greatly increased, just as will occur when the solute dissolves in the polar solvent. In step 2, the polar solvent is expanded to make spaces that the ions will occupy. In the last step, the ions are inserted into the spaces in the polar solvent. Which of the following best describes the enthalpy change, ΔH , for each step?

- (A) All three steps are exothermic.
- (B) All three steps are endothermic.
- (C) Steps 1 and 2 are exothermic, and the final step is endothermic.
- * (D) Steps 1 and 2 are endothermic, and the final step is exothermic.

Topic
6.1 Endothermic and Exothermic Processes

2013 Practice Exam #36

Q: KCl enthalpy - which processes are exothermic



The elements K and Cl react directly to form the compound KCl according to the equation above. Refer to the information above and the table below to answer the questions that follow.

Process	ΔH° (kJ/mol _{rxn})
$\text{K}(s) \rightarrow \text{K}(g)$	v
$\text{K}(g) \rightarrow \text{K}^+(g) + e^-$	w
$\text{Cl}_2(g) \rightarrow 2 \text{Cl}(g)$	x
$\text{Cl}(g) + e^- \rightarrow \text{Cl}^-(g)$	y
$\text{K}^+(g) + \text{Cl}^-(g) \rightarrow \text{KCl}(s)$	z

Which of the values of ΔH° for a process in the table is (are) less than zero (i.e., indicate(s) an exothermic process) ?

(A) z only

* (B) y and z only

(C) x, y , and z only

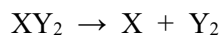
(D) w, x, y , and z

Topic
6.2 Energy Diagrams

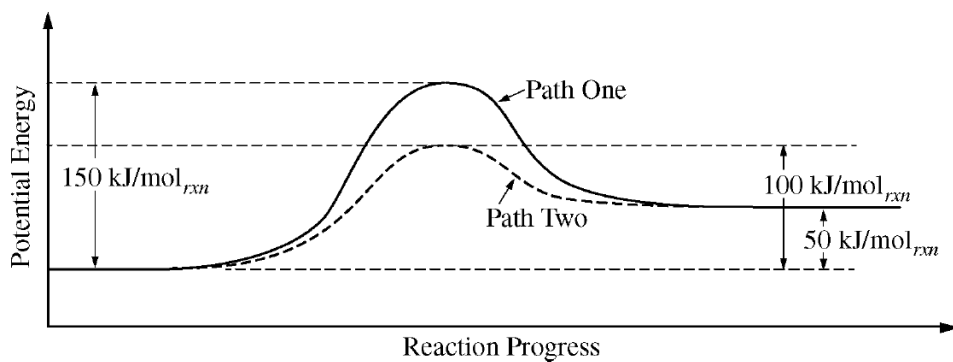
2014 Practice Exam #45

Q: Rxn energy profile - heat flow if 1 mol XY₂ reacts

Questions X-Y relate to the following information.



The equation above represents the decomposition of a compound XY₂. The diagram below shows two reaction profiles (path one and path two) for the decomposition of XY₂.



Which of the following best describes the flow of heat when 1.0 mol of XY₂ decomposes?

- (A) 50 kJ of heat is transferred to the surroundings.
- * (B) 50 kJ of heat is transferred from the surroundings.
- (C) 100 kJ of heat is transferred to the surroundings.
- (D) 100 kJ of heat is transferred from the surroundings.

Topic
6.3 Heat Transfer and Thermal Equilibrium

2021 Practice Exam (from AP Classroom)

Q: Energy transfer

A 30. g sample of $\text{Al}(s)$ is heated to 50°C and placed in a calorimeter containing 150 g of water at 20°C . As the system approaches thermal equilibrium, energy is transferred

- (A) from the $\text{Al}(s)$ to the water and the temperature of the water decreases
- * (B) from the $\text{Al}(s)$ to the water and the temperature of the $\text{Al}(s)$ decreases
- (C) from the water to the $\text{Al}(s)$ and the temperature of the water increases
- (D) from the water to the $\text{Al}(s)$ and the temperature of the $\text{Al}(s)$ increases

Topic
6.3 Heat Transfer and Thermal Equilibrium

2019 Practice Exam #30

Q: Change in KE and speed of Xe atoms with higher T

A 1.0 mol sample of He(g) at 25°C is mixed with a 1.0 mol sample of Xe(g) at 50°C. Which of the following correctly predicts the changes in average kinetic energy and the average speed of the Xe(g) atoms that will occur as the mixture approaches thermal equilibrium?

	Average Kinetic Energy of Xe Atoms	Average Speed of Xe Atoms
(A)	Will increase	Will increase
(B)	Will increase	Will decrease
(C)	Will decrease	Will increase
* (D)	Will decrease	Will decrease

Topic
6.3 Heat Transfer and Thermal Equilibrium

2013 Practice Exam #9

Q: Energy change when heated metal is added to water

A 100 g sample of a metal was heated to 100°C and then quickly transferred to an insulated container holding 100 g of water at 22°C. The temperature of the water rose to reach a final temperature of 35°C. Which of the following can be concluded?

- (A) The metal temperature changed more than the water temperature did; therefore the metal lost more thermal energy than the water gained.
- * (B) The metal temperature changed more than the water temperature did, but the metal lost the same amount of thermal energy as the water gained.
- (C) The metal temperature changed more than the water temperature did; therefore the heat capacity of the metal must be greater than the heat capacity of the water.
- (D) The final temperature is less than the average starting temperature of the metal and the water; therefore the total energy of the metal and water decreased.

Topic
6.4 Heat Capacity and Calorimetry

2023 Practice Exam (from AP Classroom)

Q: Heat capacities of liquids

Substance	Specific Heat (J/(g·°C))
Water	4.18
Ethanol	2.44
Fe(s)	0.449

Two identical insulated containers hold equal masses of liquid at the same temperature; one contains water and the other contains ethanol. Two identical cubes of Fe(s) are heated to the same temperature, one cube is placed in each container, and both systems are allowed to reach thermal equilibrium. Based on the information in the table shown, which of the following best predicts what will be observed?

- (A) Both systems will have the same final temperature because the mass and initial temperature of the liquids are the same.
- (B) Both systems will have the same final temperature because the Fe(s) cubes will transfer the same amount of heat to both liquids.
- * (C) The ethanol system will have the higher final temperature because the specific heat of ethanol is lower than that of water.
- (D) The ethanol system will have the lower final temperature because the specific heat of ethanol is lower than that of water.

Topic
6.4 Heat Capacity and Calorimetry

2022 Practice Exam (from AP Classroom)

Q: Adding thermal energy to samples

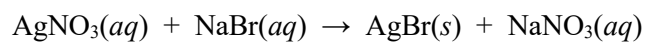
A quantity of 10,000 J of thermal energy is transferred to four different substances. In which of the following experiments could the greatest mass of the given substance undergo the indicated change?

- (A) Melting ice at 0°C to form liquid water at 0°C ($\Delta H_{\text{fus}} = 330 \text{ J/g}$)
- (B) Boiling liquid acetone at 56°C to form acetone vapor at 56°C ($\Delta H_{\text{vap}} = 540 \text{ J/g}$)
- (C) Increasing the temperature of liquid glycerin from 20°C to 120°C (Specific heat = $2.4 \text{ J/(g}\cdot\text{°C)}$)
- * (D) Increasing the temperature of solid copper from 0°C to 200°C (Specific heat = $0.40 \text{ J/(g}\cdot\text{°C)}$)

Topic
6.4 Heat Capacity and Calorimetry

2022 Practice Exam (from AP Classroom)

Q: Calorimetry precipitation



A 10.0 mL sample of 1.0 *M* AgNO₃(aq) and a 10.0 mL sample of 1.0 *M* NaBr(aq), both originally at 25°C, are combined in a constant-pressure calorimeter where the reaction represented above occurs. If the final temperature of the mixture is 35°C, what is the value of ΔH for the reaction? (Assume that the heat absorbed by the calorimeter is negligible, that the total mass of the mixture is 20.0 g, and that the specific heat capacity of the mixture is 4.2 J/(g·°C).)

- * (A) −84,000 J/mol_{rxn}
- (B) −84 J/mol_{rxn}
- (C) +84 J/mol_{rxn}
- (D) +84,000 J/mol_{rxn}

Topic
6.4 Heat Capacity and Calorimetry

2021 Practice Exam (from AP Classroom)

Q: Observations from mixing liquids

Compound	Structure	Boiling Point (°C)
Methanol	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	65
Ethanol	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	78
Propanal	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{:O:} \\ \quad \quad // \\ \text{H}-\text{C}-\text{C}-\text{C} \\ \quad \quad \backslash \\ \text{H} \quad \text{H} \quad \text{H} \end{array} $	49
Hexane	$ \begin{array}{cccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $	69

When a 50. mL sample of $\text{C}_2\text{H}_5\text{OH}$ is mixed with a 50. mL sample of H_2O , the resulting mixture has a volume of 95 mL, and the container is warm to the touch. Which of the following best describes these observations?

- (A) A chemical reaction occurs, as evidenced by the volume of the resultant mixture being less than the total volume of the initial components.
- (B) A chemical change occurs, as evidenced by the formation of new covalent bonds, releasing more energy than is absorbed by the breaking of the existing covalent bonds.

- * (C) A physical change occurs, and the solvation process is exothermic.
- (D) A physical change occurs, and the solvation process is endothermic.

Topic
6.4 Heat Capacity and Calorimetry

2021 Practice Exam (from AP Classroom)

Q: Change in KE for Fe and Al

Substance	Specific Heat (J/(g·°C))	Mass of Sample (g)
Fe(s)	0.46	1.0
Al(s)	0.91	1.0

Samples of Fe and Al are heated from 25°C to 75°C. Based on the information in the table above, the change in the average kinetic energy of the atoms in the samples is

- (A) higher for the Fe sample, because with its lower specific heat it absorbs more energy
- (B) higher for the Al sample, because with its higher specific heat it absorbs more energy
- * (C) the same for both metal samples, because the initial and final temperatures are the same
- (D) the same for both metal samples, because the masses are equal

Topic
6.4 Heat Capacity and Calorimetry

2021 Practice Exam (from AP Classroom)

Q: Information to calculate enthalpy change

In an experiment to estimate the enthalpy change of a reaction, a student makes two aqueous solutions, each containing one of the reactants. The student combines the solutions, both originally at the same temperature, in a calorimeter and records the final temperature of the mixture. In addition to the masses of the solutions and the temperature change of the mixture, which of the following pieces of information does the student need to calculate the enthalpy change of the reaction?

- (A) The density of the reaction mixture
- * (B) The specific heat capacity of the reaction mixture
- (C) The boiling point of the reaction mixture
- (D) The heat of fusion of the reaction mixture

Topic
6.4 Heat Capacity and Calorimetry

2019 Practice Exam #46

Q: Data needed to determine molar enthalpy of soln

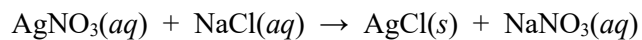
Which of the following is a list of the minimum amount of data needed for determining the molar enthalpy of solution of $\text{KCl}(s)$ in pure $\text{H}_2\text{O}(l)$? (Assume that the $\text{KCl}(aq)$ has the same specific heat capacity as pure water and that the initial temperatures of the $\text{KCl}(s)$ and the water are the same.)

- (A) Mass of $\text{KCl}(s)$, initial temperature of the water, and final temperature of the solution
- (B) Mass of H_2O , initial temperature of the water, and final temperature of the solution
- * (C) Mass of $\text{KCl}(s)$, mass of H_2O , initial temperature of the water, and final temperature of the solution
- (D) Mass of $\text{KCl}(s)$, mass of H_2O , initial temperature of the water, final temperature of the solution, and atmospheric pressure

Topic
6.4 Heat Capacity and Calorimetry

2018 Practice Exam #21

Q: Enthalpy change for precipitation of AgCl



In an experiment a student mixes a 50.0 mL sample of 0.100 *M* AgNO₃(*aq*) with a 50.0 mL sample of 0.100 *M* NaCl(*aq*) at 20.0°C in a coffee-cup calorimeter. Which of the following is the enthalpy change of the precipitation reaction represented above if the final temperature of the mixture is 21.0°C? (Assume that the total mass of the mixture is 100. g and that the specific heat capacity of the mixture is 4.2 J/(g·°C).)

- * (A) −84 kJ/mol_{rxn}
- (B) −0.42 kJ/mol_{rxn}
- (C) 0.42 kJ/mol_{rxn}
- (D) 84 kJ/mol_{rxn}

Topic
6.4 Heat Capacity and Calorimetry

2018 Practice Exam #50

Q: Heat transfer when hot Fe is added to water

A 50.0 g sample of Fe at 100°C is added to 500.0 mL of water at 35°C in a perfectly insulated container. Which of the following statements is true?

- (A) The temperature of the water will decrease.
- (B) The temperature change of the Fe will have the same magnitude as the temperature change of the water.
- (C) The heat energy lost by the Fe will be less than the heat energy gained by the water.
- * (D) The heat energy lost by the Fe will be equal to the heat energy gained by the water.

Topic
6.4 Heat Capacity and Calorimetry

2017 Practice Exam #40

Q: Final T when NH_4ClO_4 is added to 10x more water

When 5.0 g of $\text{NH}_4\text{ClO}_4(s)$ is added to 100. mL of water in a calorimeter, the temperature of the solution formed decreases by 3.0°C . If 5.0 g of $\text{NH}_4\text{ClO}_4(s)$ is added to 1000. mL of water in a calorimeter initially at 25°C , the final temperature of the solution will be approximately

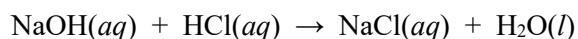
- (A) 22.0°C
- * (B) 24.7°C
- (C) 25.3°C
- (D) 28.0°C

Topic
6.4 Heat Capacity and Calorimetry

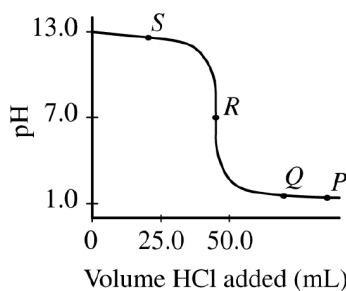
2016 Practice Exam #24

Q: NaOH-HCl titration curve - heat released double mL

Questions X-Y refer to the following information.



To determine the concentration of a $\text{NaOH}(aq)$ solution, a student titrated a 50. mL sample with 0.10 M $\text{HCl}(aq)$. The reaction is represented by the equation above. The titration is monitored using a pH meter, and the experimental results are plotted in the graph below.



Trial	Volume of 0.10 M HCl	Volume of 0.10 M NaOH	Amount of Heat Released
1	50. mL	50. mL	X
2	100. mL	50. mL	Y

A student conducted an experiment to determine $\Delta H_{\text{rxn}}^\circ$ for the reaction between $\text{HCl}(aq)$ and $\text{NaOH}(aq)$. The student ran two trials using the volumes of $\text{HCl}(aq)$ and $\text{NaOH}(aq)$ indicated in the table above, and determined the amount of heat released. Which of the following best explains the relationship between X and Y?

(A) $Y = 2X$, because the volume of $\text{HCl}(aq)$ used in trial 2 is twice the volume used in trial 1.

* (B) $Y = X$, because the number of moles of acid and base reacting with each other is the same in both trials.

(C) $Y = \frac{2X}{3}$, because the heat is distributed over more particles in trial 2 than in trial 1.

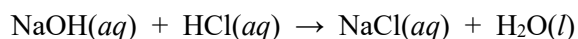
(D) The relationship between X and Y cannot be predicted.

Topic
6.4 Heat Capacity and Calorimetry

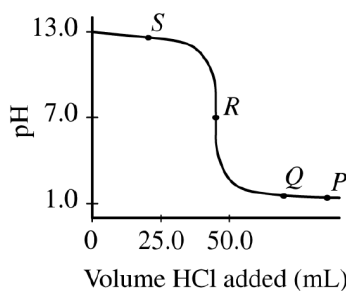
2016 Practice Exam #25

Q: NaOH-HCl titration curve - enthalpy change value

Questions X-Y refer to the following information.



To determine the concentration of a $\text{NaOH}(aq)$ solution, a student titrated a 50. mL sample with 0.10 M $\text{HCl}(aq)$. The reaction is represented by the equation above. The titration is monitored using a pH meter, and the experimental results are plotted in the graph below.



A student mixes a 10.0 mL sample of 1.0 M $\text{NaOH}(aq)$ with a 10.0 mL sample of 1.0 M $\text{HCl}(aq)$ in a polystyrene container. The temperature of the solutions before mixing was 20.0°C. If the final temperature of the mixture is 26.0°C, what is the experimental value of ΔH_{rxn}° ? (Assume that the solution mixture has a specific heat of 4.2 J/(g·K) and a density of 1.0 g/mL.)

- * (A) $-50. \text{ kJ/mol}_{rxn}$
- (B) -25 kJ/mol_{rxn}
- (C) $-5.0 \times 10^4 \text{ kJ/mol}_{rxn}$
- (D) $-5.0 \times 10^2 \text{ kJ/mol}_{rxn}$

Topic
6.4 Heat Capacity and Calorimetry

2015 Practice Exam #6

Q: Final T - hot iron ball dropped into H₂O at 50.C

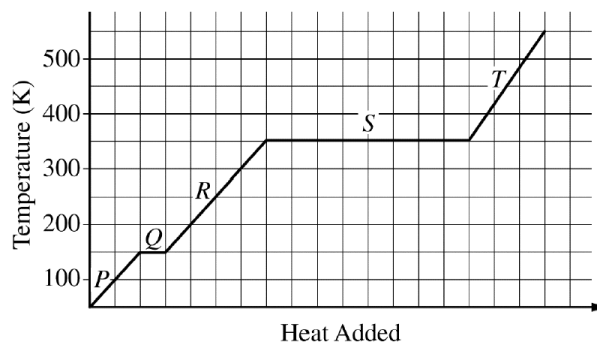
A hot iron ball is dropped into a 200. g sample of water initially at 50.°C. If 8.4 kJ of heat is transferred from the ball to the water, what is the final temperature of the water? (The specific heat of water is 4.2 J/(g·°C).)

- (A) 40.°C
- (B) 51°C
- * (C) 60.°C
- (D) 70.°C

Topic
6.4 Heat Capacity and Calorimetry

2015 Practice Exam #14

Q: Ethanol heating curve - slope T is greater than R



The heating curve for a sample of pure ethanol is provided above. The temperature was recorded as a 50.0 g sample of solid ethanol was heated at a constant rate. Which of the following explains why the slope of segment *T* is greater than the slope of segment *R* ?

- * (A) The specific heat capacity of gaseous ethanol is less than the specific heat capacity of liquid ethanol.
- (B) The specific heat capacity of gaseous ethanol is greater than the specific heat capacity of liquid ethanol.
- (C) The heat of vaporization of ethanol is less than the heat of fusion of ethanol.
- (D) The heat of vaporization of ethanol is greater than the heat of fusion of ethanol.

Topic
6.4 Heat Capacity and Calorimetry

2015 Practice Exam #23

Q: Calorimetry - energy from cashew vs marshmallow

A 1.0 g sample of a cashew was burned in a calorimeter containing 1000. g of water, and the temperature of the water changed from 20.0°C to 25.0°C. In another experiment, a 3.0 g sample of a marshmallow was burned in a calorimeter containing 2000. g of water, and the temperature of the water changed from 25.0°C to 30.0°C. Based on the data, which of the following can be concluded about the energy content for 1.0 g of each of the two substances? (The specific heat of water is 4.2 J/(g·°C).)

- (A) The combustion of 1.0 g of cashew releases less energy than the combustion of 1.0 g of marshmallow.
- (B) The combustion of 1.0 g of cashew releases the same amount of energy as the combustion of 1.0 g of marshmallow.
- * (C) The combustion of 1.0 g of cashew releases more energy than the combustion of 1.0 g of marshmallow.
- (D) No comparison can be made because the two systems started with different masses of food, different masses of water, and different initial temperatures.

Topic
6.4 Heat Capacity and Calorimetry

2014 Practice Exam #18

Q: Relative T changes - heated Cu cube added to H₂O

A 10. g cube of copper at a temperature T_1 is placed in an insulated cup containing 10. g of water at a temperature T_2 . If $T_1 > T_2$, which of the following is true of the system when it has attained thermal equilibrium? (The specific heat of copper is $0.385 \text{ J/(g}\cdot^\circ\text{C)}$ and the specific heat of water is $4.18 \text{ J/(g}\cdot^\circ\text{C)}$.)

- * (A) The temperature of the copper changed more than the temperature of the water.
- (B) The temperature of the water changed more than the temperature of the copper.
- (C) The temperature of the water and the copper changed by the same amount.
- (D) The relative temperature changes of the copper and the water cannot be determined without knowing T_1 and T_2 .

Topic
6.4 Heat Capacity and Calorimetry

2013 Practice Exam #9

Q: Energy change when heated metal is added to water

A 100 g sample of a metal was heated to 100°C and then quickly transferred to an insulated container holding 100 g of water at 22°C . The temperature of the water rose to reach a final temperature of 35°C . Which of the following can be concluded?

- (A) The metal temperature changed more than the water temperature did; therefore the metal lost more thermal energy than the water gained.
- * (B) The metal temperature changed more than the water temperature did, but the metal lost the same amount of thermal energy as the water gained.
- (C) The metal temperature changed more than the water temperature did; therefore the heat capacity of the metal must be greater than the heat capacity of the water.
- (D) The final temperature is less than the average starting temperature of the metal and the water; therefore the total energy of the metal and water decreased.

Topic
6.5 Energy of Phase Changes

2023 Practice Exam (from AP Classroom)

Q: Energy transfer for melting of ice

A 1.5 g sample of ice, $\text{H}_2\text{O}(s)$, at 0.0°C is placed in a warm room. Which of the following best describes the energy transfer involved in melting the ice to create liquid water at 0.0°C ?

(The heat of fusion of $\text{H}_2\text{O}(s)$ is 334 J/g .)

- (A) 334 joules of energy is transferred from the ice to the room.
- (B) 334 joules of energy is transferred from the room to the ice.
- (C) 501 joules of energy is transferred from the ice to the room.
- * (D) 501 joules of energy is transferred from the room to the ice.

Topic
6.5 Energy of Phase Changes

2022 Practice Exam (from AP Classroom)

Q: Calorimetry ice water mixture

Data for H ₂ O	
Specific heat capacity of liquid phase	4.2 J/(g·°C)
Heat of fusion	330 J/g

A sample of ice at 0°C is added to 100. g of water at 33°C. The mixture is stirred gently until the temperature of the water is 0°C. All of the remaining ice is quickly removed. Based on the information in the table above, the mass of ice that melted is closest to

(A) 0.13 g

(B) 0.42 g

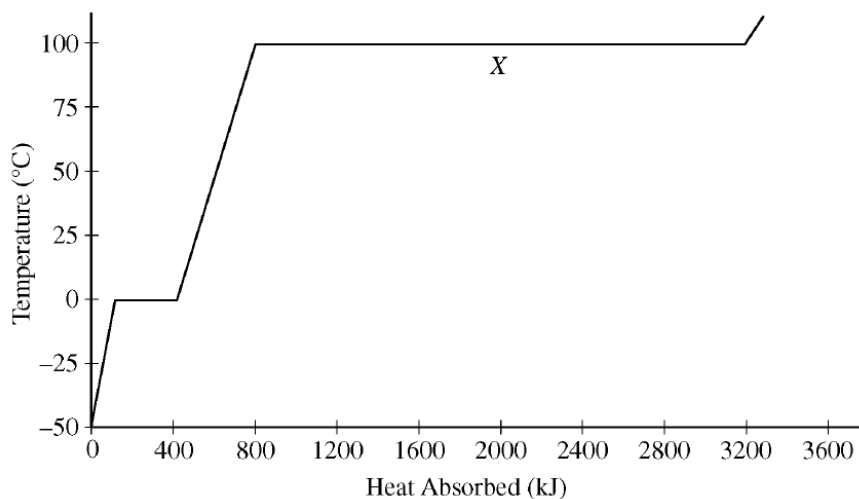
(C) 1.3 g

* (D) 42 g

Topic
6.5 Energy of Phase Changes

2016 Practice Exam #43

Q: Sign of enthalpy + entropy change - heating curve



At 1.0 atm a sample of ice is heated to liquid water and then to water vapor. The heating curve is shown in the graph above. Which of the following lists the signs for the changes in enthalpy and entropy for the process corresponding to segment X, going from left to right?

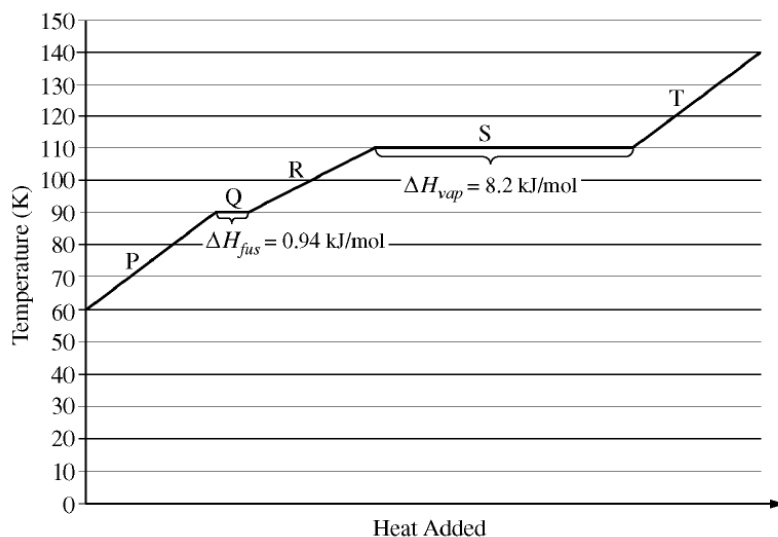
	ΔH°	ΔS°
(A)	Positive	Negative
* (B)	Positive	Positive
(C)	Negative	Negative
(D)	Negative	Positive

Topic
6.5 Energy of Phase Changes

2014 Practice Exam #39

Q: CH₄ heating curve - energy required to melt 64 g

Questions X-Y refer to the following graph, which shows the heating curve for methane, CH₄.



How much energy is required to melt 64 g of methane at 90 K? (The molar mass of methane is 16 g/mol.)

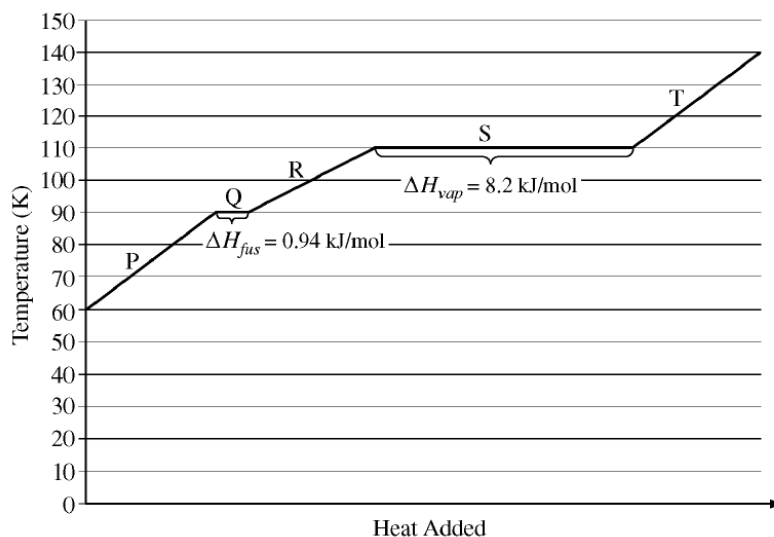
- (A) 0.24 kJ * (B) 3.8 kJ (C) 33 kJ (D) 60. kJ

Topic
6.5 Energy of Phase Changes

2014 Practice Exam #40

Q: CH₄ heating curve - more energy for vaporization

Questions X-Y refer to the following graph, which shows the heating curve for methane, CH₄.



Which of the following best explains why more energy is required for the process occurring at 110 K than for the process occurring at 90 K?

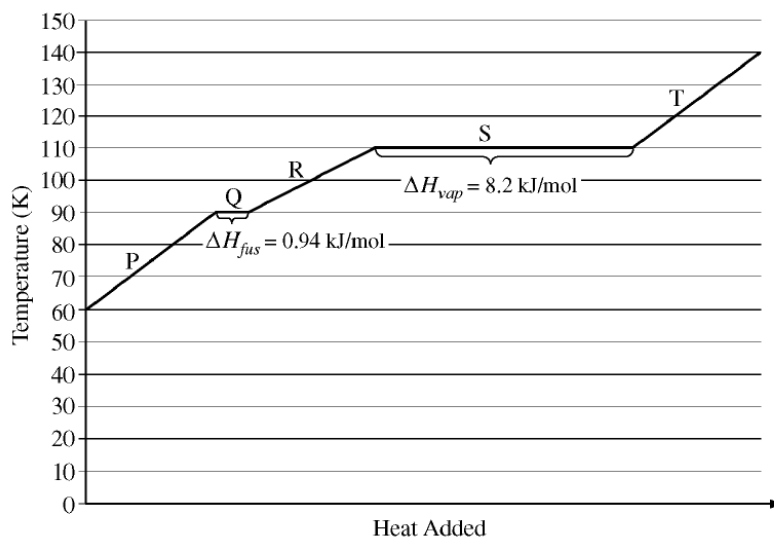
- * (A) Intermolecular attractions are completely overcome during vaporization.
- (B) Intermolecular attractions in the solid phase are weaker than in the liquid phase.
- (C) Electron clouds of methane molecules are less polarizable at lower temperatures.
- (D) Vaporization involves a large increase in temperature.

Topic
6.5 Energy of Phase Changes

2014 Practice Exam #41

Q: CH₄ heating curve - dH_{vap} less for CH₄ than H₂O

Questions X-Y refer to the following graph, which shows the heating curve for methane, CH₄.



The enthalpy of vaporization of water is 40.7 kJ/mol. Which of the following best explains why the enthalpy of vaporization of methane is less than that of water?

- * (A) Methane does not exhibit hydrogen bonding, but water does.
- (B) A methane molecule is more polarizable than a water molecule.
- (C) Methane has a smaller molar mass than water has.
- (D) Methane has a much lower density than water has.

Topic
6.6 Introduction to Enthalpy of Reaction

2023 Practice Exam (from AP Classroom)

Q: Energy transfer for melting of ice

A 1.5 g sample of ice, $\text{H}_2\text{O}(s)$, at 0.0°C is placed in a warm room. Which of the following best describes the energy transfer involved in melting the ice to create liquid water at 0.0°C ?

(The heat of fusion of $\text{H}_2\text{O}(s)$ is 334 J/g .)

- (A) 334 joules of energy is transferred from the ice to the room.
- (B) 334 joules of energy is transferred from the room to the ice.
- (C) 501 joules of energy is transferred from the ice to the room.
- * (D) 501 joules of energy is transferred from the room to the ice.

Topic
6.6 Introduction to Enthalpy of Reaction

2023 Practice Exam (from AP Classroom)

Q: Energy per gram of substance

Based on the information in the table, which of the following substances produces the most energy per gram of substance combusted?

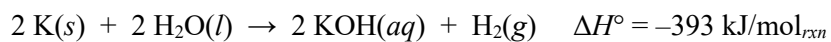
Substance	Molar Mass (g/mol)	Heat Released from Combustion of One Mole of Substance (kJ)
$\text{H}_2(l)$	2	290
$\text{CH}_4(l)$	16	900
$\text{C}_2\text{H}_5\text{OH}(l)$	46	1400
$\text{C}_{18}\text{H}_{38}(l)$	254	12,000

- * (A) $\text{H}_2(l)$
- (B) $\text{CH}_4(l)$
- (C) $\text{C}_2\text{H}_5\text{OH}(l)$
- (D) $\text{C}_{18}\text{H}_{38}(l)$

Topic
6.6 Introduction to Enthalpy of Reaction

2022 Practice Exam (from AP Classroom)

Q: Energy change for given mass of K



When 3.9 g of K(s) is added to 200. mL of water at 25°C in a calorimeter, all of the K(s) reacts with water as represented by the equation above.

Which of the following is true when the 3.9 g of K(s) has completely reacted?

- (A) 10. kJ of energy is absorbed by the reaction.
- (B) 20. kJ of energy is absorbed by the reaction.
- (C) 10. kJ of energy is released by the reaction.
- * (D) 20. kJ of energy is released by the reaction.

Topic
6.6 Introduction to Enthalpy of Reaction

2021 Practice Exam (from AP Classroom)

Q: Calculate heat of combustion

Mass of Solid	Mass of Water	ΔT_{water}
1.0 g	2000.0 g	+2.1°C

A sample of a solid organic compound is completely combusted in a calorimeter. The heat generated by combustion is transferred to the water, causing the temperature of the water to increase. Based on the data in the table above, which of the following is the best estimate of the heat of combustion, ΔH_{comb} , of the organic solid? (The specific heat of water is 4.2 J/(g·°C))

- (A) +18 kJ/g
- (B) +8.4 kJ/g
- (C) −8.4 kJ/g
- * (D) −18 kJ/g

Topic
6.6 Introduction to Enthalpy of Reaction

2019 Practice Exam #18

Q: Combustion rxn enthalpy - q for ethane vs propanol

Questions X-Y are based on the information in the table below.

Compound	Molar Mass	Balanced Equation for the Combustion of One Mole of the Compound	$\Delta H_{\text{comb}}^{\circ}$ (kJ/mol _{rxn})
$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \\ \text{Ethane} \end{array}$	30. g/mol	$\text{C}_2\text{H}_6(\text{g}) + \frac{7}{2}\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$	-1560
$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \\ \text{Propanol} \end{array}$	60. g/mol	$\text{C}_3\text{H}_8\text{O}(\text{l}) + \frac{9}{2}\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l})$	-2020
Unknown	?	$? + 5\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l})$	-2240

In an experiment, 30.0 g of ethane and 30.0 g of propanol are placed in separate reaction vessels. Each compound undergoes complete combustion with excess $\text{O}_2(\text{g})$. Which of the following best compares the quantity of heat released in each combustion reaction?

(A) $q_{\text{ethane}} < q_{\text{propanol}}$

(B) $q_{\text{ethane}} = q_{\text{propanol}}$

* (C) $q_{\text{ethane}} > q_{\text{propanol}}$

(D) The quantities of heat released in the combustions of ethane and propanol cannot be compared without knowing the specific heat capacity of the compounds.

Topic
6.6 Introduction to Enthalpy of Reaction

2019 Practice Exam #46

Q: Data needed to determine molar enthalpy of soln

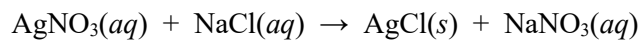
Which of the following is a list of the minimum amount of data needed for determining the molar enthalpy of solution of $\text{KCl}(s)$ in pure $\text{H}_2\text{O}(l)$? (Assume that the $\text{KCl}(aq)$ has the same specific heat capacity as pure water and that the initial temperatures of the $\text{KCl}(s)$ and the water are the same.)

- (A) Mass of $\text{KCl}(s)$, initial temperature of the water, and final temperature of the solution
- (B) Mass of H_2O , initial temperature of the water, and final temperature of the solution
- * (C) Mass of $\text{KCl}(s)$, mass of H_2O , initial temperature of the water, and final temperature of the solution
- (D) Mass of $\text{KCl}(s)$, mass of H_2O , initial temperature of the water, final temperature of the solution, and atmospheric pressure

Topic
6.6 Introduction to Enthalpy of Reaction

2018 Practice Exam #21

Q: Enthalpy change for precipitation of AgCl



In an experiment a student mixes a 50.0 mL sample of 0.100 *M* AgNO₃(*aq*) with a 50.0 mL sample of 0.100 *M* NaCl(*aq*) at 20.0°C in a coffee-cup calorimeter. Which of the following is the enthalpy change of the precipitation reaction represented above if the final temperature of the mixture is 21.0°C? (Assume that the total mass of the mixture is 100. g and that the specific heat capacity of the mixture is 4.2 J/(g·°C).)

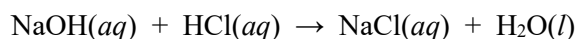
- * (A) −84 kJ/mol_{rxn}
- (B) −0.42 kJ/mol_{rxn}
- (C) 0.42 kJ/mol_{rxn}
- (D) 84 kJ/mol_{rxn}

Topic
6.6 Introduction to Enthalpy of Reaction

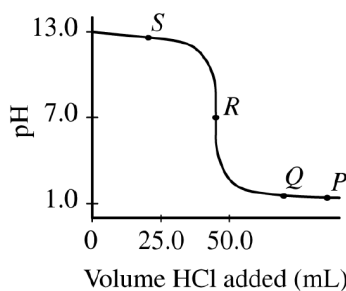
2016 Practice Exam #25

Q: NaOH-HCl titration curve - enthalpy change value

Questions X-Y refer to the following information.



To determine the concentration of a $\text{NaOH}(aq)$ solution, a student titrated a 50. mL sample with 0.10 M $\text{HCl}(aq)$. The reaction is represented by the equation above. The titration is monitored using a pH meter, and the experimental results are plotted in the graph below.



A student mixes a 10.0 mL sample of 1.0 M $\text{NaOH}(aq)$ with a 10.0 mL sample of 1.0 M $\text{HCl}(aq)$ in a polystyrene container. The temperature of the solutions before mixing was 20.0°C. If the final temperature of the mixture is 26.0°C, what is the experimental value of ΔH_{rxn}° ? (Assume that the solution mixture has a specific heat of 4.2 J/(g·K) and a density of 1.0 g/mL.)

- * (A) -50. kJ/mol_{rxn}
- (B) -25 kJ/mol_{rxn}
- (C) -5.0×10^4 kJ/mol_{rxn}
- (D) -5.0×10^2 kJ/mol_{rxn}

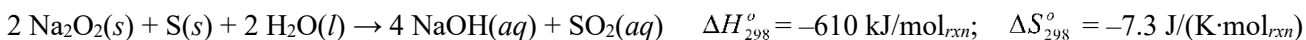
Topic
6.6 Introduction to Enthalpy of Reaction

2016 Practice Exam #37

Q: Na₂O₂ + S - limiting reactant and heat released

Questions X-Y refer to the following information.

When water is added to a mixture of Na₂O₂(s) and S(s), a redox reaction occurs, as represented by the equation below.



Two trials are run, using excess water. In the first trial, 7.8 g of Na₂O₂(s) (molar mass 78 g/mol) is mixed with 3.2 g of S(s). In the second trial, 7.8 g of Na₂O₂(s) is mixed with 6.4 g of S(s). The Na₂O₂(s) and S(s) react as completely as possible. Both trials yield the same amount of SO₂(aq). Which of the following identifies the limiting reactant and the heat released, q , for the two trials at 298 K?

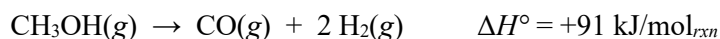
	Limiting Reactant	q
(A)	S	30. kJ
(B)	S	61 kJ
* (C)	Na ₂ O ₂	30. kJ
(D)	Na ₂ O ₂	61 kJ

Topic
6.6 Introduction to Enthalpy of Reaction

2016 Practice Exam #44

Not listed in the question bank

Questions X-Y refer to the following.



The reaction represented above goes essentially to completion. The reaction takes place in a rigid, insulated vessel that is initially at 600 K.

What happens to the temperature of the contents of the vessel as the reaction occurs?

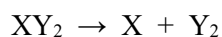
- (A) The temperature must increase, because according to LeChâtelier's principle, an increase in temperature causes more products to form.
- (B) The temperature must decrease, because the reaction takes place at a temperature above room temperature.
- * (C) The temperature must decrease, because the reaction is endothermic.
- (D) The temperature does not change, because the vessel is insulated.

Topic
6.6 Introduction to Enthalpy of Reaction

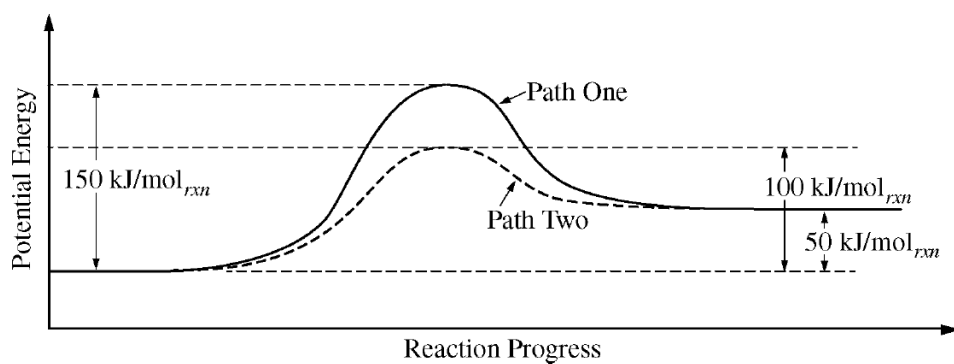
2014 Practice Exam #45

Q: Rxn energy profile - heat flow if 1 mol XY₂ reacts

Questions X-Y relate to the following information.



The equation above represents the decomposition of a compound XY₂. The diagram below shows two reaction profiles (path one and path two) for the decomposition of XY₂.



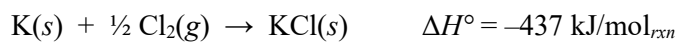
Which of the following best describes the flow of heat when 1.0 mol of XY₂ decomposes?

- (A) 50 kJ of heat is transferred to the surroundings.
- * (B) 50 kJ of heat is transferred from the surroundings.
- (C) 100 kJ of heat is transferred to the surroundings.
- (D) 100 kJ of heat is transferred from the surroundings.

Topic
6.6 Introduction to Enthalpy of Reaction

2013 Practice Exam #34

Q: KCl enthalpy - heat term when 0.050 mol Cl₂ formed



The elements K and Cl react directly to form the compound KCl according to the equation above. Refer to the information above and the table below to answer the questions that follow.

Process	ΔH° (kJ/mol _{rxn})
$\text{K}(s) \rightarrow \text{K}(g)$	v
$\text{K}(g) \rightarrow \text{K}^+(g) + e^-$	w
$\text{Cl}_2(g) \rightarrow 2 \text{Cl}(g)$	x
$\text{Cl}(g) + e^- \rightarrow \text{Cl}^-(g)$	y
$\text{K}^+(g) + \text{Cl}^-(g) \rightarrow \text{KCl}(s)$	z

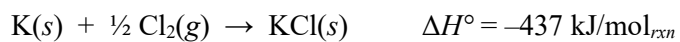
How much heat is released or absorbed when 0.050 mol of Cl₂(g) is formed from KCl(s) ?

- (A) 87.4 kJ is released
- (B) 43.7 kJ is released
- * (C) 43.7 kJ is absorbed
- (D) 87.4 kJ is absorbed

Topic
6.6 Introduction to Enthalpy of Reaction

2013 Practice Exam #36

Q: KCl enthalpy - which processes are exothermic



The elements K and Cl react directly to form the compound KCl according to the equation above. Refer to the information above and the table below to answer the questions that follow.

Process	ΔH° (kJ/mol _{rxn})
$\text{K}(s) \rightarrow \text{K}(g)$	v
$\text{K}(g) \rightarrow \text{K}^+(g) + e^-$	w
$\text{Cl}_2(g) \rightarrow 2 \text{Cl}(g)$	x
$\text{Cl}(g) + e^- \rightarrow \text{Cl}^-(g)$	y
$\text{K}^+(g) + \text{Cl}^-(g) \rightarrow \text{KCl}(s)$	z

Which of the values of ΔH° for a process in the table is (are) less than zero (i.e., indicate(s) an exothermic process) ?

(A) z only

* (B) y and z only

(C) x , y , and z only

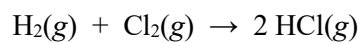
(D) w , x , y , and z

Topic
6.7 Bond Enthalpies

2023 Practice Exam (from AP Classroom)

Q: Enthalpy change from bond energies

Gaseous hydrogen and gaseous chlorine can react to form hydrogen chloride gas, as represented by the following equation.



Bond	Bond Energy (kJ/mol)
H–H	432
Cl–Cl	239
H–Cl	427

Based on the table of bond energies shown, the value of ΔH for the reaction $\text{H}_2 + \text{Cl}_2 \rightarrow \text{HCl}$ is closest to which of the following?

- (A) $-244 \text{ kJ/mol}_{\text{rxn}}$
- * (B) $-183 \text{ kJ/mol}_{\text{rxn}}$
- (C) $+183 \text{ kJ/mol}_{\text{rxn}}$
- (D) $+244 \text{ kJ/mol}_{\text{rxn}}$

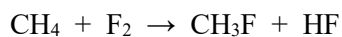
Topic
6.7 Bond Enthalpies

2022 Practice Exam (from AP Classroom)

Q: Bond enthalpies and delta H

Bond	Approximate Bond Enthalpy (kJ/mol)
C–H	410
C–F	490
H–F	570
F–F	160

Based on the bond enthalpies given in the table above, which of the following is the best estimate of ΔH° for the reaction represented below?

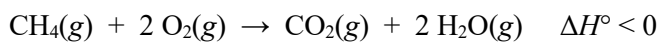


- (A) $-650 \text{ kJ/mol}_{rxn}$
- * (B) $-490 \text{ kJ/mol}_{rxn}$
- (C) $+490 \text{ kJ/mol}_{rxn}$
- (D) $+650 \text{ kJ/mol}_{rxn}$

Topic
6.7 Bond Enthalpies

2021 Practice Exam (from AP Classroom)

Q: Bond energies in reaction



Which of the following statements must be true for the combustion of $\text{CH}_4(g)$, represented by the equation above?

- (A) The bond dissociation energy between O atoms in O_2 is greater than the sum of the bond dissociation energies of the two O–H bonds in H_2O .
- (B) More bonds are formed in the products than are broken in the reactants.
- (C) The sum of the bond dissociation energies of the product molecules is equal to the sum of the bond dissociation energies of the reactant molecules.
- * (D) The sum of the bond dissociation energies of the product molecules is greater than the sum of the bond dissociation energies of the reactant molecules.

Topic
6.7 Bond Enthalpies

2019 Practice Exam #16

Q: Combustion rxn enthalpy - relative bond energies

Questions X-Y are based on the information in the table below.

Compound	Molar Mass	Balanced Equation for the Combustion of One Mole of the Compound	ΔH_{comb}° (kJ/mol _{rxn})
$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \\ \text{Ethane} \end{array}$	30. g/mol	$\text{C}_2\text{H}_6(g) + \frac{7}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$	-1560
$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \\ \text{Propanol} \end{array}$	60. g/mol	$\text{C}_3\text{H}_8\text{O}(l) + \frac{9}{2}\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2020
Unknown	?	$? + 5\text{O}_2(g) \rightarrow 4\text{CO}_2(g) + 4\text{H}_2\text{O}(l)$	-2240

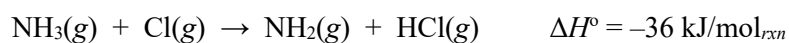
Which of the following best explains why the combustion reactions represented in the table are exothermic?

- (A) The number of bonds in the reactant molecules is greater than the number of bonds in the product molecules.
- (B) The number of bonds in the reactant molecules is less than the number of bonds in the product molecules.
- (C) The energy required to break the bonds in the reactants is greater than the energy released in forming the bonds in the products.
- * (D) The energy required to break the bonds in the reactants is less than the energy released in forming the bonds in the products.

Topic
6.7 Bond Enthalpies

2018 Practice Exam #41

Q: Given rxns with ΔH values identify strongest bond



Based on the data above, what can be concluded regarding the strength of the C–H, N–H, and O–H bonds in the molecules shown?

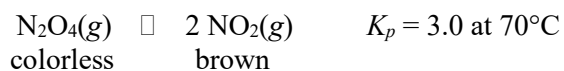
- (A) The C–H bond is the strongest.
- (B) The N–H bond is the strongest.
- * (C) The O–H bond is the strongest.
- (D) Nothing can be concluded without knowing the strength of the H–Cl bond.

Topic
6.7 Bond Enthalpies

2017 Practice Exam #25

Q: N₂O₄ NO₂ equil - enthalpy change and bond energy

Questions X-Y refer to the following information.



A mixture of NO₂(g) and N₂O₄(g) is placed in a glass tube and allowed to reach equilibrium at 70°C, as represented above.

Which of the following statements about ΔH° for the reaction is correct?

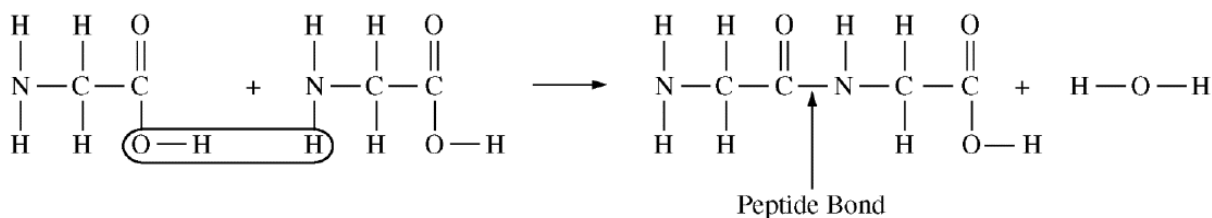
- (A) $\Delta H^\circ < 0$ because energy is released when the N–N bond breaks.
- (B) $\Delta H^\circ < 0$ because energy is required to break the N–N bond.
- (C) $\Delta H^\circ > 0$ because energy is released when the N–N bond breaks.
- * (D) $\Delta H^\circ > 0$ because energy is required to break the N–N bond.

Topic
6.7 Bond Enthalpies

2017 Practice Exam #37

Q: Peptide - given bond energies, estimate C-N bond

Questions X-Y refer to the following information.



Two molecules of the amino acid glycine join through the formation of a peptide bond, as shown above. The thermodynamic data for the reaction are listed in the following table.

ΔG_{298}°	ΔH_{298}°	ΔS_{298}°
+15 kJ/mol _{rxn}	+12 kJ/mol _{rxn}	-10 J/(K·mol _{rxn})

Bond	Bond Energy (kJ/mol)
C–O	360
N–H	390
O–H	460

Based on the bond energies listed in the table above, which of the following is closest to the bond energy of the C–N bond?

- (A) 200 kJ/mol
- *(B) 300 kJ/mol
- (C) 400 kJ/mol
- (D) 500 kJ/mol

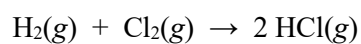
Topic
6.7 Bond Enthalpies

2016 Practice Exam #40

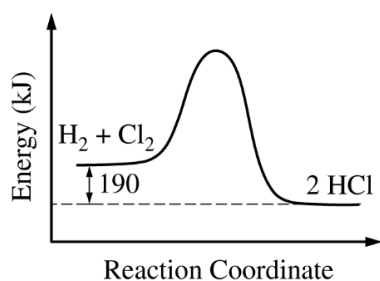
Q: Rxn energy profile for HCl formation - bond energy

Bond	Bond Energy (kJ/mol)
H-H	430
Cl-Cl	240
H-Cl	430

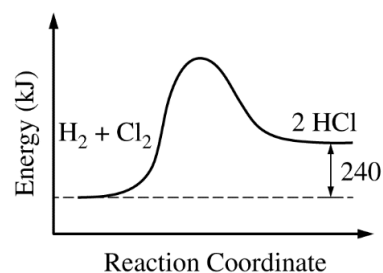
Based on the bond energies shown in the table above, which of the following diagrams best represents the change in energy as the reaction represented below proceeds?



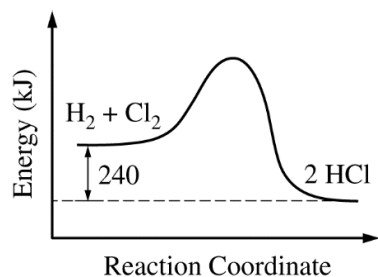
* (A)



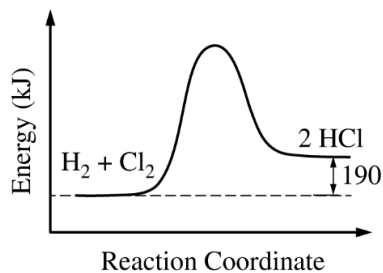
(C)



(B)



(D)

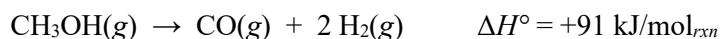


Topic
6.7 Bond Enthalpies

2016 Practice Exam #47

Q: CH₃OH decomp - relative bond enthalpies

Questions X-Y refer to the following.



The reaction represented above goes essentially to completion. The reaction takes place in a rigid, insulated vessel that is initially at 600 K.

Which of the following statements about the bonds in the reactants and products is most accurate?

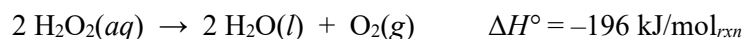
- * (A) The sum of the bond enthalpies of the bonds in the reactant is greater than the sum of the bond enthalpies of the bonds in the products.
- (B) The sum of the bond enthalpies of the bonds in the reactant is less than the sum of the bond enthalpies of the bonds in the products.
- (C) The length of the bond between carbon and oxygen in CH₃OH is shorter than the length of the bond between carbon and oxygen in CO.
- (D) All of the bonds in the reactant and products are polar.

Topic
6.7 Bond Enthalpies

2015 Practice Exam #29

Q: H₂O₂ decomp - relative bond enthalpies

Questions X-Y refer to the following information.



The decomposition of H₂O₂(aq) is represented by the equation above. A student monitored the decomposition of a 1.0 L sample of H₂O₂(aq) at a constant temperature of 300. K and recorded the concentration of H₂O₂ as a function of time. The results are given in the table below.

Time (s)	[H ₂ O ₂]
0	2.7
200.	2.1
400.	1.7
600.	1.4

Assume that the bond enthalpies of the oxygen-hydrogen bonds in H₂O are not significantly different from those in H₂O₂. Based on the value of ΔH° of the reaction, which of the following could be the bond enthalpies (in kJ/mol) for the bonds broken and formed in the reaction?

	O–O in H ₂ O ₂	O=O in O ₂	O–H
(A)	300	500	500
* (B)	150	500	500
(C)	500	300	150
(D)	250	300	150

Topic
6.7 Bond Enthalpies

2014 Practice Exam #24

Q: CH₃OH equil. - relative bond energies in reaction

Questions X-Y refer to the following information.



The synthesis of CH₃OH(g) from CO(g) and H₂(g) is represented by the equation above. The value of K_c for the reaction at 483 K is 14.5.

Which of the following statements is true about bond energies in this reaction?

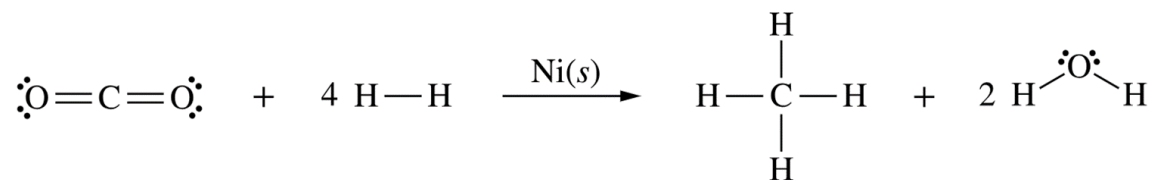
- (A) The energy absorbed as the bonds in the reactants are broken is greater than the energy released as the bonds in the product are formed.
- (B) The energy released as the bonds in the reactants are broken is greater than the energy absorbed as the bonds in the product are formed.
- * (C) The energy absorbed as the bonds in the reactants are broken is less than the energy released as the bonds in the product are formed.
- (D) The energy released as the bonds in the reactants are broken is less than the energy absorbed as the bonds in the product are formed.

Topic
6.8 Enthalpy of Formation

2023 Practice Exam (from AP Classroom)

Q: Heat of formation of CO₂

In the gas-phase reaction represented by the following equation, methane (CH₄) and water (H₂O) are produced from carbon dioxide (CO₂) and hydrogen (H₂) at high temperature and pressure.



Substance	Standard Heat of Formation (kJ/mol)
CO ₂ (g)	−394
CH ₄ (g)	−75
H ₂ (g)	0
H ₂ O(g)	−242

Based on the information given, ΔH_{rxn} is closest to which of the following?

- * (A) −165 kJ/mol_{rxn}
- (B) −77 kJ/mol_{rxn}
- (C) +77 kJ/mol_{rxn}
- (D) +165 kJ/mol_{rxn}

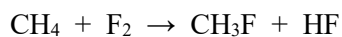
Topic
6.8 Enthalpy of Formation

2022 Practice Exam (from AP Classroom)

Q: Bond enthalpies and delta H

Bond	Approximate Bond Enthalpy (kJ/mol)
C–H	410
C–F	490
H–F	570
F–F	160

Based on the bond enthalpies given in the table above, which of the following is the best estimate of ΔH° for the reaction represented below?

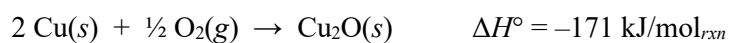
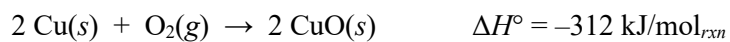


- (A) $-650 \text{ kJ/mol}_{rxn}$
- * (B) $-490 \text{ kJ/mol}_{rxn}$
- (C) $+490 \text{ kJ/mol}_{rxn}$
- (D) $+650 \text{ kJ/mol}_{rxn}$

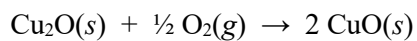
Topic
6.9 Hess's Law

2023 Practice Exam (from AP Classroom)

Q: Enthalpy of a reaction



Based on the information above, what is the value of ΔH° for the following reaction?



(A) $-483 \text{ kJ/mol}_{rxn}$

* (B) $-141 \text{ kJ/mol}_{rxn}$

(C) $+141 \text{ kJ/mol}_{rxn}$

(D) $+483 \text{ kJ/mol}_{rxn}$

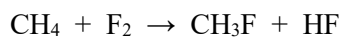
Topic
6.9 Hess's Law

2022 Practice Exam (from AP Classroom)

Q: Bond enthalpies and delta H

Bond	Approximate Bond Enthalpy (kJ/mol)
C–H	410
C–F	490
H–F	570
F–F	160

Based on the bond enthalpies given in the table above, which of the following is the best estimate of ΔH° for the reaction represented below?

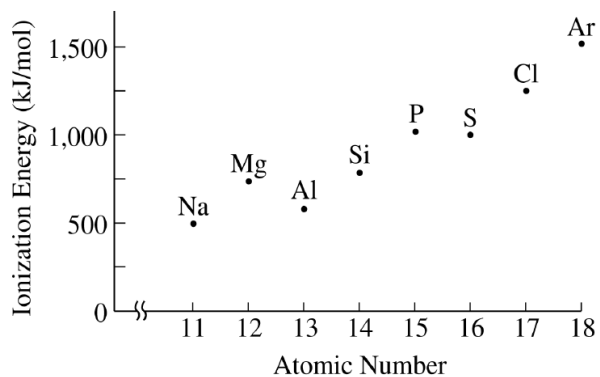


- (A) $-650 \text{ kJ/mol}_{rxn}$
- * (B) $-490 \text{ kJ/mol}_{rxn}$
- (C) $+490 \text{ kJ/mol}_{rxn}$
- (D) $+650 \text{ kJ/mol}_{rxn}$

Topic
6.9 Hess's Law

2017 Practice Exam #6

Q: Given ionization energy graph, most exothermic rxn



The first ionization energy of an element is the energy required to remove an electron from a gaseous atom of the element (i.e., $X(g) \rightarrow X^+(g) + e^-$). The values of the first ionization energies for the third-row elements are shown in the graph above. On the basis of the information given, which of the following reactions is exothermic?

- (A) $Cl(g) + Mg^+(g) \rightarrow Cl^+(g) + Mg(g)$
- * (B) $Al(g) + Mg^+(g) \rightarrow Al^+(g) + Mg(g)$
- (C) $P(g) + Mg^+(g) \rightarrow P^+(g) + Mg(g)$
- (D) $S(g) + Mg^+(g) \rightarrow S^+(g) + Mg(g)$

Topic
6.9 Hess's Law

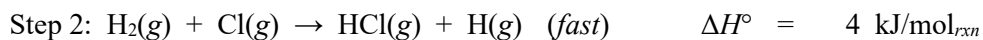
2017 Practice Exam #43

Q: HCl equil mechanism - value of enthalpy change

Questions X-Y refer to the following information.



HCl(g) can be synthesized from H₂(g) and Cl₂(g) as represented above. A student studying the kinetics of the reaction proposes the following mechanism.



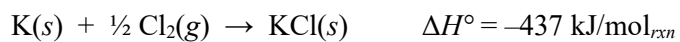
What is the value of the enthalpy change per mole of HCl(g) produced?

- * (A) -93 kJ
- (B) -121 kJ
- (C) -186 kJ
- (D) -242 kJ

Topic
6.9 Hess's Law

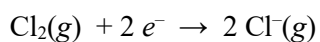
2013 Practice Exam #38

Q: KCl enthalpy - expression for enthalpy of reaction



The elements K and Cl react directly to form the compound KCl according to the equation above. Refer to the information above and the table below to answer the questions that follow.

Process	ΔH° (kJ/mol _{rxn})
$\text{K}(s) \rightarrow \text{K}(g)$	v
$\text{K}(g) \rightarrow \text{K}^+(g) + e^-$	w
$\text{Cl}_2(g) \rightarrow 2 \text{Cl}(g)$	x
$\text{Cl}(g) + e^- \rightarrow \text{Cl}^-(g)$	y
$\text{K}^+(g) + \text{Cl}^-(g) \rightarrow \text{KCl}(s)$	z



Which of the following expressions is equivalent to ΔH° for the reaction represented above?

(A) $x + y$

(B) $x - y$

* (C) $x + 2y$

(D) $\frac{x}{2} - y$

Topic
7.1 Introduction to Equilibrium

2013 Practice Exam #33

Q: PCl_5 equil. - graph of rate when Cl_2 is injected

Questions X-Y refer to the following.



$\text{PCl}_5(\text{g})$ decomposes into $\text{PCl}_3(\text{g})$ and $\text{Cl}_2(\text{g})$ according to the equation above. A pure sample of $\text{PCl}_5(\text{g})$ is placed in a rigid, evacuated 1.00 L container. The initial pressure of the $\text{PCl}_5(\text{g})$ is 1.00 atm. The temperature is held constant until the $\text{PCl}_5(\text{g})$ reaches equilibrium with its decomposition products. The figures below show the initial and equilibrium conditions of the system.

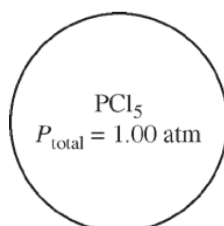


Figure 1: Initial

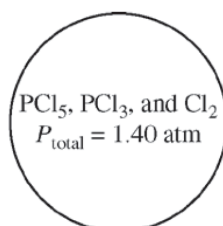
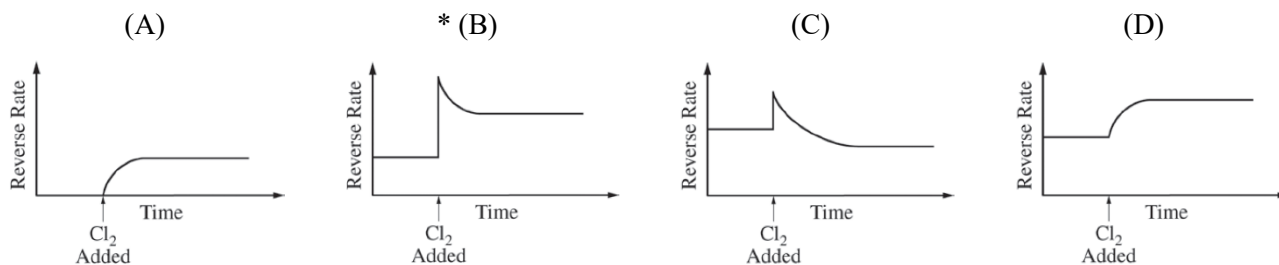


Figure 2: Equilibrium

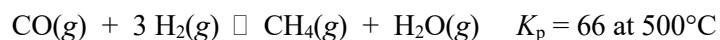
Additional $\text{Cl}_2(\text{g})$ is injected into the system at equilibrium. Which of the following graphs best shows the rate of the reverse reaction as a function of time? (Assume that the time for injection and mixing of the additional $\text{Cl}_2(\text{g})$ is negligible.)



Topic
7.2 Direction of Reversible Reactions

2021 Practice Exam (from AP Classroom)

Q: Mixture moves toward equilibrium



At a certain time, the partial pressure of the gases in the reaction mixture represented above had the values shown in the table below.

P_{CO}	P_{H_2}	P_{CH_4}	$P_{\text{H}_2\text{O}}$
0.02 atm	1.0 atm	0.4 atm	0.4 atm

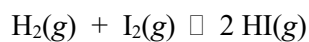
Based on the information above, which of the following occurred as the reaction mixture moved toward equilibrium?

- * (A) More $\text{CH}_4\text{(g)}$ was produced because the rate of the forward reaction was higher than the rate of the reverse reaction.
- (B) More $\text{H}_2\text{(g)}$ was produced because the rate of the reverse reaction was higher than the rate of the reverse reaction.
- (C) More $\text{CH}_4\text{(g)}$ was produced because the total pressure of the $\text{H}_2\text{(g)}$ and CO(g) combined was higher than that of the products; thus the reaction shifted to the side with the fewest number of moles of gas.
- (D) More $\text{H}_2\text{(g)}$ was produced because the pressure of CO(g) was the least and the reaction shifted to the side with the smaller number of moles of gas.

Topic
7.2 Direction of Reversible Reactions

2019 Practice Exam #3

Q: Rates of forward and reverse rxn after adding I₂



Hydrogen gas reacts with iodine gas at constant temperature in a sealed rigid container. The gases are allowed to reach equilibrium according to the equation above. Which of the following best describes what will happen to the reaction immediately after additional iodine gas is added to the system?

- (A) The rates of both the forward and reverse reactions decrease.
- (B) The rates of both the forward and reverse reactions do not change.
- * (C) The rate of the forward reaction becomes greater than the rate of the reverse reaction.
- (D) The rate of the forward reaction becomes less than the rate of the reverse reaction.

Topic
7.2 Direction of Reversible Reactions

2013 Practice Exam #30

Q: PCl_5 equil. - forward rxn rate approaching equil.

Questions X-Y refer to the following.



$\text{PCl}_5(g)$ decomposes into $\text{PCl}_3(g)$ and $\text{Cl}_2(g)$ according to the equation above. A pure sample of $\text{PCl}_5(g)$ is placed in a rigid, evacuated 1.00 L container. The initial pressure of the $\text{PCl}_5(g)$ is 1.00 atm. The temperature is held constant until the $\text{PCl}_5(g)$ reaches equilibrium with its decomposition products. The figures below show the initial and equilibrium conditions of the system.

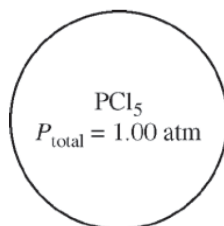


Figure 1: Initial



Figure 2: Equilibrium

As the reaction progresses toward equilibrium, the rate of the forward reaction

- (A) increases until it becomes the same as the reverse reaction rate at equilibrium
- (B) stays constant before and after equilibrium is reached
- * (C) decreases to become a constant nonzero rate at equilibrium
- (D) decreases to become zero at equilibrium

Topic
7.3 Reaction Quotient and Equilibrium Constant

2023 Practice Exam (from AP Classroom)

Q: Hydrogen iodide equilibrium



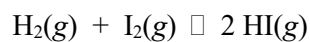
Equimolar amounts of $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ are pumped into a previously evacuated, rigid 1.0 L container and allowed to attain the equilibrium shown above at a constant temperature. If 0.600 mol of $\text{HI}(\text{g})$ is present at equilibrium, how many moles of $\text{H}_2(\text{g})$ were initially added to the container?

- (A) 0.0036 mol
- (B) 0.060 mol
- * (C) 0.36 mol
- (D) 0.60 mol

Topic
7.4 Calculating the Equilibrium Constant

2022 Practice Exam (from AP Classroom)

Q: Value of K for H₂ I₂ system



A 1.0 mol sample of H₂(g) and a 1.0 mol sample of I₂(g) are placed in a previously evacuated 1.0 L container and allowed to reach the equilibrium shown above. If the equilibrium concentration of HI(g) is 0.40 M, which of the following is the value of the equilibrium constant?

- (A) 0.16
- * (B) 0.25
- (C) 0.44
- (D) 1.0

Topic
7.4 Calculating the Equilibrium Constant

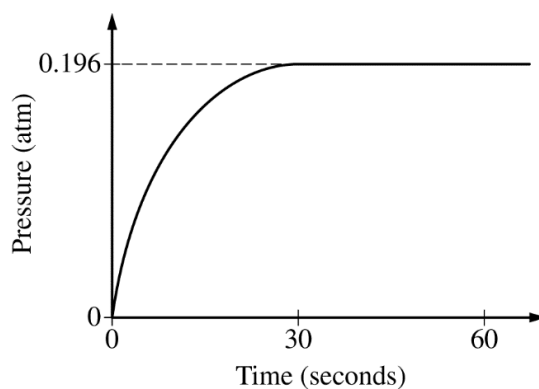
2018 Practice Exam #15

Q: CH₃OH vaporization - value of K_p

Questions X-Y refer to the following information.

Substance	Lewis Diagram	Boiling Point
CH ₃ OH	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array} $	338 K
C ₂ H ₅ OH	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\ddot{\text{O}}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	351 K

Equimolar samples of CH₃OH(*l*) and C₂H₅OH(*l*) are placed in separate, previously evacuated, rigid 2.0 L vessels. Each vessel is attached to a pressure gauge, and the temperatures are kept at 300 K. In both vessels, liquid is observed to remain present at the bottom of the container at all times. The change in pressure inside the vessel containing CH₃OH(*l*) is shown below.



The value of K_p for the evaporation of CH₃OH(*l*) at 300 K is closest to

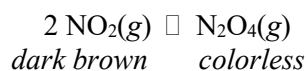
- (A) 0.04
- * (B) 0.2
- (C) 5
- (D) 30

Topic
7.4 Calculating the Equilibrium Constant

2018 Practice Exam #45

Q: NO₂ dimerization - calculate value of K

Questions X-Y refer to the following information.



The dimerization of NO₂(g), an exothermic process, is represented by the equation above.

A 0.0300 mol sample of NO₂(g) is placed in a rigid 1.00 L reaction vessel and allowed to reach equilibrium at a certain temperature. What is the value of K_c at this temperature if 0.00500 mol of N₂O₄(g) is present at equilibrium?

(A) 0.0800

(B) 0.250

(C) 4.00

* (D) 12.5

Topic
7.4 Calculating the Equilibrium Constant

2013 Practice Exam #32

Q: PCl_5 equil. - which statement about K_p is correct

Questions X-Y refer to the following.



$\text{PCl}_5(g)$ decomposes into $\text{PCl}_3(g)$ and $\text{Cl}_2(g)$ according to the equation above. A pure sample of $\text{PCl}_5(g)$ is placed in a rigid, evacuated 1.00 L container. The initial pressure of the $\text{PCl}_5(g)$ is 1.00 atm. The temperature is held constant until the $\text{PCl}_5(g)$ reaches equilibrium with its decomposition products. The figures below show the initial and equilibrium conditions of the system.

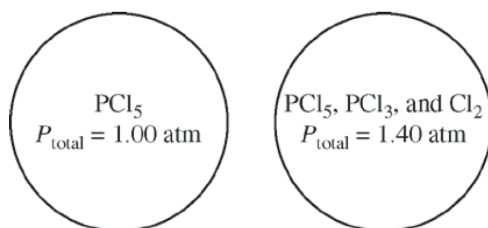


Figure 1: Initial

Figure 2: Equilibrium

Which of the following statements about K_p , the equilibrium constant for the reaction, is correct?

- (A) $K_p > 1$
- * (B) $K_p < 1$
- (C) $K_p = 1$
- (D) It cannot be determined whether $K_p > 1$, $K_p < 1$, or $K_p = 1$ without additional information.

Topic
7.4 Calculating the Equilibrium Constant

2013 Practice Exam #60

Q: 1.0 atm COCl₂ decomposes to give 1.2 atm - calc K_p



COCl₂(g) decomposes according to the equation above. When pure COCl₂(g) is injected into a rigid, previously evacuated flask at 690 K, the pressure in the flask is initially 1.0 atm. After the reaction reaches equilibrium at 690 K, the total pressure in the flask is 1.2 atm. What is the value of K_p for the reaction at 690 K?

- (A) 0.040
- * (B) 0.050
- (C) 0.80
- (D) 1.0

Topic
7.5 Magnitude of the Equilibrium Constant

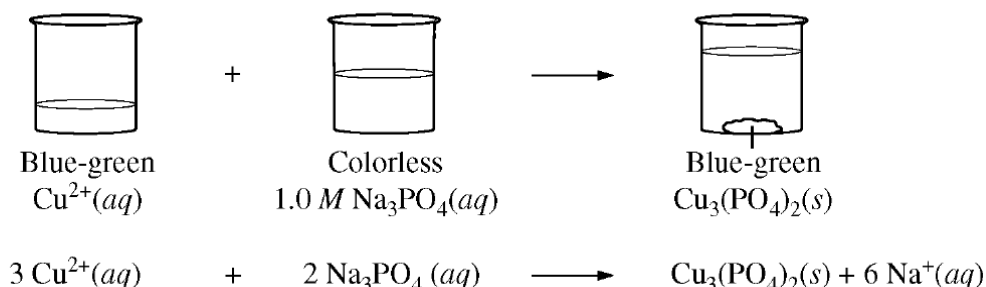
2018 Practice Exam #24

Q: Cu recovery - phosphate major species if pH is 1

Questions X-Y refer to the following information.

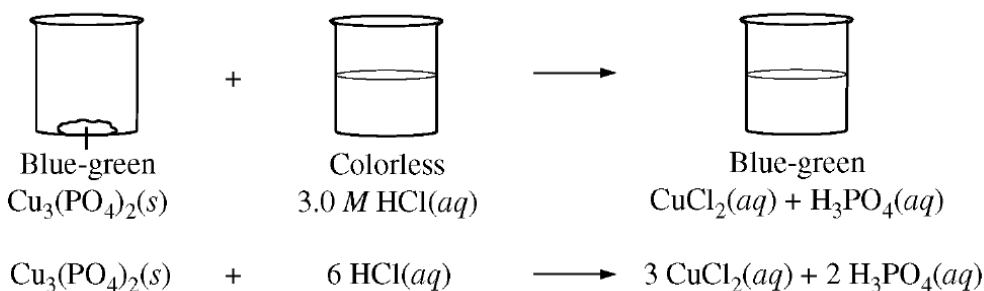
A group of students was asked to recover Cu(s) from a blue-green aqueous solution containing an unknown concentration of $\text{Cu}^{2+}(aq)$. The students took a 100.0 mL sample of the solution and added an excess of 1.0 M $\text{Na}_3\text{PO}_4(aq)$, causing the $\text{Cu}^{2+}(aq)$ to precipitate as $\text{Cu}_3(\text{PO}_4)_2(s)$, as shown in step 1 below.

Step 1



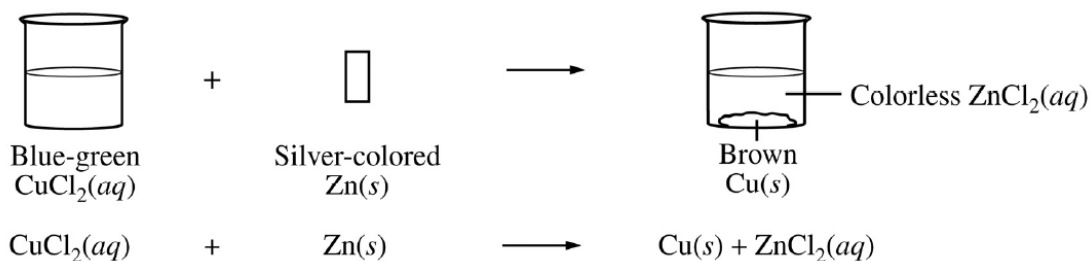
The $\text{Cu}_3(\text{PO}_4)_2(s)$ was filtered, dried, and weighed. Then the $\text{Cu}_3(\text{PO}_4)_2(s)$ was dissolved in a 3.0 M $\text{HCl}(aq)$ solution, as shown in step 2 below.

Step 2



The students added a strip of $\text{Zn}(s)$ to the solution to recover the $\text{Cu}(s)$, as shown in step 3 below.

Step 3



Finally, the $\text{Cu}(s)$ was filtered, dried, and weighed.

(This question is continued on the next page.)

Topic
7.5 Magnitude of the Equilibrium Constant

(This question is continued from the previous page.)

2018 Practice Exam #24

Q: Cu recovery - phosphate major species if pH is 1

$\text{H}_3\text{PO}_4(aq)$	
K_{a1}	7.5×10^{-3}
K_{a2}	6.2×10^{-8}
K_{a3}	4.2×10^{-13}

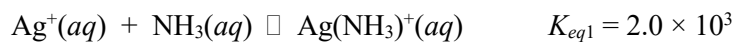
The values of the dissociation constants for H_3PO_4 are given in the table above. Given that the solution in the beaker at the end of step 2 had a pH of approximately 1, which of the following chemical species had the lowest concentration among the products of step 2?

- (A) $\text{H}^+(aq)$
- (B) $\text{H}_2\text{PO}_4^-(aq)$
- (C) $\text{HPO}_4^{2-}(aq)$
- * (D) $\text{PO}_4^{3-}(aq)$

Topic
7.5 Magnitude of the Equilibrium Constant

2017 Practice Exam #47

Q: Ag species in highest conc. based on overall Keq3



Equal volumes of 0.1 M $\text{AgNO}_3(aq)$ and 2.0 M $\text{NH}_3(aq)$ are mixed and the reactions represented above occur. Which Ag species will have the highest concentration in the equilibrium system shown below, and why?



(A) $\text{Ag}^+(aq)$, because $K_{eq3} = 4$

(B) $\text{Ag}^+(aq)$, because $K_{eq1} < K_{eq2}$

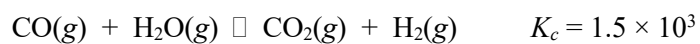
* (C) $\text{Ag}(\text{NH}_3)_2^+$, because $K_{eq3} = 1.6 \times 10^7$

(D) $\text{Ag}(\text{NH}_3)_2^+$, because $K_{eq1} < K_{eq2}$

Topic
7.5 Magnitude of the Equilibrium Constant

2016 Practice Exam #32

Q: Relative conc. when CO and H₂O approach equil.



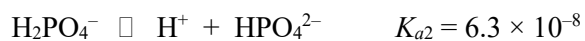
A 2.0 mol sample of CO(g) and a 2.0 mol sample of H₂O(g) are introduced into a previously evacuated 100. L rigid container, and the temperature is held constant as the reaction represented above reaches equilibrium. Which of the following is true at equilibrium?

- (A) $[\text{H}_2\text{O}] > [\text{CO}]$ and $[\text{CO}_2] > [\text{H}_2]$
- (B) $[\text{H}_2\text{O}] > [\text{H}_2]$
- * (C) $[\text{CO}_2] > [\text{CO}]$
- (D) $[\text{CO}] = [\text{H}_2\text{O}] = [\text{CO}_2] = [\text{H}_2]$

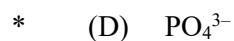
Topic
7.5 Magnitude of the Equilibrium Constant

2015 Practice Exam #15

Q: Ion in lowest conc. of 1 M NaH₂PO₄ solution



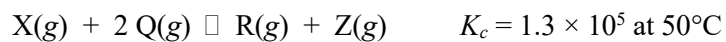
A solution is prepared by mixing 50 mL of 1 M NaH₂PO₄ with 50 mL of 1 M Na₂HPO₄. On the basis of the information above, which of the following species is present in the solution at the lowest concentration?



Topic
7.5 Magnitude of the Equilibrium Constant

2015 Practice Exam #46

Q: Concentration at equilibrium with large K - $X + 2Q$



A 1.0 mol sample of X(g) and a 1.0 mol sample of Q(g) are introduced into an evacuated, rigid 10.0 L container and allowed to reach equilibrium at 50°C according to the equation above. At equilibrium, which of the following is true about the concentrations of the gases?

(A) $[R] = \frac{1}{2} [Q]$

(B) $[Q] = \frac{1}{2} [X]$

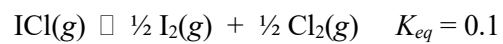
* (C) $[R] = [Z] > [Q]$

(D) $[X] = [Q] = [R] = [Z]$

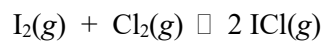
Topic
7.6 Properties of the Equilibrium Constant

2021 Practice Exam (from AP Classroom)

Q: K_{eq} manipulation



Based on the information above, what is the value of K_{eq} for the reaction represented below?



(A) 0.01

(B) 10

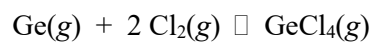
(C) 20

* (D) 100

Topic
7.6 Properties of the Equilibrium Constant

2019 Practice Exam #7

Q: Manipulating K for GeCl_4 equilibrium



The value of the equilibrium constant for the reaction represented above is 1×10^{10} . What is the value of the equilibrium constant for the following reaction?



- * (A) 1×10^{-20}
- (B) 1×10^{-10}
- (C) 1×10^{10}
- (D) 1×10^{20}

Topic
7.6 Properties of the Equilibrium Constant

2019 Practice Exam #50

Q: FeO + C Coupled reactions - K and sign of delta G



The formation of Fe(s) and O₂(g) from FeO(s) is not thermodynamically favorable at room temperature. In an effort to make the process favorable, C(s) is added to the FeO(s) at elevated temperatures. Based on the information above, which of the following gives the value of K_{eq} and the sign of ΔG° for the reaction represented by the equation below at 1000 K?



	K_{eq}	ΔG°
(A)	1×10^{-38}	Positive
(B)	1×10^{-38}	Negative
(C)	1×10^{26}	Positive
* (D)	1×10^{26}	Negative

Topic
7.6 Properties of the Equilibrium Constant

2018 Practice Exam #42

Q: Given SO₂ equilibria - relationship of K₁ and K₂

Reaction	K_{eq}
$\text{SO}_2(g) + \frac{1}{2}\text{O}_2(g) \rightleftharpoons \text{SO}_3(g)$	K_1
$2\text{SO}_3(g) \rightleftharpoons 2\text{SO}_2(g) + \text{O}_2(g)$	K_2

Which of the following shows the relationship between K_1 and K_2 in the reactions represented above?

(A) $K_2 = (K_1)^2$

(B) $K_2 = \sqrt{K_1}$

* (C) $K_2 = \frac{1}{(K_1)^2}$

(D) $K_2 = \frac{1}{K_1}$

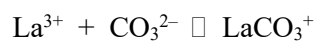
Topic
7.6 Properties of the Equilibrium Constant

2017 Practice Exam #45

Q: Determine overall K from K_1 , K_a and K_w - LaCO_3^+

Reaction	K_{eq}
$\text{La}^{3+} + \text{OH}^- + \text{HCO}_3^- \rightleftharpoons \text{LaCO}_3^+ + \text{H}_2\text{O}$	K_1
$\text{HCO}_3^- \rightleftharpoons \text{H}^+ + \text{CO}_3^{2-}$	K_a
$\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$	K_w

Based on the information above, which of the following expressions represents the equilibrium constant, K , for the reaction represented by the equation below?

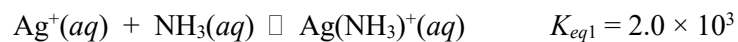


- (A) $K = (K_1)(K_a)(K_w)$
- (B) $K = \frac{(K_1)(K_a)}{K_w}$
- (C) $K = \frac{K_1}{(K_a)(K_w)}$
- * (D) $K = \frac{(K_1)(K_w)}{K_a}$

Topic
7.6 Properties of the Equilibrium Constant

2017 Practice Exam #47

Q: Ag species in highest conc. based on overall Keq3



Equal volumes of 0.1 M AgNO₃(aq) and 2.0 M NH₃(aq) are mixed and the reactions represented above occur. Which Ag species will have the highest concentration in the equilibrium system shown below, and why?



(A) Ag⁺(aq), because $K_{eq3} = 4$

(B) Ag⁺(aq), because $K_{eq1} < K_{eq2}$

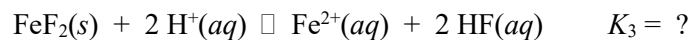
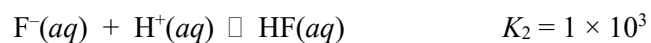
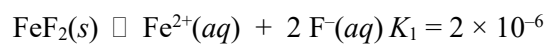
* (C) Ag(NH₃)₂⁺, because $K_{eq3} = 1.6 \times 10^7$

(D) Ag(NH₃)₂⁺, because $K_{eq1} < K_{eq2}$

Topic
7.6 Properties of the Equilibrium Constant

2014 Practice Exam #29

Q: Combining rxns - favorability from overall K value



On the basis of the information above, the dissolution of $\text{FeF}_2(s)$ in acidic solution is

- (A) thermodynamically favorable, because $K_2 > 1$
- * (B) thermodynamically favorable, because $K_3 > 1$
- (C) not thermodynamically favorable, because $K_1 < 1$
- (D) not thermodynamically favorable, because $K_3 < 1$

Topic
7.7 Calculating Equilibrium Concentrations

2023 Practice Exam (from AP Classroom)

Q: Relative concentrations in equilibrium mixture



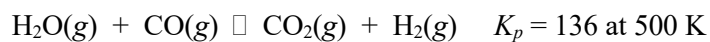
Equal volumes of 0.1 *M* solutions of $\text{Fe}^{3+}(aq)$ and $\text{SCN}^{-}(aq)$ are mixed and allowed to attain the equilibrium represented above at a temperature of 25°C. Which of the following statements is correct about the system at equilibrium?

- (A) $[\text{SCN}^{-}] > [\text{FeSCN}^{2+}]$
- * (B) $[\text{SCN}^{-}] < [\text{FeSCN}^{2+}]$
- (C) $[\text{Fe}^{3+}] > [\text{FeSCN}^{2+}]$
- (D) $[\text{Fe}^{3+}] = [\text{FeSCN}^{2+}]$

Topic
7.7 Calculating Equilibrium Concentrations

2022 Practice Exam (from AP Classroom)

Q: Calculate Q and compare to K_p



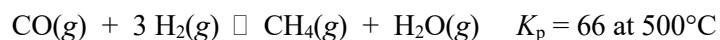
A vessel initially contains $\text{H}_2\text{O}(g)$ at a partial pressure of 0.30 atm, $\text{CO}(g)$ at a partial pressure of 0.10 atm, $\text{CO}_2(g)$ at a partial pressure of 1.5 atm, and $\text{H}_2(g)$ at a partial pressure 10. atm at 500 K. Which of the following occurs as the system approaches equilibrium at 500 K?

- * (A) The partial pressures of $\text{H}_2\text{O}(g)$ and $\text{CO}(g)$ increase because $Q > K_p$.
- (B) The partial pressures of $\text{H}_2\text{O}(g)$ and $\text{CO}(g)$ increase because $Q < K_p$.
- (C) The partial pressures of $\text{CO}_2(g)$ and $\text{H}_2(g)$ increase because $Q > K_p$.
- (D) The partial pressures of $\text{CO}_2(g)$ and $\text{H}_2(g)$ increase because $Q < K_p$.

Topic
7.7 Calculating Equilibrium Concentrations

2021 Practice Exam (from AP Classroom)

Q: Mixture moves toward equilibrium



At a certain time, the partial pressure of the gases in the reaction mixture represented above had the values shown in the table below.

P_{CO}	P_{H_2}	P_{CH_4}	$P_{\text{H}_2\text{O}}$
0.02 atm	1.0 atm	0.4 atm	0.4 atm

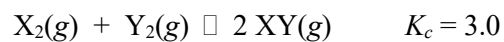
Based on the information above, which of the following occurred as the reaction mixture moved toward equilibrium?

- * (A) More $\text{CH}_4\text{(g)}$ was produced because the rate of the forward reaction was higher than the rate of the reverse reaction.
- (B) More $\text{H}_2\text{(g)}$ was produced because the rate of the reverse reaction was higher than the rate of the reverse reaction.
- (C) More $\text{CH}_4\text{(g)}$ was produced because the total pressure of the $\text{H}_2\text{(g)}$ and CO(g) combined was higher than that of the products; thus the reaction shifted to the side with the fewest number of moles of gas.
- (D) More $\text{H}_2\text{(g)}$ was produced because the pressure of CO(g) was the least and the reaction shifted to the side with the smaller number of moles of gas.

Topic
7.7 Calculating Equilibrium Concentrations

2019 Practice Exam #47

Q: Q vs K - which initial conc. forms more product



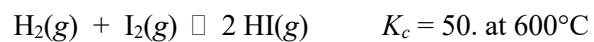
A mixture of $\text{X}_2(\text{g})$, $\text{Y}_2(\text{g})$, and $\text{XY}(\text{g})$ is placed in a previously evacuated, rigid container and allowed to reach equilibrium at a constant temperature, as shown above. Which of the following sets of initial concentrations would lead to the formation of more product as the system moves toward equilibrium?

	$[\text{X}_2]_{\text{initial}}$	$[\text{Y}_2]_{\text{initial}}$	$[\text{XY}]_{\text{initial}}$
* (A)	0.40 M	0.40 M	0.20 M
(B)	0.30 M	0.30 M	0.90 M
(C)	0.15 M	0.15 M	0.30 M
(D)	0.10 M	0.10 M	0.20 M

Topic
7.7 Calculating Equilibrium Concentrations

2018 Practice Exam #37

Q: H₂ I₂ HI - what is produced comparing Q and K



Equimolar samples of each of three gases, H₂(g), I₂(g), and HI(g), are introduced into a 3.0 L container that is heated to 600°C. According to the information above, which of the following will occur as the system approaches equilibrium?

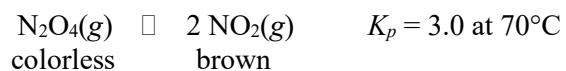
- (A) More H₂(g) will be produced because $Q > K_c$.
- (B) More I₂(g) will be produced because $Q < K_c$.
- * (C) More HI(g) will be produced because $Q < K_c$.
- (D) No change will occur because $Q = K_c$.

Topic
7.7 Calculating Equilibrium Concentrations

2017 Practice Exam #22

Q: N₂O₄ NO₂ equil - P of NO₂ if P of N₂O₄ is 1.33atm

Questions X-Y refer to the following information.



A mixture of NO₂(g) and N₂O₄(g) is placed in a glass tube and allowed to reach equilibrium at 70°C, as represented above.

If $P_{\text{N}_2\text{O}_4}$ is 1.33 atm when the system is at equilibrium at 70°C, what is P_{NO_2} ?

(A) 0.44 atm

* (B) 2.0 atm

(C) 2.3 atm

(D) 4.0 atm

Topic
7.7 Calculating Equilibrium Concentrations

2017 Practice Exam #41

Q: O₂ and O₃ equil - change in O₃ amount and Q vs K



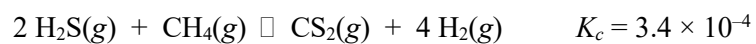
For the system represented above, [O₂] and [O₃] initially are 0.150 mol/L and 2.5 mol/L respectively. Which of the following best predicts what will occur as the system approaches equilibrium at 570 K?

- (A) The amount of O₃(g) will increase, because $Q < K_c$.
- (B) The amount of O₃(g) will decrease, because $Q < K_c$.
- (C) The amount of O₃(g) will increase, because $Q > K_c$.
- * (D) The amount of O₃(g) will decrease, because $Q > K_c$.

Topic
7.7 Calculating Equilibrium Concentrations

2016 Practice Exam #42

Q: H₂S + CH₄ - highest conc. at equilibrium given K



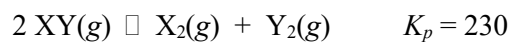
A 0.10 mol sample of each of the four species in the reaction represented above is injected into a rigid, previously evacuated 1.0 L container. Which of the following species will have the highest concentration when the system reaches equilibrium?

- * (A) H₂S(g)
- (B) CH₄(g)
- (C) CS₂(g)
- (D) H₂(g)

Topic
7.7 Calculating Equilibrium Concentrations

2015 Practice Exam #16

Q: Given partial P, direction rxn proceeds to equil.



A certain gas, $\text{XY}(g)$, decomposes as represented by the equation above. A sample of each of the three gases is put in a previously evacuated container. The initial partial pressures of the gases are shown in the table below.

Gas	Initial Partial Pressure (atm)
XY	0.010
X_2	0.20
Y_2	2.0

The temperature of the reaction mixture is held constant. In which direction will the reaction proceed?

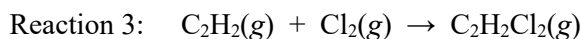
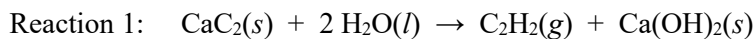
- (A) The reaction will form more products.
- * (B) The reaction will form more reactant.
- (C) The mixture is at equilibrium, so there will be no change.
- (D) It cannot be determined unless the volume of the container is known.

Topic
7.7 Calculating Equilibrium Concentrations

2015 Practice Exam #34

Q: CaC_2 rxn - predict precipitation of $\text{Ca}(\text{OH})_2$ Q vs K

Questions X-Y refer to the reactions represented below, which are involved in a demonstration commonly known as "underwater fireworks."



$\text{Ca}(\text{OH})_2(s)$ precipitates when a 1.0 g sample of $\text{CaC}_2(s)$ is added to 1.0 L of distilled water at room temperature. If a 0.064 g sample of $\text{CaC}_2(s)$ (molar mass 64 g/mol) is used instead and all of it reacts, which of the following will occur and why? (The value of K_{sp} for $\text{Ca}(\text{OH})_2$ is 8.0×10^{-8} .)

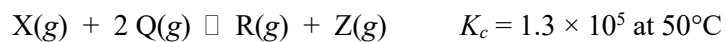
- (A) $\text{Ca}(\text{OH})_2$ will precipitate because $Q > K_{sp}$.
- (B) $\text{Ca}(\text{OH})_2$ will precipitate because $Q < K_{sp}$.
- (C) $\text{Ca}(\text{OH})_2$ will not precipitate because $Q > K_{sp}$.

* (D) $\text{Ca}(\text{OH})_2$ will not precipitate because $Q < K_{sp}$.

Topic
7.7 Calculating Equilibrium Concentrations

2015 Practice Exam #46

Q: Concentration at equilibrium with large K - X + 2Q



A 1.0 mol sample of X(g) and a 1.0 mol sample of Q(g) are introduced into an evacuated, rigid 10.0 L container and allowed to reach equilibrium at 50°C according to the equation above. At equilibrium, which of the following is true about the concentrations of the gases?

(A) $[\text{R}] = \frac{1}{2} [\text{Q}]$

(B) $[\text{Q}] = \frac{1}{2} [\text{X}]$

* (C) $[\text{R}] = [\text{Z}] > [\text{Q}]$

(D) $[\text{X}] = [\text{Q}] = [\text{R}] = [\text{Z}]$

Topic
7.7 Calculating Equilibrium Concentrations

2014 Practice Exam #22

Q: CH₃OH equil. - conc. at equil with 1.0 mol initial

Questions X-Y refer to the following information.



The synthesis of CH₃OH(g) from CO(g) and H₂(g) is represented by the equation above. The value of K_c for the reaction at 483 K is 14.5.

A 1.0 mol sample of CO(g) and a 1.0 mol sample of H₂(g) are pumped into a rigid, previously evacuated 2.0 L reaction vessel at 483 K. Which of the following is true at equilibrium?

(A) $[\text{H}_2] = 2[\text{CO}]$

* (B) $[\text{H}_2] < [\text{CO}]$

(C) $[\text{CO}] = [\text{CH}_3\text{OH}] < [\text{H}_2]$

(D) $[\text{CO}] = [\text{CH}_3\text{OH}] = [\text{H}_2]$

Topic
7.7 Calculating Equilibrium Concentrations

2014 Practice Exam #36

Q: Q vs K - pressure change as system reaches equil.



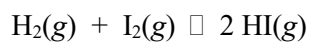
At a certain point in time, a 1.00 L rigid reaction vessel contains 1.5 mol of $\text{PCl}_3(\text{g})$, 1.0 mol of $\text{Cl}_2(\text{g})$, and 2.5 mol of $\text{PCl}_5(\text{g})$. Which of the following describes how the measured pressure in the reaction vessel will change and why it will change that way as the reaction system approaches equilibrium at constant temperature?

- (A) The pressure will increase because $Q < K_c$.
- (B) The pressure will increase because $Q > K_c$.
- * (C) The pressure will decrease because $Q < K_c$.
- (D) The pressure will decrease because $Q > K_c$.

Topic
7.7 Calculating Equilibrium Concentrations

2013 Practice Exam #7

Q: H₂ I₂ HI - What occurs as system moves to equil.



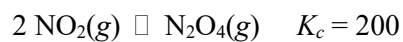
At 450°C, 2.0 moles each of H₂(g), I₂(g), and HI(g) are combined in a 1.0 L rigid container. The value of K_c at 450°C is 50. Which of the following will occur as the system moves toward equilibrium?

- (A) More H₂(g) and I₂(g) will form.
- * (B) More HI(g) will form.
- (C) The total pressure will decrease.
- (D) No net reaction will occur, because the number of molecules is the same on both sides of the equation.

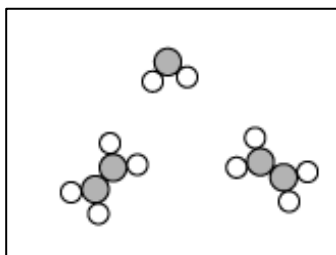
Topic
7.8 Representations of Equilibrium

2021 Practice Exam (from AP Classroom)

Q: Equilibrium particulate representation

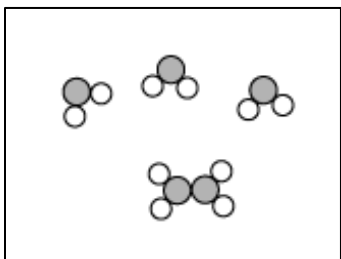


The equilibrium system shown above is represented in the diagram below in which each molecule represents one mole of the substance in a 100. L container at a constant temperature.

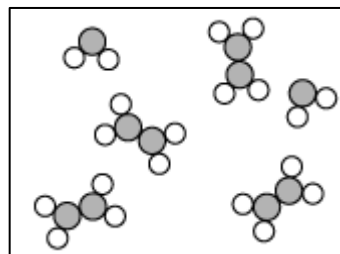


Additional $\text{N}_2\text{O}_4(g)$ is added to the container and allowed to reestablish equilibrium. Which of the following best represents the system after equilibrium has been reestablished?

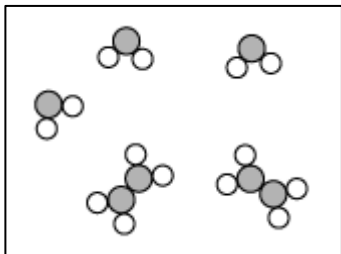
(A)



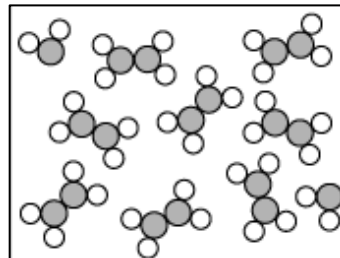
(C)



(B)



* (D)



Topic
7.9 Introduction to Le Châtelier's Principle

2023 Practice Exam (from AP Classroom)

Q: Change to increase HOCl



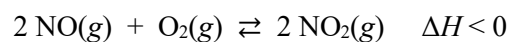
A chemical system at equilibrium is represented above. Which of the following changes will increase the number of moles of HOCl(g) present in the system?

- * (A) Increasing the temperature
- (B) Decreasing the volume of the reaction vessel
- (C) Adding a catalyst
- (D) Removing Cl₂O(g)

Topic
7.9 Introduction to Le Châtelier's Principle

2023 Practice Exam (from AP Classroom)

Q: Nitrogen dioxide equilibrium



Which of the following changes will increase the amount of $\text{NO}_2(g)$ in the reaction system at equilibrium represented above?

- (A) Adding a catalyst to the reaction system
- (B) Increasing the pressure by adding $\text{Ne}(g)$ to the system at constant temperature
- (C) Increasing the temperature at constant volume
- * (D) Decreasing the volume at constant temperature

Topic
7.9 Introduction to Le Châtelier's Principle

2022 Practice Exam (from AP Classroom)

Q: Change in NO CO₂ equilibrium system



Which of the following changes will increase the amount of NO₂(g) in the equilibrium system represented by the equation above?

- * (A) Removing CO(g) from the system
- (B) Removing CO₂(g) from the system
- (C) Increasing the volume of the reaction vessel
- (D) Decreasing the volume of the reaction vessel

Topic
7.9 Introduction to Le Châtelier's Principle

2022 Practice Exam (from AP Classroom)

Q: Solubility change with temperature

Compound	$\Delta H_{\text{solution}}$ (kJ/mol)
NaF(s)	+0.91
MgF ₂ (s)	−18

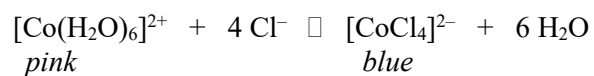
Based on the information in the table above, the solubility of which compound, if any, will increase if the water temperature is increased?

- * (A) NaF(s) only
- (B) MgF₂(s) only
- (C) Both NaF(s) and MgF₂(s)
- (D) The solubility of neither NaF(s) nor MgF₂(s) will increase.

Topic
7.9 Introduction to Le Châtelier's Principle

2021 Practice Exam (from AP Classroom)

Q: Reaction shift and color change



The solvent in the nonaqueous system represented above is 2-propanol. If a small amount of water is added to the system, how will the color of the solution be affected, and why?

- * (A) The solution will become more pink because more $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ will be produced.
- (B) The solution will become more pink because the pH of the solution will increase.
- (C) The solution will become more blue because more $[\text{CoCl}_4]^{2-}$ will be produced.
- (D) The solution will become more blue because the pH of the solution will decrease.

Topic
7.9 Introduction to Le Châtelier's Principle

2018 Practice Exam #20

Q: Equil. system that increases products at higher V

For which of the equilibrium systems represented below will the amount of product(s) at equilibrium increase if the volume of the reaction vessel is increased at a constant temperature?

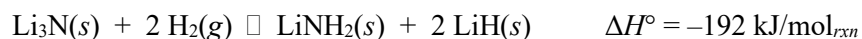
- * (A) $\text{PCl}_5(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g)$
- (B) $2 \text{NO}(g) + \text{O}_2(g) \rightleftharpoons 2 \text{NO}_2(g)$
- (C) $\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{NO}(g)$
- (D) $2 \text{CO}(g) \rightleftharpoons \text{C}(s) + \text{CO}_2(g)$

Topic
7.9 Introduction to Le Châtelier's Principle

2018 Practice Exam #36

Q: H₂ storage - maximize amount of H₂ in equilibrium

Questions X-Y refer to the following information.



Because pure H₂ is a hazardous substance, safer and more cost effective techniques to store it as a solid for shipping purposes have been developed. One such method is the reaction represented above, which occurs at 200°C.

The amount of H₂(g) present in a reaction mixture at equilibrium can be maximized by

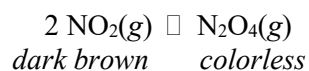
- (A) increasing the temperature and increasing the pressure by decreasing the volume
- * (B) increasing the temperature and decreasing the pressure by increasing the volume
- (C) decreasing the temperature and increasing the pressure by decreasing the volume
- (D) decreasing the temperature and decreasing the pressure by increasing the volume

Topic
7.9 Introduction to Le Châtelier's Principle

2018 Practice Exam #46

Q: NO₂ dimerization - changes when T is decreased

Questions X-Y refer to the following information.



The dimerization of NO₂(g), an exothermic process, is represented by the equation above.

A mixture of NO₂(g) and N₂O₄(g) is at equilibrium in a rigid reaction vessel. If the temperature of the mixture is decreased, then

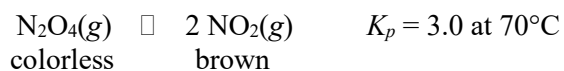
- (A) [NO₂] will increase and the mixture will turn a darker brown
- * (B) [N₂O₄] will increase and the mixture will turn a lighter brown
- (C) [N₂O₄] will decrease and the mixture will turn a lighter brown
- (D) no change will be observed

Topic
7.9 Introduction to Le Châtelier's Principle

2017 Practice Exam #23

Q: N₂O₄ NO₂ equil - mixture is lighter color at low T

Questions X-Y refer to the following information.



A mixture of NO₂(g) and N₂O₄(g) is placed in a glass tube and allowed to reach equilibrium at 70°C, as represented above.

Which of the following statements best helps to explain why the contents of the tube containing the equilibrium mixture turned a lighter color when the tube was placed into an ice bath?

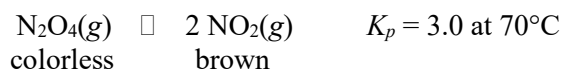
- (A) The forward reaction is exothermic.
- * (B) The forward reaction is endothermic.
- (C) The ice bath lowered the activation energy.
- (D) The ice bath raised the activation energy.

Topic
7.9 Introduction to Le Châtelier's Principle

2017 Practice Exam #24

Q: N₂O₄ NO₂ equil - effect of adding Ar to mixture

Questions X-Y refer to the following information.



A mixture of NO₂(g) and N₂O₄(g) is placed in a glass tube and allowed to reach equilibrium at 70°C, as represented above.

Which of the following best predicts how the partial pressures of the reacting species will be affected if a small amount of Ar(g) is added to the equilibrium mixture at constant volume?

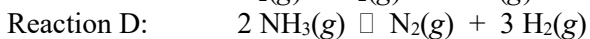
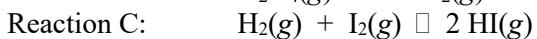
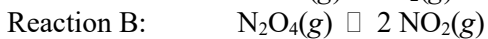
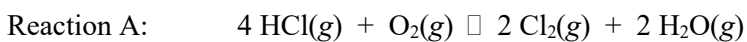
- (A) P_{NO_2} will decrease and $P_{\text{N}_2\text{O}_4}$ will increase.
- (B) P_{NO_2} will increase and $P_{\text{N}_2\text{O}_4}$ will decrease.
- (C) Both P_{NO_2} and $P_{\text{N}_2\text{O}_4}$ will decrease.

* (D) No change will take place.

Topic
7.9 Introduction to Le Châtelier's Principle

2017 Practice Exam #26

Q: Reducing volume on equil. rxn increases products



The reactions represented above are carried out in sealed, rigid containers and allowed to reach equilibrium. If the volume of each container is reduced from 1.0 L to 0.5 L at constant temperature, for which of the reactions will the amount of product(s) be increased?

- * (A) Reaction A
- (B) Reaction B
- (C) Reaction C
- (D) Reaction D

Topic
7.9 Introduction to Le Châtelier's Principle

2017 Practice Exam #33

Q: Effect of adding NaOH to dichromate-chromate equil



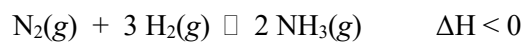
The equilibrium system represented by the equation above initially contains equal concentrations of $\text{Cr}_2\text{O}_7^{2-}(aq)$ and $\text{CrO}_4^{2-}(aq)$. Which of the following statements correctly predicts the result of adding a sample of 6.0 *M* NaOH(*aq*) to the system, and provides an explanation?

- (A) The mixture will become more orange because $\text{OH}^-(aq)$ will oxidize the Cr in $\text{CrO}_4^{2-}(aq)$.
- (B) The mixture will become more yellow because $\text{OH}^-(aq)$ will reduce the Cr in $\text{Cr}_2\text{O}_7^{2-}(aq)$.
- * (C) The mixture will become more yellow because $\text{OH}^-(aq)$ will shift the equilibrium toward products.
- (D) The color of the mixture will not change because $\text{OH}^-(aq)$ does not appear in the equilibrium expression.

Topic
7.9 Introduction to Le Châtelier's Principle

2016 Practice Exam #4

Q: Ammonia synthesis equil - increase amount of NH₃



NH₃(g) was synthesized at 200°C in the presence of a powdered Os(s) catalyst, leading to the equilibrium system represented above. Which of the following changes would result in more NH₃(g) in the mixture after equilibrium is reestablished?

- (A) Replacing the powdered Os(s) with a solid cube of Os(s) of the same total mass
- (B) Increasing the temperature of the system to 250°C at constant pressure
- (C) Removing some H₂(g)
- * (D) Adding some N₂(g)

Topic
7.9 Introduction to Le Châtelier's Principle

2015 Practice Exam #33

Q: $\text{HF(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{F}^-(\text{aq})$



The dissociation of the weak acid HF in water is represented by the equation above. Adding a 1.0 mL sample of which of the following would increase the percent ionization of HF(aq) in 10 mL of a solution of 1.0 M HF ?

- (A) 1.0 M KF
- (B) 1.0 M H₂SO₄
- (C) 10.0 M HF
- * (D) Distilled water

Topic
7.9 Introduction to Le Châtelier's Principle

2015 Practice Exam #40

Q: Decrease amount of CaO in CaCO₃ equilibrium



$$\Delta H^\circ = 178 \text{ kJ/mol}_{\text{rxn}}$$

The reaction system represented above is at equilibrium. Which of the following will decrease the amount of CaO(*s*) in the system?

- (A) Increasing the volume of the reaction vessel at constant temperature
- * (B) Lowering the temperature of the system
- (C) Removing some CO₂(*g*) at constant temperature
- (D) Removing some CaCO₃(*s*) at constant temperature

Topic
7.9 Introduction to Le Châtelier's Principle

2014 Practice Exam #4

Q: BaO₂ decomp equilibrium - increase amount of BaO₂



$$\Delta H^\circ = 162 \text{ kJ/mol}_{\text{rxn}}$$

A sealed rigid vessel contains BaO₂(s) in equilibrium with BaO(s) and O₂(g) as represented by the equation above. Which of the following changes will increase the amount of BaO₂(s) in the vessel?

- (A) Removing a small amount of O₂(g)
- (B) Removing a small amount of BaO(s)
- (C) Adding He gas to the vessel
- * (D) Lowering the temperature

Topic
7.9 Introduction to Le Châtelier's Principle

2014 Practice Exam #21

Q: CH₃OH equil. - effect of higher temperature on K

Questions X-Y refer to the following information.



The synthesis of CH₃OH(g) from CO(g) and H₂(g) is represented by the equation above. The value of K_c for the reaction at 483 K is 14.5.

Which of the following explains the effect on the equilibrium constant, K_c , when the temperature of the reaction system is increased to 650 K?

- (A) K_c will increase because the activation energy of the forward reaction increases more than that of the reverse reaction.
- (B) K_c will increase because there are more reactant molecules than product molecules.
- * (C) K_c will decrease because the reaction is exothermic.
- (D) K_c is constant and will not change.

Topic
7.9 Introduction to Le Châtelier's Principle

2014 Practice Exam #23

Q: CH₃OH equil. - total P after volume is halved

Questions X-Y refer to the following information.



The synthesis of CH₃OH(g) from CO(g) and H₂(g) is represented by the equation above. The value of K_c for the reaction at 483 K is 14.5.

A mixture of CO(g) and H₂(g) is pumped into a previously evacuated 2.0 L reaction vessel. The total pressure of the reaction system is 1.2 atm at equilibrium. What will be the total pressure of the system if the volume of the reaction vessel is reduced to 1.0 L at constant temperature?

- (A) Less than 1.2 atm
- * (B) Greater than 1.2 atm but less than 2.4 atm
- (C) 2.4 atm
- (D) Greater than 2.4 atm

Topic
7.10 Reaction Quotient and Le Châtelier's Principle

2021 Practice Exam (from AP Classroom)

Q: K_{sp} and mixing solutions



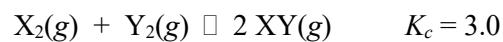
The dissolution of $\text{BaCO}_3(s)$ in water is represented above. A 20.0 mL sample of $1.0 \times 10^{-4} M \text{Ba}(\text{NO}_3)_2(aq)$ is mixed with an 80.0 mL sample of $1.0 \times 10^{-4} M \text{Na}_2\text{CO}_3(aq)$. Which of the following correctly predicts and explains the outcome?

- (A) A precipitate will form, because $Q = 1.0 \times 10^{-8}$.
- (B) A precipitate will form, because $Q = 1.6 \times 10^{-9}$.
- (C) A precipitate will not form, because $Q = 1.0 \times 10^{-8}$.
- * (D) A precipitate will not form, because $Q = 1.6 \times 10^{-9}$.

Topic
7.10 Reaction Quotient and Le Châtelier's Principle

2019 Practice Exam #47

Q: Q vs K - which initial conc. forms more product



A mixture of $\text{X}_2(\text{g})$, $\text{Y}_2(\text{g})$, and $\text{XY}(\text{g})$ is placed in a previously evacuated, rigid container and allowed to reach equilibrium at a constant temperature, as shown above. Which of the following sets of initial concentrations would lead to the formation of more product as the system moves toward equilibrium?

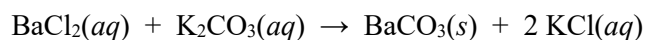
	$[\text{X}_2]_{\text{initial}}$	$[\text{Y}_2]_{\text{initial}}$	$[\text{XY}]_{\text{initial}}$
* (A)	0.40 M	0.40 M	0.20 M
(B)	0.30 M	0.30 M	0.90 M
(C)	0.15 M	0.15 M	0.30 M
(D)	0.10 M	0.10 M	0.20 M

Topic
7.11 Introduction to Solubility Equilibria

2023 Practice Exam (from AP Classroom)

Q: Least number of moles of precipitate

Students are asked to design an experiment to determine the molarity of a $\text{BaCl}_2(aq)$ solution. After examining the K_{sp} values of some barium-containing compounds, the students decide to use $0.100\text{ M K}_2\text{CO}_3(aq)$ to precipitate the barium ions. An excess of $\text{K}_2\text{CO}_3(aq)$ is added to a 50.0 mL sample of the $\text{BaCl}_2(aq)$ solution, and the reaction represented by the following equation occurs.



The $\text{BaCO}_3(s)$ is filtered, dried, and weighed. The data are recorded in the following table.

Volume of $\text{BaCl}_2(aq)$	Volume of $0.100\text{ M K}_2\text{CO}_3(aq)$	Mass of $\text{BaCO}_3(s)$
50.0 mL	$150.\text{ mL}$	1.97 g

The molar masses of BaCl_2 and BaCO_3 are 208 g/mol and 197 g/mol , respectively.

Substance	K_{sp}
$\text{Ba}(\text{NO}_3)_2$	3.33×10^{-1}
BaF_2	1.84×10^{-7}
BaSO_4	1.08×10^{-10}
BaCrO_4	1.17×10^{-10}

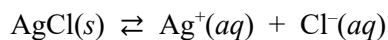
Considering the K_{sp} values listed above, which of the following solutions, when used instead of $\text{K}_2\text{CO}_3(aq)$ in the precipitation procedure, would produce the least number of moles of precipitate?

- * (A) $0.200\text{ M NaNO}_3(aq)$
- (B) $0.200\text{ M NaF}(aq)$
- (C) $0.100\text{ M Na}_2\text{SO}_4(aq)$
- (D) $0.100\text{ M Na}_2\text{CrO}_4(aq)$

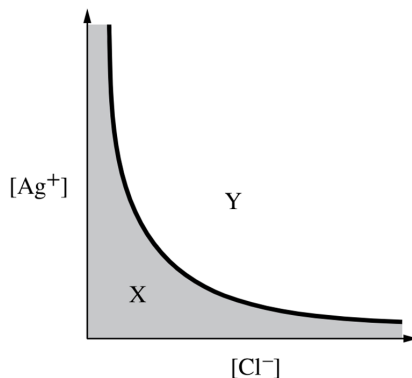
Topic
7.11 Introduction to Solubility Equilibria

2023 Practice Exam (from AP Classroom)

Q: Saturation curve of AgCl



The preceding equation represents the equilibrium of a saturated solution of $\text{AgCl}(aq)$ in contact with $\text{AgCl}(s)$. All points on the curve in the following graph represent values of $[\text{Ag}^+]$ and $[\text{Cl}^-]$ for which the product $[\text{Ag}^+][\text{Cl}^-]$ is equal to the value of K_{sp} for AgCl. Which of the following provides the correct comparison of Q and K_{sp} and describes the net process that occurs at any point in region Y (unshaded) of the graph?



- (A) $Q > K_{sp}$ and dissolution of $\text{AgCl}(s)$ occurs.
- (B) $Q < K_{sp}$ and dissolution of $\text{AgCl}(s)$ occurs.
- * (C) $Q > K_{sp}$ and precipitation of $\text{AgCl}(s)$ occurs.
- (D) $Q < K_{sp}$ and precipitation of $\text{AgCl}(s)$ occurs.

Topic
7.11 Introduction to Solubility Equilibria

2022 Practice Exam (from AP Classroom)

Q: Ion concentration in PbF_2 solution

The value of K_{sp} for the salt PbF_2 is 3.2×10^{-8} . The $[\text{Pb}^{2+}]$ in a saturated solution of PbF_2 is approximately

- (A) $2 \times 10^{-4} M$
- (B) $4 \times 10^{-4} M$
- * (C) $2 \times 10^{-3} M$
- (D) $4 \times 10^{-3} M$

Topic
7.11 Introduction to Solubility Equilibria

2022 Practice Exam (from AP Classroom)

Q: Rank solubilities from K_{sp}

Compound	K_{sp}
$\text{Fe}(\text{OH})_2$	4.9×10^{-17}
$\text{Cu}(\text{OH})_2$	1.6×10^{-19}
$\text{Co}(\text{OH})_2$	1.1×10^{-15}

Which of the following ranks the compounds listed in the table above in order of increasing solubility?

(A) $\text{Fe}(\text{OH})_2 < \text{Cu}(\text{OH})_2 < \text{Co}(\text{OH})_2$

(B) $\text{Fe}(\text{OH})_2 < \text{Co}(\text{OH})_2 < \text{Cu}(\text{OH})_2$

(C) $\text{Co}(\text{OH})_2 < \text{Fe}(\text{OH})_2 < \text{Cu}(\text{OH})_2$

* (D) $\text{Cu}(\text{OH})_2 < \text{Fe}(\text{OH})_2 < \text{Co}(\text{OH})_2$

Topic
7.11 Introduction to Solubility Equilibria

2021 Practice Exam (from AP Classroom)

Q: K_{sp} from ion concentration

Compound	$[\text{Pb}^{2+}]$ in Saturated Solution
PbS	$1.7 \times 10^{-14} M$
PbCO ₃	$2.7 \times 10^{-7} M$
PbCrO ₄	$5.5 \times 10^{-7} M$
PbSO ₄	$1.6 \times 10^{-4} M$

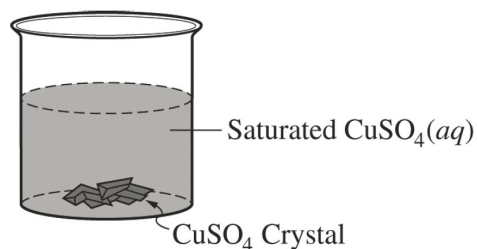
Based on $[\text{Pb}^{2+}]$ in saturated solutions of the compounds listed in the table above, which of the compounds has the smallest K_{sp} value?

- * (A) PbS
- (B) PbCO₃
- (C) PbCrO₄
- (D) PbSO₄

Topic
7.11 Introduction to Solubility Equilibria

2019 Practice Exam #34

Q: Conc. of sulfate constant - CuSO_4 soln evaporates



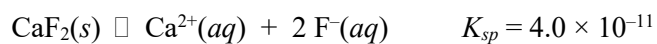
The saturated $\text{CuSO}_4(aq)$ shown above is left uncovered on a lab bench at a constant temperature. As the solution evaporates, 1.0 mL samples of the solution are removed every three days and the $[\text{SO}_4^{2-}]$ in the samples is measured. It is observed that the $[\text{SO}_4^{2-}]$ in the solution did not change over time. Which of the following best helps to explain the observation?

- (A) As the solution evaporates, $\text{Cu}^{2+}(aq)$ and $\text{SO}_4^{2-}(aq)$ leave the beaker along with the water molecules.
- (B) As the solution evaporates, the dissolution of $\text{CuSO}_4(s)$ in the beaker decreases.
- (C) The evaporation of water is endothermic, so more $\text{CuSO}_4(s)$ dissolves exothermically in the solution, which increases the $[\text{SO}_4^{2-}]$.
- * (D) As water evaporates, more $\text{CuSO}_4(s)$ precipitates out of the solution in the beaker.

Topic
7.11 Introduction to Solubility Equilibria

2019 Practice Exam #49

Q: Max. Ca^{2+} to keep F^- at level for dental health



The concentration of $\text{F}^-(aq)$ in drinking water that is considered to be ideal for promoting dental health is $4.0 \times 10^{-5} M$. Based on the information above, the maximum concentration of $\text{Ca}^{2+}(aq)$ that can be present in drinking water without lowering the concentration of $\text{F}^-(aq)$ below the ideal level is closest to

- (A) $0.25 M$
- * (B) $0.025 M$
- (C) $1.6 \times 10^{-6} M$
- (D) $1.6 \times 10^{-15} M$

Topic
7.11 Introduction to Solubility Equilibria

2018 Practice Exam #29

Q: Equimolar samples of $\text{Pb(OH)}_2(s)$...

Compound	K_{sp} at 25°C
$\text{Pb(OH)}_2(s)$	1.2×10^{-15}
$\text{PbI}_2(s)$	1.4×10^{-8}
$\text{PbF}_2(s)$	4.0×10^{-8}

Equimolar samples of $\text{Pb(OH)}_2(s)$, $\text{PbI}_2(s)$, and $\text{PbF}_2(s)$ are placed in three separate beakers, each containing 250 mL of water at 25°C . After the solutions are stirred, solid remains in the bottom of each beaker. Based on the K_{sp} values for the compounds listed in the table above, a solution of which of the compounds will have the lowest $[\text{Pb}^{2+}]$?

- * (A) $\text{Pb(OH)}_2(s)$ only
- (B) $\text{PbI}_2(s)$ only
- (C) $\text{PbF}_2(s)$ only
- (D) Both $\text{PbI}_2(s)$ and $\text{PbF}_2(s)$ will produce solutions with the same, lowest $[\text{Pb}^{2+}]$.

Topic
7.11 Introduction to Solubility Equilibria

2017 Practice Exam #39

Q: Silver halide K_{sp} - order solns by increasing Ag^+

Solution	Solute	K_{sp} at 25°C
X	AgBr	5.0×10^{-13}
Y	AgCl	1.8×10^{-10}
Z	AgI	8.3×10^{-17}

Three saturated solutions (X, Y, and Z) are prepared at 25°C. Based on the information in the table above, which of the following lists the solutions in order of increasing $[Ag^+]$?

(A) $X < Z < Y$

(B) $Y < X < Z$

(C) $Z < Y < X$

* (D) $Z < X < Y$

Topic
7.11 Introduction to Solubility Equilibria

2016 Practice Exam #12

Q: Given K_{sp} - compound that gives highest Cl^- conc.

Compound	K_{sp}
PbCl_2	1.2×10^{-5}
CuCl	1.6×10^{-7}
AgCl	1.8×10^{-10}
Hg_2Cl_2	1.4×10^{-18}

Based on the K_{sp} values in the table above, a saturated solution of which of the following compounds has the highest $[\text{Cl}^-]$?

- * (A) PbCl_2
- (B) CuCl
- (C) AgCl
- (D) Hg_2Cl_2

Topic
7.11 Introduction to Solubility Equilibria

2016 Practice Exam #33

Q: Predict precipitation of Ag^+ and Pb^{2+} with K_2SO_4

Compound	K_{sp} at 298 K
Ag_2SO_4	1×10^{-5}
PbSO_4	1×10^{-8}

A 1.0 L solution of $\text{AgNO}_3(aq)$ and $\text{Pb}(\text{NO}_3)_2(aq)$ has a Ag^+ concentration of 0.020 M and a Pb^{2+} concentration of 0.0010 M. A 0.0010 mol sample of $\text{K}_2\text{SO}_4(s)$ is added to the solution. Based on the information in the table above, which of the following will occur? (Assume that the volume change of the solution is negligible.)

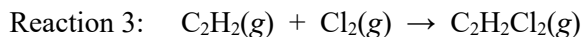
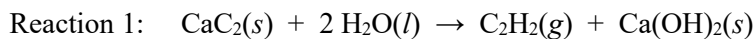
- (A) No precipitate will form.
- (B) Only $\text{Ag}_2\text{SO}_4(s)$ will precipitate.
- * (C) Only $\text{PbSO}_4(s)$ will precipitate.
- (D) Both $\text{Ag}_2\text{SO}_4(s)$ and $\text{PbSO}_4(s)$ will precipitate.

Topic
7.11 Introduction to Solubility Equilibria

2015 Practice Exam #34

Q: CaC_2 rxn - predict precipitation of $\text{Ca}(\text{OH})_2$ Q vs K

Questions X-Y refer to the reactions represented below, which are involved in a demonstration commonly known as "underwater fireworks."



$\text{Ca}(\text{OH})_2(s)$ precipitates when a 1.0 g sample of $\text{CaC}_2(s)$ is added to 1.0 L of distilled water at room temperature. If a 0.064 g sample of $\text{CaC}_2(s)$ (molar mass 64 g/mol) is used instead and all of it reacts, which of the following will occur and why? (The value of K_{sp} for $\text{Ca}(\text{OH})_2$ is 8.0×10^{-8} .)

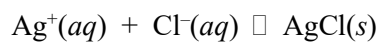
- (A) $\text{Ca}(\text{OH})_2$ will precipitate because $Q > K_{sp}$.
- (B) $\text{Ca}(\text{OH})_2$ will precipitate because $Q < K_{sp}$.
- (C) $\text{Ca}(\text{OH})_2$ will not precipitate because $Q > K_{sp}$.

* (D) $\text{Ca}(\text{OH})_2$ will not precipitate because $Q < K_{sp}$.

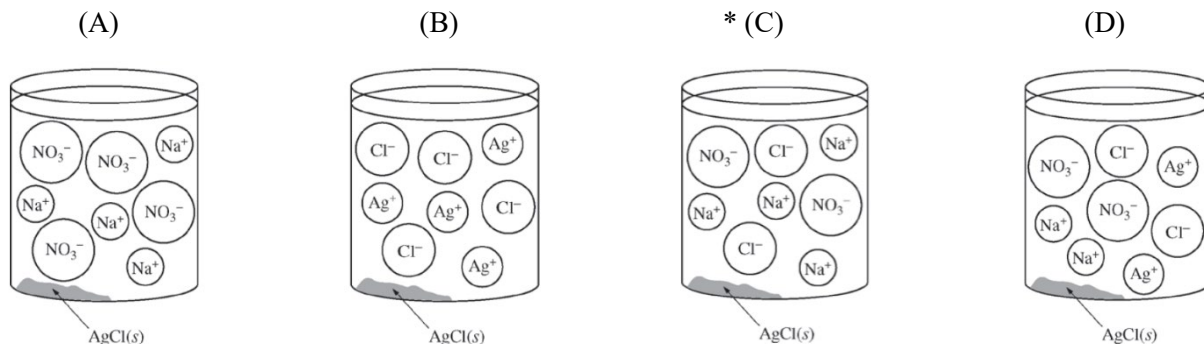
Topic
7.11 Introduction to Solubility Equilibria

2013 Practice Exam #28

Q: Particulate diagram - soln after AgCl precipitates



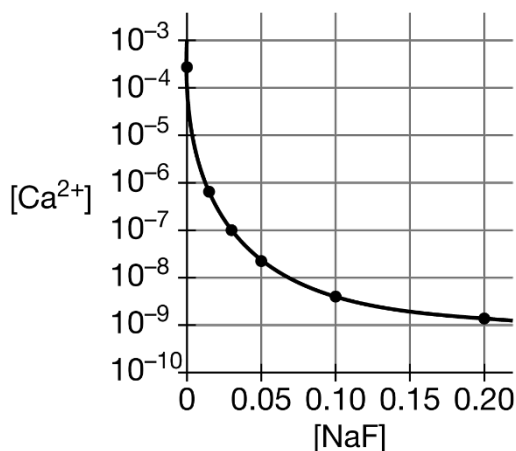
A student mixes dilute $\text{AgNO}_3(aq)$ with excess $\text{NaCl}(aq)$ to form $\text{AgCl}(s)$, as represented by the net ionic equation above. Which of the diagrams below best represents the ions that are present in significant concentrations in solution? (K_{sp} for AgCl is 1.8×10^{-10} .)



Topic
7.12 Common-Ion Effect

2021 Practice Exam (from AP Classroom)

Q: Solubility of CaF_2 in NaF



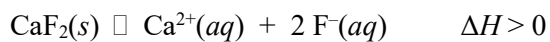
Which of the following statements best explains the trend in the molar solubility of $\text{CaF}_2(s)$ in various concentrations of $\text{NaF}(aq)$ shown in the graph above?

- * (A) Higher concentrations of $\text{F}^-(aq)$ allow less $\text{CaF}_2(s)$ to dissolve before the solution becomes saturated.
- (B) Higher concentrations of $\text{Na}^+(aq)$ lead to more favorable attractions between $\text{Na}^+(aq)$ ions and $\text{F}^-(aq)$ ions, thus less $\text{CaF}_2(s)$ dissolves.
- (C) Higher concentrations of $\text{F}^-(aq)$ produce more $\text{OH}^-(aq)$ through hydrolysis, causing $\text{Ca}(\text{OH})_2(s)$ to precipitate, thus more $\text{CaF}_2(s)$ dissolves.
- (D) Higher concentrations of $\text{F}^-(aq)$ cause the formation of the $\text{CaF}_4^{2-}(aq)$ complex ion, which allows more $\text{CaF}_2(s)$ to dissolve.

Topic
7.12 Common-Ion Effect

2018 Practice Exam #28

Q: Change that will decrease Ca^{2+} in saturated CaF_2



Dissolution of the slightly soluble salt CaF_2 is shown by the equation above. Which of the following changes will decrease $[\text{Ca}^{2+}]$ in a saturated solution of CaF_2 , and why? (Assume that after each change some $\text{CaF}_2(s)$ remains in contact with the solution.)

- (A) Allowing some of the water to evaporate from the solution, because more $\text{CaF}_2(s)$ will precipitate
- (B) Adding $0.1 \text{ M HNO}_3(aq)$, because some $\text{F}^{-}(aq)$ ions will become protonated
- (C) Adding $0.1 \text{ M NaNO}_3(aq)$, because additional liquid will dilute the solution
- * (D) Adding $\text{NaF}(s)$, because the reaction will proceed toward reactants

Topic
8.1 Introduction to Acids and Bases

2021 Practice Exam (from AP Classroom)

Q: Water pH and pOH at 37 degrees C

The value of K_w at 37°C is 2.4×10^{-14} . Which of the following statements about the pH and pOH of pure water at 37°C is correct?

- (A) $\text{pH} < 7$ and $\text{pOH} > 7$ because water dissociates to a lesser extent at 37°C than at 25°C .
- (B) $\text{pH} > 7$ and $\text{pOH} < 7$ because the dissociation of water is endothermic, and $\text{pH} + \text{pOH} = 14$.
- * (C) $\text{pH} = \text{pOH} < 7$ because water dissociates to a greater extent at 37°C than at 25°C .
- (D) $\text{pH} = \text{pOH} = 7$ because $[\text{H}_3\text{O}^+] = [\text{OH}^-]$ for pure water.

Topic
8.1 Introduction to Acids and Bases

2019 Practice Exam #29

Q: pH of pure water at 40 degree Celsius given Kw

The value of K_w at 40°C is 3.0×10^{-14} . What is the pH of pure water at 40°C?

- (A) 3.0
- * (B) 6.8
- (C) 7.0
- (D) 7.2

Topic
8.1 Introduction to Acids and Bases

2019 Practice Exam #32

Q: Volume of H₂O to take HNO₃ from pH 4.20 to 5.20

At 25°C, enough distilled water is added to a 30.0 mL sample of HNO₃(aq) with a pH of 4.20 so that the final pH of the diluted solution is 5.20. The volume of distilled water added to the original solution is closest to

- (A) 30.0 mL
- (B) 60.0 mL
- * (C) 270. mL
- (D) 300. mL

Topic
8.1 Introduction to Acids and Bases

2015 Practice Exam #30

Q: Account for pH of 6.8 for pure water at 37 C

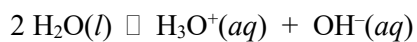
Which of the following accounts for the observation that the pH of pure water at 37°C is 6.8?

- (A) At 37°C water is naturally acidic.
- * (B) At 37°C the autoionization constant for water, K_w , is larger than it is at 25°C.
- (C) At 37°C water has a lower density than it does at 25°C; therefore $[H^+]$ is greater.
- (D) At 37°C water ionizes to a lesser extent than it does at 25°C.

Topic
8.1 Introduction to Acids and Bases

2014 Practice Exam #20

Q: Autoionization of H₂O and temperature - pK_w and pH



The autoionization of water is represented by the equation above. Values of pK_w at various temperatures are listed in the table below.

Temperature (°C)	pK _w
0	14.9
10	14.5
20	14.2
30	13.8
40	13.5

Based on the information above, which of the following statements is true?

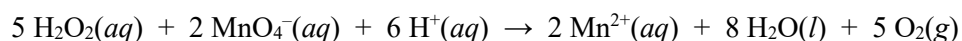
- (A) The dissociation of water is an exothermic process.
- (B) The pH of pure water is 7.00 at any temperature.
- (C) As the temperature increases, the pH of pure water increases.
- * (D) As the temperature increases, the pH of pure water decreases.

Topic
8.1 Introduction to Acids and Bases

2014 Practice Exam #34

Q: H₂O₂ titration - pH of soln as titration proceeds

Questions X-Y refer to the following.



In a titration experiment, H₂O₂(aq) reacts with MnO₄⁻(aq) as represented by the equation above. The dark purple KMnO₄ solution is added from a buret to a colorless, acidified solution of H₂O₂(aq) in an Erlenmeyer flask. (Note: At the end point of the titration, the solution is a pale pink color.)

Which of the following best describes what happens to the pH of the H₂O₂ solution as the titration proceeds?

- (A) The +2 charge on the manganese ions maintains the acidity of the solution.
- (B) The production of water dilutes the solution, making it basic.
- * (C) As H⁺ ions are consumed, the solution becomes less acidic and the pH increases.
- (D) As H⁺ ions are consumed, the solution becomes less acidic and the pH decreases.

Topic
8.2 pH and pOH of Strong Acids and Bases

2023 Practice Exam (from AP Classroom)

Q: Strong Base pH

The pH of a 0.009 *M* solution of $\text{KOH}(aq)$ is closest to which of the following?

(A) 2

(B) 5

(C) 9

* (D) 12

Topic
8.2 pH and pOH of Strong Acids and Bases

2022 Practice Exam (from AP Classroom)

Q: Hydronium concentration when combine acids

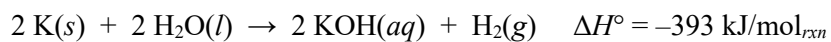
A student mixes 100. mL of 0.25 M $\text{HCl}(aq)$ with 200. mL of 0.50 M $\text{HClO}_4(aq)$ and then dilutes the mixture with distilled water to a total volume of 500. mL. The $[\text{H}_3\text{O}^+]$ in the final solution is closest to

- (A) 0.0025 M
- (B) 0.12 M
- * (C) 0.25 M
- (D) 0.75 M

Topic
8.2 pH and pOH of Strong Acids and Bases

2022 Practice Exam (from AP Classroom)

Q: pH of solution



When 3.9 g of K(s) is added to 200. mL of water at 25°C in a calorimeter, all of the K(s) reacts with water as represented by the equation above.

Which of the following is true about the pH of the water after the reaction is complete?

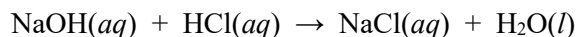
- (A) pH < 7
- (B) pH = 7
- * (C) pH > 7
- (D) The pH of the water cannot be determined without additional information.

Topic
8.2 pH and pOH of Strong Acids and Bases

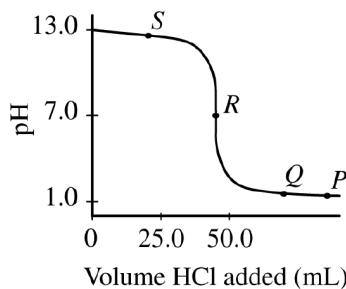
2016 Practice Exam #23

Q: NaOH-HCl titration curve - curve with 1.0 M HCl

Questions X-Y refer to the following information.



To determine the concentration of a $\text{NaOH}(aq)$ solution, a student titrated a 50. mL sample with 0.10 M $\text{HCl}(aq)$. The reaction is represented by the equation above. The titration is monitored using a pH meter, and the experimental results are plotted in the graph below.



One student titrated the $\text{NaOH}(aq)$ with 1.0 M $\text{HCl}(aq)$ instead of 0.10 M $\text{HCl}(aq)$. How would the student's titration curve differ from the original curve?

- (A) The initial pH would be 11 instead of 13.
- (B) The pH at the equivalence point would be 5 instead of 7.
- (C) The pH far beyond the equivalence point would be higher than in the original curve.
- * (D) The pH far beyond the equivalence point would be lower than in the original curve.

Topic
8.2 pH and pOH of Strong Acids and Bases

2013 Practice Exam #49

Q: pH of 4 acids - which acid is HCl

Questions X-Y refer to the following.

Concentration (<i>M</i>)	pH of Acid 1	pH of Acid 2	pH of Acid 3	pH of Acid 4
0.010	3.44	2.00	2.92	2.20
0.050	3.09	1.30	2.58	1.73
0.10	2.94	1.00	2.42	1.55
0.50	2.69	0.30	2.08	1.16
1.0	2.44	0.00	1.92	0.98

The pH of solutions of four acids prepared at various concentrations were measured and recorded in the table above. The four acids are, in no particular order, chlorous, hydrochloric, lactic, and propanoic.

Which of the four acids listed in the table is hydrochloric acid?

(A) Acid 1

* (B) Acid 2

(C) Acid 3

(D) Acid 4

Topic
8.3 Weak Acid and Base Equilibria

2023 Practice Exam (from AP Classroom)

Q: Information from conductivity

	HX(aq)	HZ(aq)
Conductivity	low	high

A student tests the electrical conductivity of 0.10 *M* solutions of two different monoprotic acids, HX(aq) and HZ(aq). Results from the experiment are shown in the table. Which of the following is a question that could be answered based on the data in the table?

- * (A) Which acid has the larger K_a value?
- (B) Which acid has the larger molar mass?
- (C) Which acid solution has the larger density?
- (D) Which acid solution has the larger standard molar entropy?

Topic
8.3 Weak Acid and Base Equilibria

2023 Practice Exam (from AP Classroom)

Q: Experimental evidence to confirm weak acid

A student titrates 25 mL of a 0.10 *M* solution of an unknown acid, HX, with a 0.10 *M* solution of sodium hydroxide, NaOH(*aq*), to the equivalence point. Which of the following pieces of experimental evidence would best help the student confirm that HX is a weak acid?

- * (A) The initial pH of the acid solution is greater than 1.
- (B) The initial pH of the acid solution is less than 1.
- (C) Less than 25 mL of NaOH(*aq*) is required to reach the equivalence point.
- (D) More than 25 mL of NaOH(*aq*) is required to reach the equivalence point.

Topic
8.3 Weak Acid and Base Equilibria

2022 Practice Exam (from AP Classroom)

Q: Species in H_2SO_3 solution

Which of the following identifies the four species that are present in an aqueous solution of the weak acid $\text{H}_2\text{C}_2\text{O}_4$ from the highest to the lowest concentration at equilibrium?

- (A) $\text{H}_3\text{O}^+ > \text{HC}_2\text{O}_4^- > \text{C}_2\text{O}_4^{2-} > \text{H}_2\text{C}_2\text{O}_4$
- (B) $\text{H}_3\text{O}^+ > \text{C}_2\text{O}_4^{2-} > \text{HC}_2\text{O}_4^- > \text{H}_2\text{C}_2\text{O}_4$
- (C) $\text{H}_2\text{C}_2\text{O}_4 > \text{HC}_2\text{O}_4^- > \text{C}_2\text{O}_4^{2-} > \text{H}_3\text{O}^+$
- * (D) $\text{H}_2\text{C}_2\text{O}_4 > \text{H}_3\text{O}^+ > \text{HC}_2\text{O}_4^- > \text{C}_2\text{O}_4^{2-}$

Topic
8.3 Weak Acid and Base Equilibria

2021 Practice Exam (from AP Classroom)

Q: K_a K_b and pH

$\text{HOCl}(aq)$	$K_a = 3.0 \times 10^{-8}$
$\text{HC}_2\text{H}_3\text{O}_2(aq)$	$K_a = 1.8 \times 10^{-5}$
$\text{NH}_3(aq)$	$K_b = 1.8 \times 10^{-5}$
$\text{C}_6\text{H}_5\text{NH}_2(aq)$	$K_b = 3.8 \times 10^{-10}$

The K_a or K_b values of some weak acids and bases are listed in the table above. Which of the following solutions has the highest pH?

- (A) 0.1 M $\text{HOCl}(aq)$
- (B) 0.1 M $\text{HC}_2\text{H}_3\text{O}_2(aq)$
- * (C) 0.1 M $\text{NH}_3(aq)$
- (D) 0.1 M $\text{C}_6\text{H}_5\text{NH}_2(aq)$

Topic
8.3 Weak Acid and Base Equilibria

2021 Practice Exam (from AP Classroom)

Q: Concentration of weak acid



The ionization of cyanic acid, HOCN, is represented above. A certain solution of HOCN has a pH of 2.0. What is the approximate concentration of unionized HOCN(*aq*) in the solution?

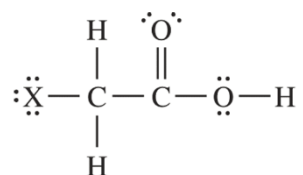
- (A) $3 \times 10^{-4} M$
- (B) $1 \times 10^{-2} M$
- * (C) $3 \times 10^{-1} M$
- (D) $2 \times 10^0 M$

Topic
8.3 Weak Acid and Base Equilibria

2019 Practice Exam #27

Q: Haloacetic acids - percent ionization

Questions X-Y are based on the following information.



The structure of haloacetic acids, XCH_2COOH (where X is either F, Cl, Br, or I), is shown above. The dissociation constants and molar masses of four haloacetic acids are listed in the table below.

Acid	$\text{p}K_a$	K_a	Molar Mass (g/mol)
Fluoroacetic acid	2.59	2.57×10^{-3}	78.0
Chloroacetic acid	2.87	1.35×10^{-3}	94.5
Bromoacetic acid	2.90	1.26×10^{-3}	138.9
Iodoacetic acid	3.18	6.61×10^{-4}	185.9

An aqueous solution contains small but equal concentrations of both chloroacetic and fluoroacetic acids. Which statement comparing the percent ionizations of the two acids in the solution is true?

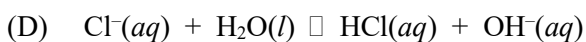
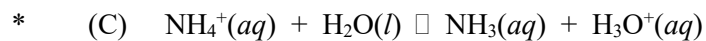
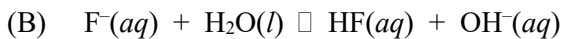
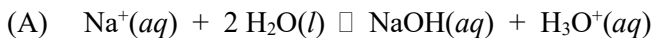
- (A) The percent ionization of chloroacetic acid is greater than that of fluoroacetic acid.
- * (B) The percent ionization of chloroacetic acid is less than that of fluoroacetic acid.
- (C) The percent ionizations cannot be compared without knowing the concentrations of the two acids.
- (D) The percent ionizations cannot be compared without knowing the pH of the solution.

Topic
8.3 Weak Acid and Base Equilibria

2019 Practice Exam #39

Q: Formation of acidic solution - NaF vs NH₄Cl

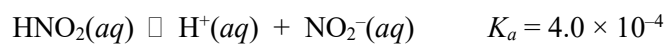
Samples of NaF(s) and NH₄Cl(s) are dissolved in separate beakers that each contain 100 mL of water. One of the salts produces a slightly acidic solution. Which of the following equations best represents the formation of the slightly acidic solution?



Topic
8.3 Weak Acid and Base Equilibria

2018 Practice Exam #11

Q: Percent ionization in 1.0 M HNO₂



On the basis of the information above, what is the approximate percent ionization of HNO₂ in a 1.0 M HNO₂(aq) solution?

(A) 0.00040%

(B) 0.020%

(C) 0.040%

* (D) 2.0%

Topic
8.3 Weak Acid and Base Equilibria

2018 Practice Exam #39

Q: pH and major species for 0.5 M HCHO₂ given K_a



HCHO₂(aq), a weak acid ($K_a = 2 \times 10^{-4}$), dissociates in water according to the equation above. Which of the following provides the best estimate of the pH of 0.5 M HCHO₂(aq) and identifies the species at the highest concentration (excluding H₂O) in the solution?

	pH	Species at Highest Concentration
(A)	1	H ₃ O ⁺ (aq)
(B)	1	HCHO ₂ (aq)
(C)	2	H ₃ O ⁺ (aq)
* (D)	2	HCHO ₂ (aq)

Topic
8.3 Weak Acid and Base Equilibria

2016 Practice Exam #34

Q: Approximate pH of 0.01 M HNO₂ given K_a

The pH of a 0.01 M HNO₂(aq) solution is in which of the following ranges?
 (For HNO₂(aq), $K_a = 4.0 \times 10^{-4}$)

- (A) Between 1 and 2
- * (B) Between 2 and 3
- (C) Between 4 and 5
- (D) Between 6 and 7

Topic
8.3 Weak Acid and Base Equilibria

2016 Practice Exam #48

Q: Rank acid strength from concentration and pH data

Acid	Concentration	pH
X	0.005 <i>M</i>	2.3
Y	2.0 <i>M</i>	2.8
Z	3.0 <i>M</i>	2.8

Which of the following correctly ranks the three monoprotic acids listed in the table above from the weakest to the strongest?

(A) $X < Y < Z$

(B) $X < Z < Y$

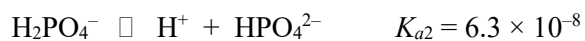
(C) $Y < Z < X$

* (D) $Z < Y < X$

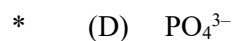
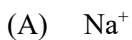
Topic
8.3 Weak Acid and Base Equilibria

2015 Practice Exam #15

Q: Ion in lowest conc. of 1 M NaH₂PO₄ solution



A solution is prepared by mixing 50 mL of 1 M NaH₂PO₄ with 50 mL of 1 M Na₂HPO₄. On the basis of the information above, which of the following species is present in the solution at the lowest concentration?



Topic
8.3 Weak Acid and Base Equilibria

2015 Practice Exam #22

Q: Given K_a - acid with highest pH at equivalence pt

Solution	Acid	K_a
1	$\text{CH}_3\text{CO}_2\text{H}$	1.75×10^{-5}
2	$\text{CF}_3\text{CO}_2\text{H}$	1.0×10^0

Acid-dissociation constants of two acids are listed in the table above. A 20. mL sample of a 0.10 M solution of each acid is titrated to the equivalence point with 20. mL of 0.10 M NaOH. Which of the following is a true statement about the pH of the solutions at the equivalence point?

- (A) Solution 1 has a higher pH at the equivalence point because $\text{CH}_3\text{CO}_2\text{H}$ is the stronger acid.
- * (B) Solution 1 has a higher pH at the equivalence point because $\text{CH}_3\text{CO}_2\text{H}$ has the stronger conjugate base.
- (C) Solution 1 has a lower pH at the equivalence point because $\text{CH}_3\text{CO}_2\text{H}$ is the stronger acid.
- (D) Solution 1 has a lower pH at the equivalence point because $\text{CH}_3\text{CO}_2\text{H}$ has the stronger conjugate base.

Topic
8.3 Weak Acid and Base Equilibria

2013 Practice Exam #22

Q: Approx. pH of 0.01 M caffeine given K_b

Caffeine ($C_8H_{10}N_4O_2$) is a weak base with a K_b value of 4×10^{-4} . The pH of a 0.01 M solution of caffeine is in the range of

- (A) 2–3
- (B) 5–6
- (C) 7–8
- * (D) 11–12

Topic
8.3 Weak Acid and Base Equilibria

2013 Practice Exam #48

Q: pH of 4 acids - smallest K_a value

Questions X-Y refer to the following.

Concentration (M)	pH of Acid 1	pH of Acid 2	pH of Acid 3	pH of Acid 4
0.010	3.44	2.00	2.92	2.20
0.050	3.09	1.30	2.58	1.73
0.10	2.94	1.00	2.42	1.55
0.50	2.69	0.30	2.08	1.16
1.0	2.44	0.00	1.92	0.98

The pH of solutions of four acids prepared at various concentrations were measured and recorded in the table above. The four acids are, in no particular order, chlorous, hydrochloric, lactic, and propanoic.

For which acid is the value of the acid-dissociation constant, K_a , the smallest?

- * (A) Acid 1
- (B) Acid 2
- (C) Acid 3
- (D) Acid 4

Topic
8.3 Weak Acid and Base Equilibria

2013 Practice Exam #50

Q: pH of 4 acids - major species in 1.0 M soln acid 1

Questions X-Y refer to the following.

Concentration (<i>M</i>)	pH of Acid 1	pH of Acid 2	pH of Acid 3	pH of Acid 4
0.010	3.44	2.00	2.92	2.20
0.050	3.09	1.30	2.58	1.73
0.10	2.94	1.00	2.42	1.55
0.50	2.69	0.30	2.08	1.16
1.0	2.44	0.00	1.92	0.98

The pH of solutions of four acids prepared at various concentrations were measured and recorded in the table above. The four acids are, in no particular order, chlorous, hydrochloric, lactic, and propanoic.

Of the following species, which has the greatest concentration in a 1.0 *M* solution of acid 1 at equilibrium?

- (A) OH^-
- (B) H_3O^+
- * (C) Acid 1
- (D) The conjugate base of acid 1

Topic
8.4 Acid-Base Reactions and Buffers

2018 Practice Exam #31

Q: Approx. pH of 150mL 0.10M KOH with 50mL 0.20M HBr

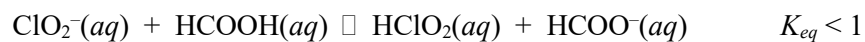
The pH of a solution made by combining 150.0 mL of 0.10 *M* KOH(*aq*) with 50.0 mL of 0.20 *M* HBr(*aq*) is closest to which of the following?

- (A) 2
- (B) 4
- (C) 7
- * (D) 12

Topic
8.4 Acid-Base Reactions and Buffers

2017 Practice Exam #46

Q: Relative strengths of acids-bases given small K



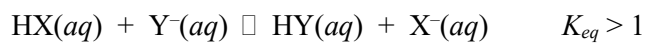
What are the relative strengths of the acids and bases in the reaction represented by the equation above?

	<u>Acid Strength</u>	<u>Base Strength</u>
(A)	$\text{HClO}_2 < \text{HCOOH}$	$\text{ClO}_2^- < \text{HCOO}^-$
(B)	$\text{HClO}_2 < \text{HCOOH}$	$\text{ClO}_2^- > \text{HCOO}^-$
(C)	$\text{HClO}_2 > \text{HCOOH}$	$\text{ClO}_2^- > \text{HCOO}^-$
* (D)	$\text{HClO}_2 > \text{HCOOH}$	$\text{ClO}_2^- < \text{HCOO}^-$

Topic
8.4 Acid-Base Reactions and Buffers

2016 Practice Exam #20

Q: $\text{HX} + \text{Y}^-$ - strongest acid given large K



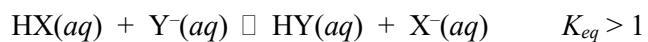
Based on the information given above, which of the following is the strongest acid?

- * (A) $\text{HX}(aq)$
- (B) $\text{Y}^-(aq)$
- (C) $\text{HY}(aq)$
- (D) $\text{X}^-(aq)$

Topic
8.4 Acid-Base Reactions and Buffers

2015 Practice Exam #45

Q: Given K, which species is the strongest base



A solution of a salt of a weak acid HY is added to a solution of another weak acid HX. Based on the information given above, which of the following species is the strongest base?

- (A) $\text{HX}(aq)$
- * (B) $\text{Y}^-(aq)$
- (C) $\text{HY}(aq)$
- (D) $\text{X}^-(aq)$

Topic
8.4 Acid-Base Reactions and Buffers

2014 Practice Exam #11

Q: pH if 200 mL 2.0 M NaOH added to 500 mL 1.0 M HCl

When 200. mL of 2.0 *M* NaOH(*aq*) is added to 500. mL of 1.0 *M* HCl(*aq*), the pH of the resulting mixture is closest to

- * (A) 1.0
- (B) 3.0
- (C) 7.0
- (D) 13.0

Topic
8.4 Acid-Base Reactions and Buffers

2014 Practice Exam #19

Q: HCl-HClO₂ mixture - species increases as KOH added

A solution containing HCl and the weak acid HClO₂ has a pH of 2.4. Enough KOH(*aq*) is added to the solution to increase the pH to 10.5. The amount of which of the following species increases as the KOH(*aq*) is added?

(A) Cl⁻(*aq*)

(B) H⁺(*aq*)

* (C) ClO₂⁻(*aq*)

(D) HClO₂(*aq*)

Topic
8.5 Acid-Base Titrations

2023 Practice Exam (from AP Classroom)

Q: Experimental evidence to confirm weak acid

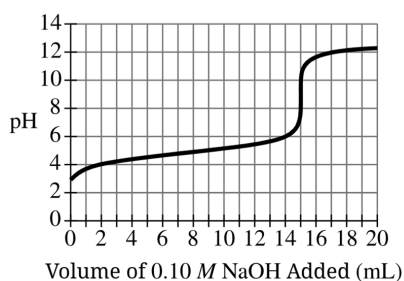
A student titrates 25 mL of a 0.10 *M* solution of an unknown acid, HX, with a 0.10 *M* solution of sodium hydroxide, NaOH(*aq*), to the equivalence point. Which of the following pieces of experimental evidence would best help the student confirm that HX is a weak acid?

- * (A) The initial pH of the acid solution is greater than 1.
- (B) The initial pH of the acid solution is less than 1.
- (C) Less than 25 mL of NaOH(*aq*) is required to reach the equivalence point.
- (D) More than 25 mL of NaOH(*aq*) is required to reach the equivalence point.

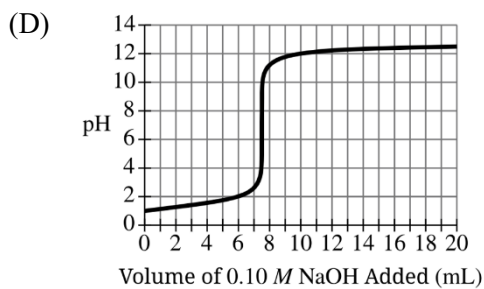
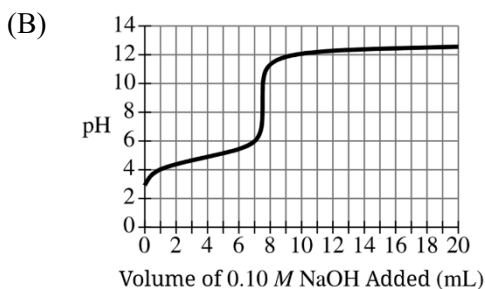
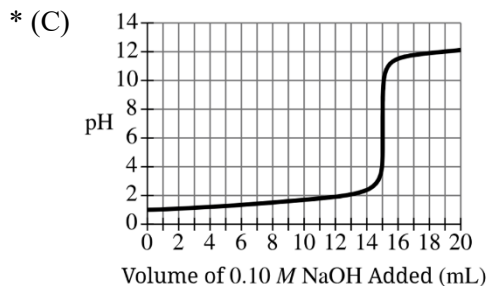
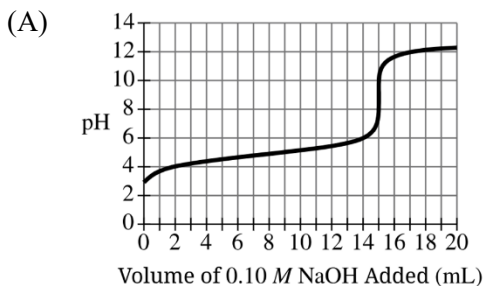
Topic
8.5 Acid-Base Titrations

2023 Practice Exam (from AP Classroom)

Q: Weak Acid titration



A 15.0 mL sample of 0.10 M $\text{HC}_2\text{H}_3\text{O}_2$ is titrated with 0.10 M NaOH , and the data are shown in the graph above. Which of the following graphs shows the change in pH when a 15.0 mL sample of 0.10 M HCl is titrated with 0.10 M NaOH ?



Topic
8.5 Acid-Base Titrations

2022 Practice Exam (from AP Classroom)

Q: Different acids titrated

Acid	Concentration of Acid (M)	Volume of Sample (mL)	Volume of Standardized NaOH(aq) Added to Reach Equivalence Point (mL)
$\text{HClO}_4(aq)$	0.100	25.0	24.0
$\text{HClO}(aq)$	0.200	25.0	?

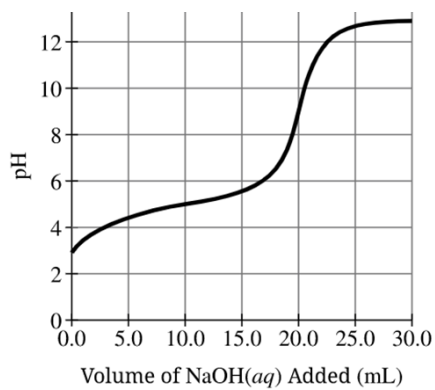
Samples of two different acids are titrated using the same standardized solution of NaOH(aq). According to the data in the table above, how many milliliters of the standardized NaOH(aq) are required to reach the equivalence point when the 25.0 mL sample of 0.200 M HClO(aq) is titrated?

- (A) 12.0 mL
- (B) 24.0 mL
- * (C) 48.0 mL
- (D) It cannot be determined without knowing the values of K_a for $\text{HClO}_4(aq)$ and $\text{HClO}(aq)$.

Topic
8.5 Acid-Base Titrations

2022 Practice Exam (from AP Classroom)

Q: K_a from titration curve



A 0.10 M solution of a weak acid is titrated with 0.10 M NaOH(aq) . Based on the titration curve above, which of the following could be the identity of the weak acid?

(A) HCN with a K_a value of 5×10^{-10}

(B) HOCl with a K_a value of 3×10^{-8}

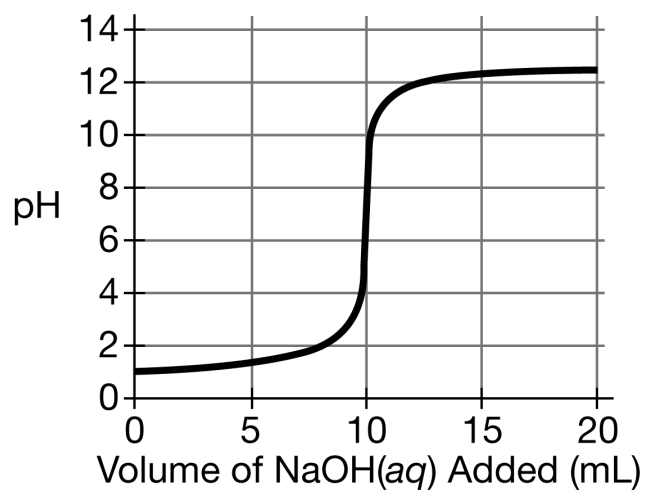
* (C) $\text{CH}_3\text{CH}_2\text{COOH}$ with a K_a value of 1×10^{-5}

(D) ClCH_2COOH with a K_a value of 1×10^{-3}

Topic
8.5 Acid-Base Titrations

2021 Practice Exam (from AP Classroom)

Q: Concentration of titrant



A 20.0 mL sample of a 0.125 *M* monoprotic acid solution is titrated with a NaOH(*aq*) solution of unknown concentration. Based on the titration curve above, what is the molar concentration of the NaOH(*aq*) solution?

- (A) 0.063 *M*
- (B) 0.125 *M*
- * (C) 0.250 *M*
- (D) 0.500 *M*

Topic
8.5 Acid-Base Titrations

2021 Practice Exam (from AP Classroom)

Q: pH at equivalence point

A 0.08 *M* solution of CH_3COOH ($\text{p}K_{\text{a}} = 4.74$) is titrated with 0.10 *M* $\text{NaOH}(aq)$. What is the pH at the equivalence point of the titration and why?

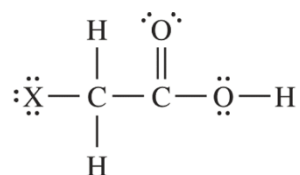
- (A) $\text{pH} < 7$, because $\text{NaOH}(aq)$ is a strong base.
- (B) $\text{pH} = 7$, because the titration reaction is a neutralization reaction.
- * (C) $\text{pH} > 7$, because $\text{CH}_3\text{COO}^-(aq)$ is a weak base.
- (D) $\text{pH} > 7$, because the concentration of $\text{NaOH}(aq)$ is greater than that of $\text{CH}_3\text{COOH}(aq)$.

Topic
8.5 Acid-Base Titrations

2019 Practice Exam #28

Q: Haloacetic acids - vol. NaOH to reach equivalence

Questions X-Y are based on the following information.



The structure of haloacetic acids, XCH_2COOH (where X is either F, Cl, Br, or I), is shown above. The dissociation constants and molar masses of four haloacetic acids are listed in the table below.

Acid	$\text{p}K_a$	K_a	Molar Mass (g/mol)
Fluoroacetic acid	2.59	2.57×10^{-3}	78.0
Chloroacetic acid	2.87	1.35×10^{-3}	94.5
Bromoacetic acid	2.90	1.26×10^{-3}	138.9
Iodoacetic acid	3.18	6.61×10^{-4}	185.9

A student titrates 10.0 mL samples of 1.0 M solutions of each of the haloacetic acids with a standard solution of NaOH. Which of the following statements correctly predicts the volume of NaOH(aq) needed to reach the equivalence point?

- (A) Fluoroacetic acid will need the smallest volume of NaOH(aq) to reach the equivalence point.
- (B) Iodoacetic acid will need the smallest volume of NaOH(aq) to reach the equivalence point.
- * (C) All of the acids will need the same volume of NaOH(aq) to reach the equivalence point.
- (D) All of the haloacetic acids are weak; therefore none will reach an equivalence point.

Topic
8.5 Acid-Base Titrations

2019 Practice Exam #41

Q: Acetylsalicylic acid - molarities at equivalence



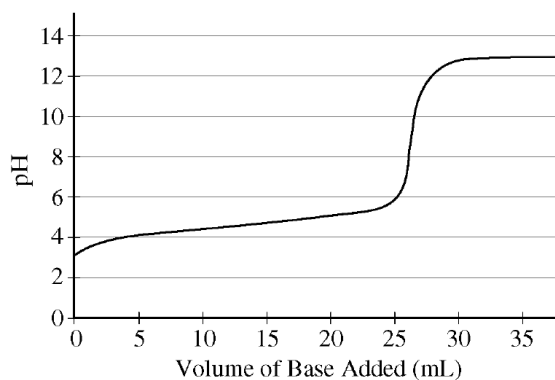
The reaction represented above occurs when 2.00×10^{-4} mol of pure acetylsalicylic acid, $\text{C}_9\text{H}_8\text{O}_4$, is completely dissolved in 15.00 mL of water in a flask and titrated to the equivalence point with 0.100 M $\text{NaOH}(aq)$. Which of the following statements about the titration is true at the equivalence point?

- (A) $[\text{C}_9\text{H}_8\text{O}_4]$ is greater than $[\text{C}_9\text{H}_7\text{O}_4^-]$.
- * (B) $[\text{C}_9\text{H}_8\text{O}_4]$ is less than $[\text{C}_9\text{H}_7\text{O}_4^-]$.
- (C) $[\text{C}_9\text{H}_8\text{O}_4]$ is equal to $[\text{C}_9\text{H}_7\text{O}_4^-]$.
- (D) The relationship between $[\text{C}_9\text{H}_8\text{O}_4]$ and $[\text{C}_9\text{H}_7\text{O}_4^-]$ cannot be determined without additional information.

Topic
8.5 Acid-Base Titrations

2016 Practice Exam #9

Q: Identify titration type from pH curve



A student performs an acid-base titration and plots the experimental results in the graph above. Which of the following statements best explains the experimental findings?

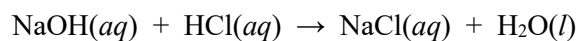
- (A) A strong acid was titrated with a strong base, as evidenced by the equivalence point at $\text{pH} = 7$.
- (B) A strong acid was titrated with a strong base, as evidenced by the equivalence point at $\text{pH} > 7$.
- * (C) A weak acid was titrated with a strong base, as evidenced by the equivalence point at $\text{pH} > 7$.
- (D) A weak acid was titrated with a weak base, as evidenced by the equivalence point at pH approximately 7.

Topic
8.5 Acid-Base Titrations

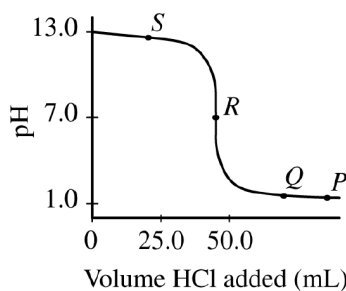
2016 Practice Exam #22

Q: NaOH-HCl titration curve - ions at equiv pt

Questions X-Y refer to the following information.



To determine the concentration of a $\text{NaOH}(aq)$ solution, a student titrated a 50. mL sample with 0.10 M $\text{HCl}(aq)$. The reaction is represented by the equation above. The titration is monitored using a pH meter, and the experimental results are plotted in the graph below.



At the point labeled R on the pH curve, which of the following ions are present in the reaction mixture at a concentration greater than 0.01 M ?

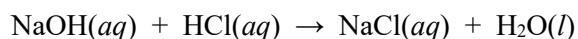
- * (A) Na^+ and Cl^- only
- (B) Na^+ , Cl^- , and H^+ only
- (C) Na^+ , Cl^- , and OH^- only
- (D) Na^+ , Cl^- , H^+ , and OH^-

Topic
8.5 Acid-Base Titrations

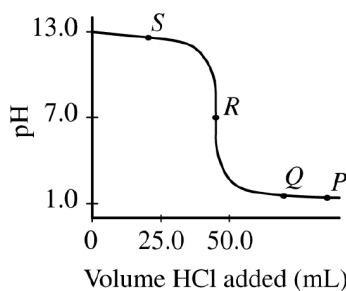
2016 Practice Exam #23

Q: NaOH-HCl titration curve - curve with 1.0 M HCl

Questions X-Y refer to the following information.



To determine the concentration of a $\text{NaOH}(aq)$ solution, a student titrated a 50. mL sample with 0.10 M $\text{HCl}(aq)$. The reaction is represented by the equation above. The titration is monitored using a pH meter, and the experimental results are plotted in the graph below.



One student titrated the $\text{NaOH}(aq)$ with 1.0 M $\text{HCl}(aq)$ instead of 0.10 M $\text{HCl}(aq)$. How would the student's titration curve differ from the original curve?

- (A) The initial pH would be 11 instead of 13.
- (B) The pH at the equivalence point would be 5 instead of 7.
- (C) The pH far beyond the equivalence point would be higher than in the original curve.
- * (D) The pH far beyond the equivalence point would be lower than in the original curve.

Topic
8.5 Acid-Base Titrations

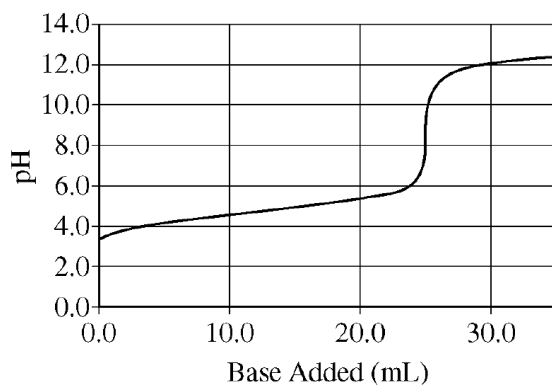
2015 Practice Exam #19

Q: $\text{Li} + \text{H}_2\text{O}$ - pK_a value of the acid from pH curve

Questions X-Y refer to the following information.

A 0.35 g sample of $\text{Li}(s)$ is placed in an Erlenmeyer flask containing 100 mL of water at 25°C . A balloon is placed over the mouth of the flask to collect the hydrogen gas that is generated.

After all of the $\text{Li}(s)$ has reacted with $\text{H}_2\text{O}(l)$, the solution in the flask is added to a clean, dry buret and used to titrate an aqueous solution of a monoprotic acid. The pH curve for this titration is shown in the diagram below.



On the basis of the pH curve, the pK_a value of the acid is closest to

- (A) 4
- * (B) 5
- (C) 8
- (D) 12

Topic
8.5 Acid-Base Titrations

2015 Practice Exam #22

Q: Given K_a - acid with highest pH at equivalence pt

Solution	Acid	K_a
1	$\text{CH}_3\text{CO}_2\text{H}$	1.75×10^{-5}
2	$\text{CF}_3\text{CO}_2\text{H}$	1.0×10^0

Acid-dissociation constants of two acids are listed in the table above. A 20. mL sample of a 0.10 M solution of each acid is titrated to the equivalence point with 20. mL of 0.10 M NaOH. Which of the following is a true statement about the pH of the solutions at the equivalence point?

- (A) Solution 1 has a higher pH at the equivalence point because $\text{CH}_3\text{CO}_2\text{H}$ is the stronger acid.
- * (B) Solution 1 has a higher pH at the equivalence point because $\text{CH}_3\text{CO}_2\text{H}$ has the stronger conjugate base.
- (C) Solution 1 has a lower pH at the equivalence point because $\text{CH}_3\text{CO}_2\text{H}$ is the stronger acid.
- (D) Solution 1 has a lower pH at the equivalence point because $\text{CH}_3\text{CO}_2\text{H}$ has the stronger conjugate base.

Topic
8.5 Acid-Base Titrations

2015 Practice Exam #41

Q: Acid soln between 0.20 M and 0.30 M from titration

Acid Solution	Volume of NaOH Added (mL)
A	40
B	75
C	115
D	200

To maximize the yield in a certain manufacturing process, a solution of a weak monoprotic acid that has a concentration between 0.20 *M* and 0.30 *M* is required. Four 100. mL samples of the acid at different concentrations are each titrated with a 0.20 *M* NaOH solution. The volume of NaOH needed to reach the end point for each sample is given in the table above. Which solution is the most suitable to maximize the yield?

(A) Solution A

(B) Solution B

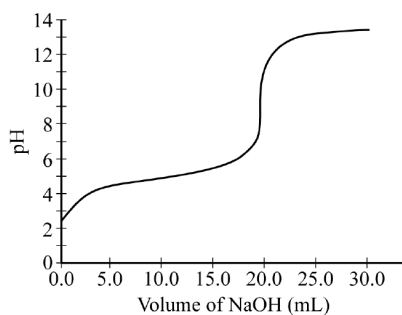
* (C) Solution C

(D) Solution D

Topic
8.5 Acid-Base Titrations

2014 Practice Exam #38

Q: Weak acid titration curve - pK_a and NaOH molarity



Data collected during the titration of a 20.0 mL sample of a 0.10 M solution of a monoprotic acid with a solution of NaOH of unknown concentration are plotted in the graph above. Based on the data, which of the following are the approximate pK_a of the acid and the molar concentration of the NaOH?

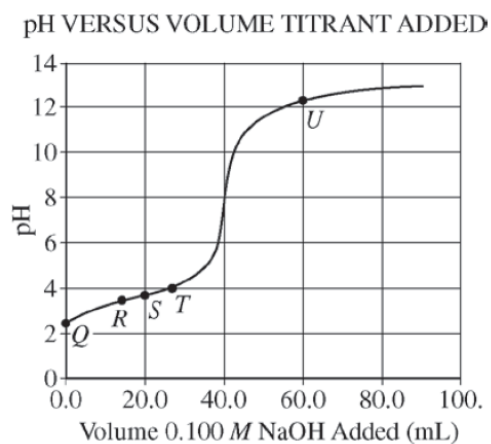
	pK_a	[NaOH]
(A)	4.7	0.050 M
* (B)	4.7	0.10 M
(C)	9.3	0.050 M
(D)	9.3	0.10 M

Topic
8.5 Acid-Base Titrations

2013 Practice Exam #14

Q: Titration curve - highest conc. at point R

Questions X-Y refer to the following.



A 50.0 mL sample of an acid, HA, of unknown molarity is titrated, and the pH of the resulting solution is measured with a pH meter and graphed as a function of the volume of 0.100 M NaOH added.

At point R in the titration, which of the following species has the highest concentration?

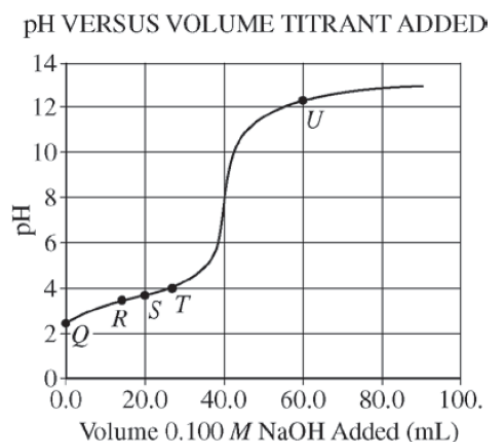
- * (A) HA
- (B) A^-
- (C) H_3O^+
- (D) OH^-

Topic
8.5 Acid-Base Titrations

2013 Practice Exam #15

Q: Titration curve - particulate beyond equiv point U

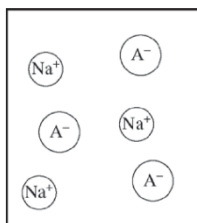
Questions X-Y refer to the following.



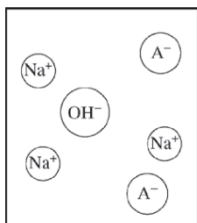
A 50.0 mL sample of an acid, HA, of unknown molarity is titrated, and the pH of the resulting solution is measured with a pH meter and graphed as a function of the volume of 0.100 M NaOH added.

Which of the following is the best particulate representation of the species (other than H_2O) that are present in significant concentrations in the solution at point U in the titration?

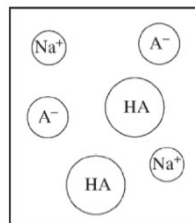
(A)



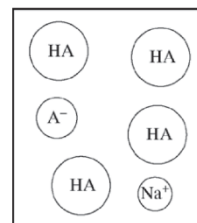
* (B)



(C)



(D)

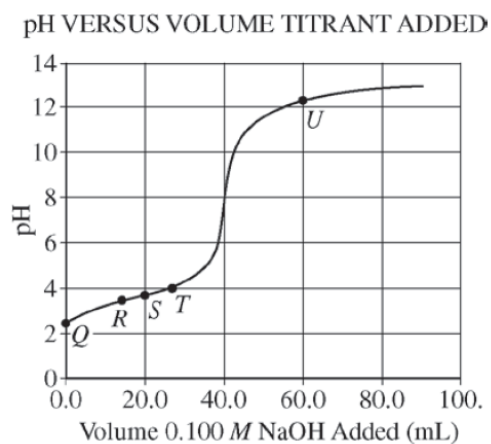


Topic
8.5 Acid-Base Titrations

2013 Practice Exam #16

Q: Titration curve - point where A⁻ conc. is twice HA

Questions X-Y refer to the following.



A 50.0 mL sample of an acid, HA, of unknown molarity is titrated, and the pH of the resulting solution is measured with a pH meter and graphed as a function of the volume of 0.100 M NaOH added.

At which point on the titration curve is $[A^-]$ closest to twice that of $[HA]$?

(A) R

(B) S

* (C) T

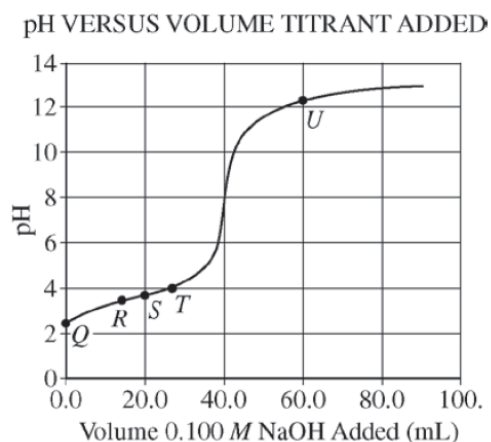
(D) U

Topic
8.5 Acid-Base Titrations

2013 Practice Exam #17

Q: Titration curve - indicator changes past equiv pt.

Questions X-Y refer to the following.



A 50.0 mL sample of an acid, HA, of unknown molarity is titrated, and the pH of the resulting solution is measured with a pH meter and graphed as a function of the volume of 0.100 M NaOH added.

A student carries out the same titration, but uses an indicator instead of a pH meter. If the indicator changes color slightly past the equivalence point, what will the student obtain for the calculated concentration of the acid?

- (A) Slightly less than 0.0800 M
- * (B) Slightly more than 0.0800 M
- (C) Slightly less than 0.125 M
- (D) Slightly more than 0.125 M

Topic
8.5 Acid-Base Titrations

2013 Practice Exam #51

Q: pH of 4 acids - volume of base needed to titrate

Questions X-Y refer to the following.

Concentration (<i>M</i>)	pH of Acid 1	pH of Acid 2	pH of Acid 3	pH of Acid 4
0.010	3.44	2.00	2.92	2.20
0.050	3.09	1.30	2.58	1.73
0.10	2.94	1.00	2.42	1.55
0.50	2.69	0.30	2.08	1.16
1.0	2.44	0.00	1.92	0.98

The pH of solutions of four acids prepared at various concentrations were measured and recorded in the table above. The four acids are, in no particular order, chlorous, hydrochloric, lactic, and propanoic.

If equal volumes of the four acids at a concentration of 0.50 *M* are each titrated with a strong base, which will require the greatest volume of base to reach the equivalence point?

- (A) Acid 1
- (B) Acid 2
- (C) Acid 3

* (D) All the acids will require the same volume of base to reach the equivalence point.

Topic
8.6 Molecular Structure of Acids and Bases

2022 Practice Exam (from AP Classroom)

Q: Compound acts as base

Substance	Structural Formula	Molar Mass (g/mol)
Propylamine	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{N} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \end{array} $	59
Pentane	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} - \text{H} \\ & & & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	72
2-Propanol	$ \begin{array}{ccccccc} & & & \text{H} & & & \\ & & & & & & \\ & \text{H} & & \text{O} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \end{array} $	60
Propanoic acid	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{O} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{O} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & & \end{array} $	74

A student was given samples of four different unknown liquids. The unknown liquids are propylamine, pentane, 2-propanol, and propanoic acid. The structures and molar masses of the compounds are shown in the table above. On the basis of this information, the student designed some experiments to identify the samples.

Of the following, which identifies the aqueous solution of the compound that will have the highest pH and explains why?

- * (A) Propylamine, because the lone pair of electrons on N can accept an H^+ from the solution
- (B) Pentane, because it can produce the largest number of H^+ ions per molecule
- (C) 2-Propanol, because it can completely dissociate into C_3H_7^+ and OH^-
- (D) Propanoic acid, because it dissociates into H^+ and $\text{C}_3\text{H}_5\text{O}_2^-$

Topic
8.6 Molecular Structure of Acids and Bases

2021 Practice Exam (from AP Classroom)

Q: Weakest acid

Acid	Structure
HClO	$\text{H}-\ddot{\text{O}}-\ddot{\text{Cl}}:$
HBrO	$\text{H}-\ddot{\text{O}}-\ddot{\text{Br}}:$
HIO	$\text{H}-\ddot{\text{O}}-\ddot{\text{I}}:$

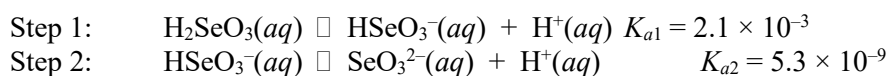
A 0.1 *M* aqueous solution of which of the acids shown in the table above would have a pH closest to 7.0, and why?

- (A) HClO, because Cl has the highest electronegativity.
- (B) HBrO, because Br has the lowest electronegativity.
- * (C) HIO, because I has the lowest electronegativity.
- (D) All three solutions will have the same pH because they are all monoprotic acids.

Topic
8.6 Molecular Structure of Acids and Bases

2018 Practice Exam #32

Q: Selenous acid - why K_{a2} is smaller than K_{a1}



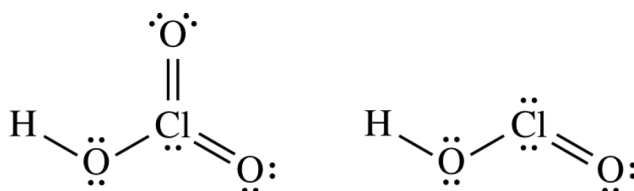
The step-wise dissociation of selenous acid, $\text{H}_2\text{SeO}_3(aq)$, is represented by the equations above. Which of the following best helps explain why the value of K_{a2} is so much smaller than the value of K_{a1} ?

- (A) The Se atom in H_2SeO_3 is in a higher oxidation state than the Se atom in HSeO_3^- .
- (B) Water is more attracted to the HSeO_3^- ions than to the SeO_3^{2-} ions, which drives the step 2 equilibrium toward the reactant.
- (C) The HSeO_3^- ions produced in step 1 are asymmetrical, but the SeO_3^{2-} ions produced in step 2 are symmetrical
- * (D) Removing the first H^+ from H_2SeO_3 requires less energy than removing the second H^+ , because the second H^+ is removed from a negatively charged species.

Topic
8.6 Molecular Structure of Acids and Bases

2015 Practice Exam #38

Q: Lewis structures - acid strength HClO_3 vs HClO_2



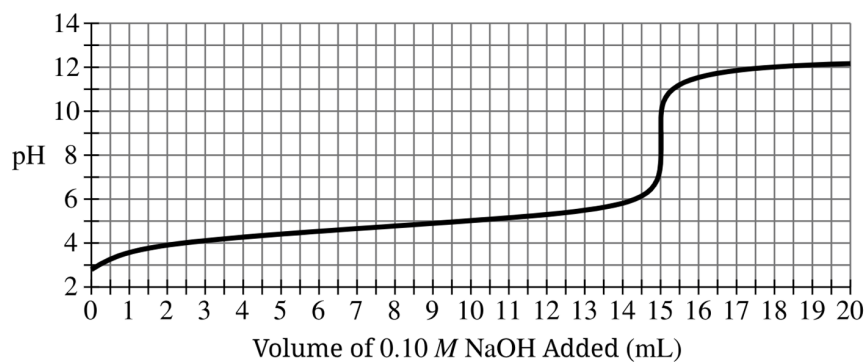
The Lewis electron-dot diagrams of the HClO_3 molecule and the HClO_2 molecule are shown above at the left and right, respectively. Which of the following statements identifies the stronger acid and correctly identifies a factor that contributes to its being the stronger acid?

- (A) $\text{HClO}_3(aq)$ is the stronger acid because its molecules experience stronger London dispersion forces.
- * (B) $\text{HClO}_3(aq)$ is the stronger acid because the additional electronegative oxygen atom on the chlorine atom stabilizes the conjugate base.
- (C) $\text{HClO}_2(aq)$ is the stronger acid because its molecules experience weaker London dispersion forces.
- (D) $\text{HClO}_2(aq)$ is the stronger acid because the lone pairs of electrons on the chlorine atom stabilize the conjugate base.

Topic
8.7 pH and pK_a

2023 Practice Exam (from AP Classroom)

Q: Best indicator for titration



A sample of an acid is titrated with 0.10 *M* NaOH, and the results are shown in the graph. Based on the pH range of the color change given for each indicator, which of the following indicators would be the best choice for the titration?

- (A) Thymol blue; 1.2 – 2.8
- (B) Congo red; 3.0 – 5.0
- * (C) Phenol red; 6.8 – 8.2
- (D) Indigo carmine; 11.6 – 14.0

Topic
8.7 pH and pK_a

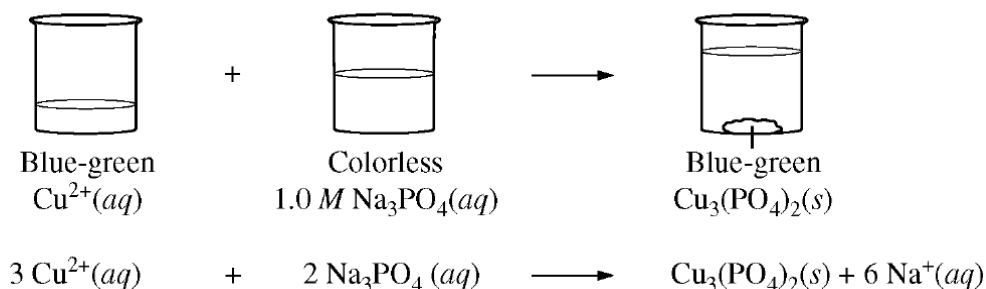
2018 Practice Exam #24

Q: Cu recovery - phosphate major species if pH is 1

Questions X-Y refer to the following information.

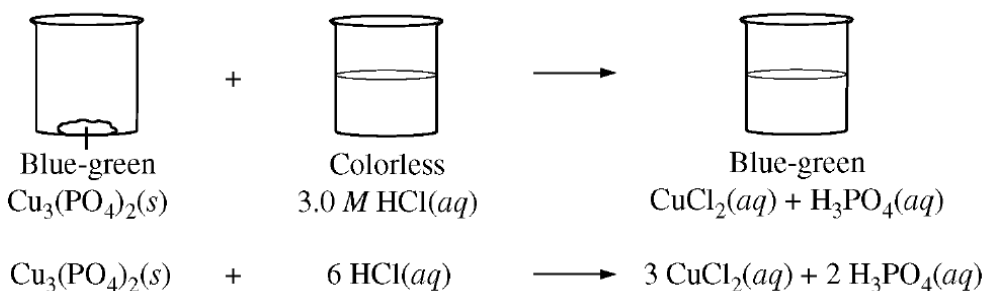
A group of students was asked to recover $\text{Cu}(s)$ from a blue-green aqueous solution containing an unknown concentration of $\text{Cu}^{2+}(aq)$. The students took a 100.0 mL sample of the solution and added an excess of 1.0 M $\text{Na}_3\text{PO}_4(aq)$, causing the $\text{Cu}^{2+}(aq)$ to precipitate as $\text{Cu}_3(\text{PO}_4)_2(s)$, as shown in step 1 below.

Step 1



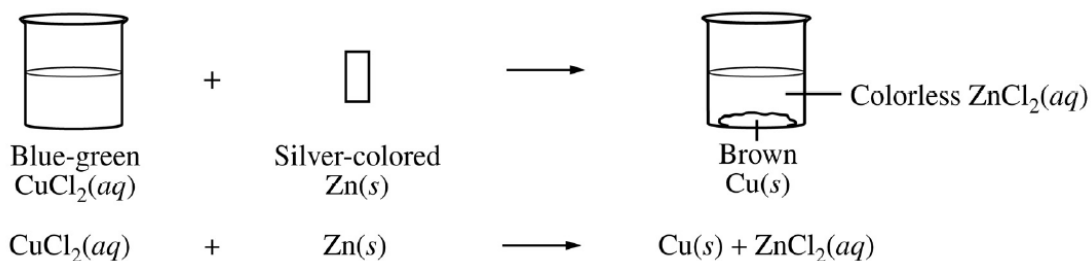
The $\text{Cu}_3(\text{PO}_4)_2(s)$ was filtered, dried, and weighed. Then the $\text{Cu}_3(\text{PO}_4)_2(s)$ was dissolved in a 3.0 M $\text{HCl}(aq)$ solution, as shown in step 2 below.

Step 2



The students added a strip of $\text{Zn}(s)$ to the solution to recover the $\text{Cu}(s)$, as shown in step 3 below.

Step 3



Finally, the $\text{Cu}(s)$ was filtered, dried, and weighed.

(This question is continued on the next page.)

Topic
8.7 pH and pK_a

(This question is continued from the previous page.)

2018 Practice Exam #24

Q: Cu recovery - phosphate major species if pH is 1

$H_3PO_4(aq)$	
K_{a1}	7.5×10^{-3}
K_{a2}	6.2×10^{-8}
K_{a3}	4.2×10^{-13}

The values of the dissociation constants for H_3PO_4 are given in the table above. Given that the solution in the beaker at the end of step 2 had a pH of approximately 1, which of the following chemical species had the lowest concentration among the products of step 2?

- (A) $H^+(aq)$
- (B) $H_2PO_4^-(aq)$
- (C) $HPO_4^{2-}(aq)$
- * (D) $PO_4^{3-}(aq)$

Topic
8.8 Properties of Buffers

2019 Practice Exam #21

Q: Adding HCl and NaOH to acetate buffer

A solution is prepared by mixing equal volumes of $0.20\text{ M HC}_2\text{H}_3\text{O}_2$ and $0.40\text{ M NaC}_2\text{H}_3\text{O}_2$. Which of the following correctly describes what occurs if a small amount of $\text{HCl}(aq)$ or $\text{NaOH}(aq)$ is added?

- (A) If $\text{HCl}(aq)$ is added, the pH will increase only slightly because the Cl^- ions will react with $\text{C}_2\text{H}_3\text{O}_2^-$ ions.
- * (B) If $\text{HCl}(aq)$ is added, the pH will decrease only slightly because the H^+ ions will react with $\text{C}_2\text{H}_3\text{O}_2^-$ ions.
- (C) If $\text{NaOH}(aq)$ is added, the pH will increase only slightly because the OH^- ions will react with $\text{C}_2\text{H}_3\text{O}_2^-$ ions.
- (D) If $\text{NaOH}(aq)$ is added, the pH will decrease only slightly because the OH^- ions will react with $\text{HC}_2\text{H}_3\text{O}_2$ molecules.

Topic
8.8 Properties of Buffers

2018 Practice Exam #30

Q: Equation when HNO₃ is added to CH₃NH₂ buffer

When a small amount of 12 M HNO₃(aq) is added to a buffer solution made by mixing CH₃NH₂(aq) and CH₃NH₃Cl(aq), the pH of the buffer solution changes from 10.64 to 10.62. Which of the following equations represents the reaction that accounts for the fact that the pH does not change significantly when the HNO₃(aq) is added?

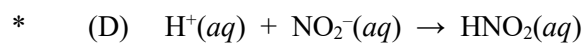
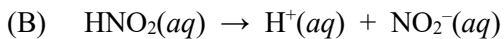
- * (A) $\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{CH}_3\text{NH}_3^+(\text{aq})$
- (B) $\text{CH}_3\text{NH}_3^+(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{CH}_3\text{NH}_4^{2+}(\text{aq})$
- (C) $\text{NO}_3^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{HNO}_3(\text{aq})$
- (D) $\text{OH}^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$

Topic
8.8 Properties of Buffers

2017 Practice Exam #49

Q: Equation for HCl added to HNO₂-KNO₂ buffer

A student prepares a solution by combining 100 mL of 0.30 M HNO₂(aq) and 100 mL of 0.30 M KNO₂(aq). Which of the following equations represents the reaction that best helps to explain why adding a few drops of 1.0 M HCl(aq) does not significantly change the pH of the solution?



Topic
8.8 Properties of Buffers

2015 Practice Exam #10

Q: Acetate buffer - major species in soln and pH

An acetate buffer solution is prepared by combining 50. mL of 0.20 *M* acetic acid, $\text{HC}_2\text{H}_3\text{O}_2(aq)$, and 50. mL of 0.20 *M* sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2(aq)$. A 5.0 mL sample of 0.10 *M* $\text{NaOH}(aq)$ is added to the buffer solution. Which of the following is a correct pairing of the acetate species present in greater concentration and of the pH of the solution after the $\text{NaOH}(aq)$ is added? (The $\text{p}K_a$ of acetic acid is 4.7.)

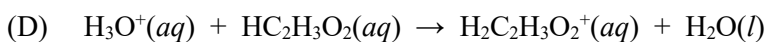
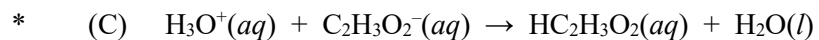
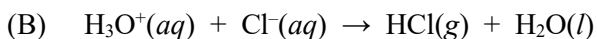
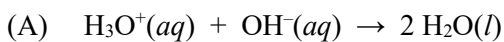
	Acetate Species	pH
(A)	$\text{HC}_2\text{H}_3\text{O}_2$	< 4.7
(B)	$\text{HC}_2\text{H}_3\text{O}_2$	> 4.7
(C)	$\text{C}_2\text{H}_3\text{O}_2^-$	< 4.7
* (D)	$\text{C}_2\text{H}_3\text{O}_2^-$	> 4.7

Topic
8.8 Properties of Buffers

2014 Practice Exam #25

Q: Buffer mechanism - HCl added to acetate buffer

A solution is prepared by adding 100 mL of 1.0 M $\text{HC}_2\text{H}_3\text{O}_2(aq)$ to 100 mL of 1.0 M $\text{NaC}_2\text{H}_3\text{O}_2(aq)$. The solution is stirred and its pH is measured to be 4.73. After 3 drops of 1.0 M HCl are added to the solution, the pH of the solution is measured and is still 4.73. Which of the following equations represents the chemical reaction that accounts for the fact that acid was added but there was no detectable change in pH?



Topic
8.8 Properties of Buffers

2013 Practice Exam #52

Q: pH of 4 acids - buffer mechanism with strong acid

Questions X-Y refer to the following.

Concentration (<i>M</i>)	pH of Acid 1	pH of Acid 2	pH of Acid 3	pH of Acid 4
0.010	3.44	2.00	2.92	2.20
0.050	3.09	1.30	2.58	1.73
0.10	2.94	1.00	2.42	1.55
0.50	2.69	0.30	2.08	1.16
1.0	2.44	0.00	1.92	0.98

The pH of solutions of four acids prepared at various concentrations were measured and recorded in the table above. The four acids are, in no particular order, chlorous, hydrochloric, lactic, and propanoic.

A 25 mL sample of a 1.0 *M* solution of acid 1 is mixed with 25 mL of 0.50 *M* NaOH. Which of the following best explains what happens to the pH of the mixture when a few drops of 1.0 *M* HNO₃ are added?

- (A) The pH of the mixture increases sharply, because HNO₃ is a strong acid.
- (B) The pH of the mixture decreases sharply, because H₃O⁺ ions were added.
- * (C) The pH of the mixture stays about the same, because the conjugate base of acid 1 reacts with the added H₃O⁺ ions.
- (D) The pH of the mixture stays about the same, because the OH⁻ ions in the solution react with the added H₃O⁺ ions.

Topic
8.9 Henderson-Hasselbalch Equation

2023 Practice Exam (from AP Classroom)

Q: pH and pKa of weak acids

Acid	pK_a
$\text{HClO}_2(aq)$	1.92
$\text{HNO}_2(aq)$	3.25
$\text{HC}_3\text{H}_5\text{O}_2(aq)$	4.88
$\text{HOCl}(aq)$	7.42

Based on the information in the table, which of the following mixtures forms a buffer with a pH closest to 3?

- (A) 50.0 mL of 0.10 M $\text{HClO}_2(aq)$ and 25.0 mL of 0.10 M $\text{NaOH}(aq)$
- * (B) 50.0 mL of 0.20 M $\text{HNO}_2(aq)$ and 50.0 mL of 0.10 M $\text{NaOH}(aq)$
- (C) 50.0 mL of 0.10 M $\text{HC}_3\text{H}_5\text{O}_2(aq)$ and 50.0 mL of 0.050 M $\text{NaOH}(aq)$
- (D) 50.0 mL of 0.10 M $\text{HOCl}(aq)$ and 25.0 mL of 0.10 M $\text{NaOH}(aq)$

Topic
8.9 Henderson-Hasselbalch Equation

2023 Practice Exam (from AP Classroom)

Q: Sodium bicarbonate buffer

A student attempts to prepare a buffer solution with a pH of 10.0 by adding NaHCO_3 ($\text{p}K_a = 10.3$) and Na_2CO_3 to distilled water. Instead of the desired pH, the measured pH of the buffer solution is 9.5. Which of the following is the most likely reason that the pH is too low?

- * (A) Too much NaHCO_3 was used.
- (B) Too much Na_2CO_3 was used.
- (C) There was water in the flask before NaHCO_3 and Na_2CO_3 were added.
- (D) In order to prepare the buffer, a few drops of a strong base should have been added.

Topic
8.9 Henderson-Hasselbalch Equation

2022 Practice Exam (from AP Classroom)

Q: Buffer from K_a values

Acid	K_a
$\text{HF}(aq)$	4×10^{-4}
$\text{HC}_2\text{H}_3\text{O}_2(aq)$	2×10^{-5}
$\text{HClO}(aq)$	3×10^{-8}
$\text{HCN}(aq)$	5×10^{-10}

Based on the K_a values listed in the table above, equal volumes of which of the following pairs of solutions when mixed together will result in a buffer solution with a pH between 7 and 8?

- (A) $0.10\text{ M HC}_2\text{H}_3\text{O}_2(aq)$ and $0.10\text{ M HF}(aq)$
- (B) $0.10\text{ M HC}_2\text{H}_3\text{O}_2(aq)$ and $0.10\text{ M NaC}_2\text{H}_3\text{O}_2(aq)$
- (C) $0.10\text{ M HC}_2\text{H}_3\text{O}_2(aq)$ and $0.10\text{ M HCN}(aq)$
- * (D) $0.10\text{ M HClO}(aq)$ and $0.10\text{ M NaClO}(aq)$

Topic
8.9 Henderson-Hasselbalch Equation

2021 Practice Exam (from AP Classroom)

Q: Create buffer

Solution	pK_a
$HF(aq)$	3.17
$HC_2H_3O_2(aq)$	4.74
$NH_4^+(aq)$	9.26

Based on the information in the table above, which of the following pairs of solutions can be used to create a buffer with a pH of 9.3? (Assume all solutions are 1.0 M.)

- (A) 100.0 mL of $HC_2H_3O_2(aq)$ and 50.0 mL of $KOH(aq)$
- (B) 50.0 mL of $HF(aq)$ and 50.0 mL of $NaF(aq)$
- (C) 100.0 mL of $NH_3(aq)$ and 100.0 mL of $HCl(aq)$
- * (D) 50.0 mL of $NH_3(aq)$ and 50.0 mL of $NH_4Cl(aq)$

Topic
8.9 Henderson-Hasselbalch Equation

2015 Practice Exam #10

Q: Acetate buffer - major species in soln and pH

An acetate buffer solution is prepared by combining 50. mL of 0.20 *M* acetic acid, $\text{HC}_2\text{H}_3\text{O}_2(aq)$, and 50. mL of 0.20 *M* sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2(aq)$. A 5.0 mL sample of 0.10 *M* $\text{NaOH}(aq)$ is added to the buffer solution. Which of the following is a correct pairing of the acetate species present in greater concentration and of the pH of the solution after the $\text{NaOH}(aq)$ is added? (The $\text{p}K_a$ of acetic acid is 4.7.)

	Acetate Species	pH
(A)	$\text{HC}_2\text{H}_3\text{O}_2$	< 4.7
(B)	$\text{HC}_2\text{H}_3\text{O}_2$	> 4.7
(C)	$\text{C}_2\text{H}_3\text{O}_2^-$	< 4.7
* (D)	$\text{C}_2\text{H}_3\text{O}_2^-$	> 4.7

Topic
8.9 Henderson-Hasselbalch Equation

2015 Practice Exam #37

Q: Given K_a - make a buffer with approximate pH of 3

	K_a
$\text{HC}_3\text{H}_5\text{O}_3(aq)$	8.3×10^{-4}
$\text{CH}_3\text{NH}_3^+(aq)$	2.3×10^{-11}

The acid dissociation constants of $\text{HC}_3\text{H}_5\text{O}_3(aq)$ and $\text{CH}_3\text{NH}_3^+(aq)$ are given in the table above. Which of the following mixtures is a buffer with a pH of approximately 3 ?

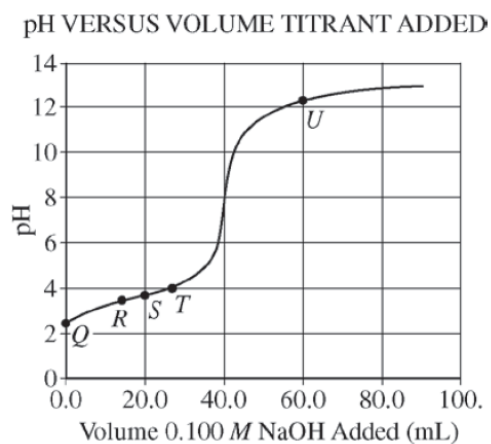
- (A) A mixture of 100. mL of 0.1 M $\text{CH}_3\text{NH}_3\text{Cl}$ and 50. mL of 0.1 M NaOH
- * (B) A mixture of 100. mL of 0.1 M $\text{HC}_3\text{H}_5\text{O}_3$ and 50. mL of 0.1 M NaOH
- (C) A mixture of 100. mL of 0.1 M $\text{NaC}_3\text{H}_5\text{O}_3$ and 100. mL of 0.1 M NaOH
- (D) A mixture of 100. mL of 0.1 M $\text{CH}_3\text{NH}_3\text{Cl}$ and 100. mL of 0.1 M CH_3NH_2

Topic
8.9 Henderson-Hasselbalch Equation

2013 Practice Exam #16

Q: Titration curve - point where A⁻ conc. is twice HA

Questions X-Y refer to the following.



A 50.0 mL sample of an acid, HA, of unknown molarity is titrated, and the pH of the resulting solution is measured with a pH meter and graphed as a function of the volume of 0.100 M NaOH added.

At which point on the titration curve is $[A^-]$ closest to twice that of $[HA]$?

(A) R

(B) S

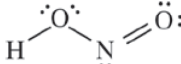
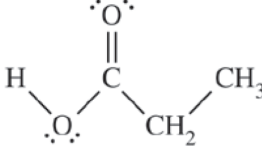
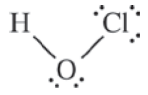
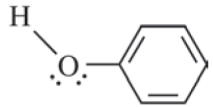
* (C) T

(D) U

Topic
8.9 Henderson-Hasselbalch Equation

2013 Practice Exam #55

Q: Buffer design - pH of 7.5 given K_a and structure

Acid	Structure	K_a
HNO_2		4.0×10^{-4}
$\text{HC}_3\text{H}_5\text{O}_2$		1.3×10^{-5}
HClO		3.0×10^{-8}
HOC_6H_5		1.6×10^{-10}

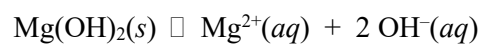
The table above shows the values of K_a for four weak acids. Which of the following pairs of chemical species, when combined in equimolar amounts, results in a buffer with a pH closest to 7.5?

- (A) HNO_2 and OH^-
- (B) $\text{HC}_3\text{H}_5\text{O}_2$ and $\text{C}_3\text{H}_5\text{O}_2^-$
- * (C) HClO and ClO^-
- (D) $\text{C}_6\text{H}_5\text{OH}$ and $\text{C}_6\text{H}_5\text{O}^-$

Topic
8.11 pH and Solubility

2015 Practice Exam #13

Q: Which change increases Mg(OH)_2 solubility



The exothermic dissolution of $\text{Mg(OH)}_2(s)$ in water is represented by the equation above. The K_{sp} of Mg(OH)_2 is 1.8×10^{-11} . Which of the following changes will increase the solubility of Mg(OH)_2 in an aqueous solution?

- * (A) Decreasing the pH
- (B) Increasing the pH
- (C) Adding NH_3 to the solution
- (D) Adding $\text{Mg(NO}_3)_2$ to the solution

Topic
9.1 Introduction to Entropy

2023 Practice Exam (from AP Classroom)

Q: Negative Entropy

Which of the following processes will most likely have a negative ΔS_{rxn}° ?

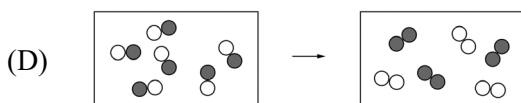
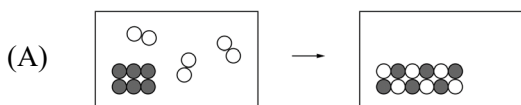
- * (A) $3 \text{H}_2(g) + \text{N}_2(g) \rightarrow 2 \text{NH}_3(g)$
- (B) $\text{H}_2(g) + \text{Cl}_2(g) \rightarrow 2 \text{HCl}(g)$
- (C) $\text{H}_2\text{O}(s) \rightarrow \text{H}_2\text{O}(l)$
- (D) $2 \text{O}_3(g) \rightarrow 3 \text{O}_2(g)$

Topic
9.1 Introduction to Entropy

2022 Practice Exam (from AP Classroom)

Q: Entropy from particle diagram

Which of the following pairs of diagrams represents the change with the greatest positive value of ΔS° ?



Topic
9.1 Introduction to Entropy

2021 Practice Exam (from AP Classroom)

Q: Reaction with negative delta S

Which of the following equations represents a reaction with a negative ΔS° ?

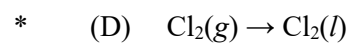
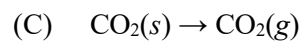
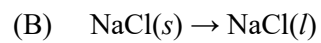
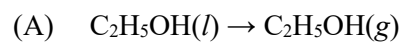
- * (A) $2 \text{NO}(g) + \text{O}_2(g) \rightarrow 2 \text{NO}_2(g)$
- (B) $2 \text{KClO}_3(s) \rightarrow 2 \text{KCl}(s) + 3 \text{O}_2(g)$
- (C) $\text{PCl}_5(g) \rightarrow \text{PCl}_3(g) + \text{Cl}_2(g)$
- (D) $\text{C}_3\text{H}_8(g) + 5 \text{O}_2(g) \rightarrow 3 \text{CO}_2(g) + 4 \text{H}_2\text{O}(g)$

Topic
9.1 Introduction to Entropy

2019 Practice Exam #1

Q: Process for which entropy change is negative

In which of the following processes will ΔS° be negative?



Topic
9.1 Introduction to Entropy

2018 Practice Exam #49

Q: Particulate representation shows entropy decrease

Which of the following particulate representations shows a process during which the entropy of the system decreases?

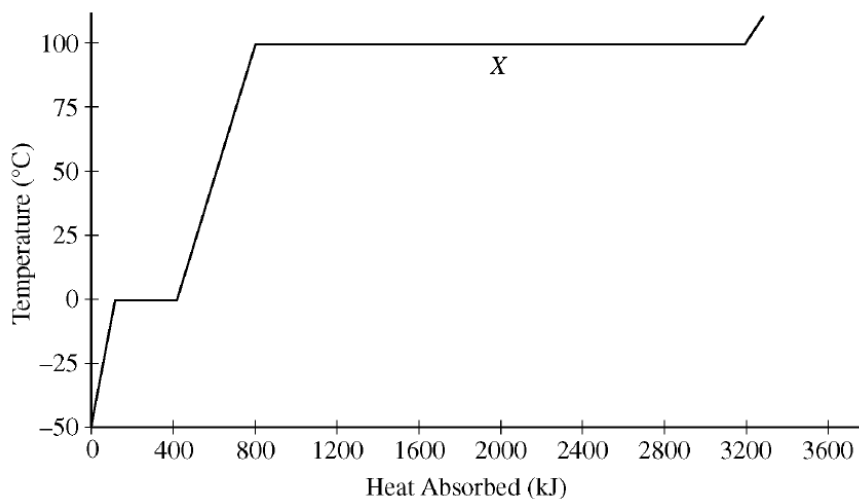
	<u>Before</u>	→	<u>After</u>
(A)			
(B)			
(C)			
(D)			

*

Topic
9.1 Introduction to Entropy

2016 Practice Exam #43

Q: Sign of enthalpy + entropy change - heating curve



At 1.0 atm a sample of ice is heated to liquid water and then to water vapor. The heating curve is shown in the graph above. Which of the following lists the signs for the changes in enthalpy and entropy for the process corresponding to segment X, going from left to right?

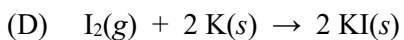
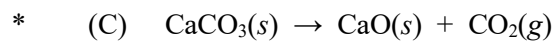
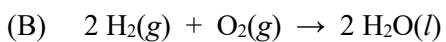
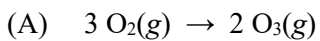
	ΔH°	ΔS°
(A)	Positive	Negative
* (B)	Positive	Positive
(C)	Negative	Negative
(D)	Negative	Positive

Topic
9.1 Introduction to Entropy

2014 Practice Exam #13

Q: Which equation has a positive entropy change

Which of the following equations represents a reaction for which the standard entropy change is positive ($\Delta S^\circ > 0$) ?

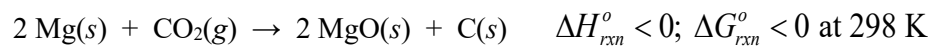


Topic
9.2 Absolute Entropy and Entropy Change

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2022 Practice Exam (from AP Classroom)

Q: Reaction driven by enthalpy entropy



Which of the following is true about the reaction represented above?

- * (A) At 298 K, it is driven by enthalpy only.
- (B) At 298 K, it is driven by entropy only.
- (C) At 298 K, it is driven by both enthalpy and entropy.
- (D) It is thermodynamically favorable at all temperatures.

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2021 Practice Exam (from AP Classroom)

Q: Delta H and delta S

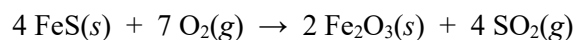
The equilibrium constant for a reaction is greater than 1.0 at temperatures above 500 K but less than 1.0 at temperatures below 500 K. What can be concluded about the values of ΔH° and ΔS° for the reaction? (Assume that ΔH° and ΔS° are independent of temperature.)

- * (A) $\Delta H^\circ > 0$ and $\Delta S^\circ > 0$
- (B) $\Delta H^\circ > 0$ and $\Delta S^\circ < 0$
- (C) $\Delta H^\circ < 0$ and $\Delta S^\circ > 0$
- (D) $\Delta H^\circ < 0$ and $\Delta S^\circ < 0$

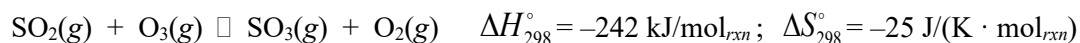
Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2021 Practice Exam (from AP Classroom)

Q: Sign of delta G naught



Due to the presence of FeS(*s*) as an impurity, the combustion of some types of coal results in the formation of SO₂(*g*), as represented by the equation above. Also, SO₂(*g*) can react with O₃(*g*) to form SO₃(*g*), as represented by the equation below.



Which of the following is most likely to be true about the reaction between SO₂(*g*) and O₃(*g*) at 298 K?

- * (A) $\Delta G^{\circ} < 0$ and $T\Delta S^{\circ}$ is smaller in magnitude than ΔH° .
- (B) $\Delta G^{\circ} < 0$ and $T\Delta S^{\circ}$ is larger in magnitude than ΔH° .
- (C) $\Delta G^{\circ} > 0$ and $T\Delta S^{\circ}$ is smaller in magnitude than ΔH° .
- (D) $\Delta G^{\circ} > 0$ and $T\Delta S^{\circ}$ is larger in magnitude than ΔH° .

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2019 Practice Exam #20

Q: Why endothermic KNO_3 dissolution is favorable

As a sample of $\text{KNO}_3(s)$ is stirred into water at 25°C , the compound dissolves endothermically. Which of the following best helps to explain why the process is thermodynamically favorable at 25°C ?

- (A) All endothermic processes are thermodynamically favorable.
- (B) Stirring the solution during dissolution adds the energy needed to drive an endothermic process.
- (C) Dissolving the salt decreases the enthalpy of the system.
- * (D) Dissolving the salt increases the entropy of the system.

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2019 Practice Exam #33

Q: Sign on enthalpy + entropy - K decreases at high T

A student observes that the equilibrium constant for a reaction is greater than 1.0 at temperatures below 500 K but less than 1.0 at temperatures above 500 K. What can the student conclude about the values of ΔH° and ΔS° for the reaction? (Assume that ΔH° and ΔS° are independent of temperature.)

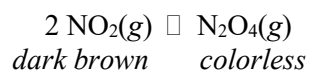
- (A) $\Delta H^\circ > 0$ and $\Delta S^\circ > 0$
- (B) $\Delta H^\circ > 0$ and $\Delta S^\circ < 0$
- (C) $\Delta H^\circ < 0$ and $\Delta S^\circ > 0$
- * (D) $\Delta H^\circ < 0$ and $\Delta S^\circ < 0$

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2018 Practice Exam #44

Q: NO₂ dimerization - favored at which temperatures

Questions X-Y refer to the following information.



The dimerization of NO₂(g), an exothermic process, is represented by the equation above.

The forward reaction is thermodynamically favored at which of the following temperatures?

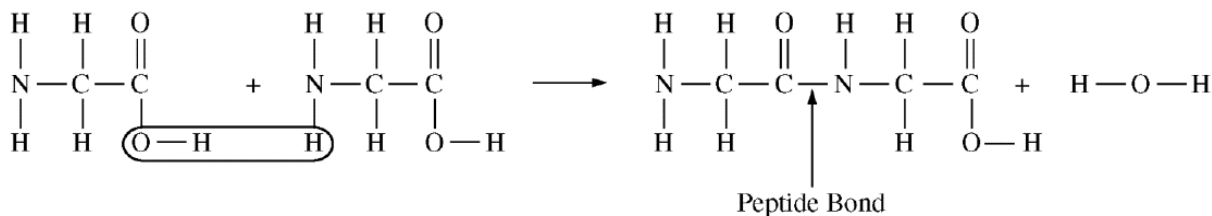
- (A) All temperatures
- * (B) Low temperatures only
- (C) High temperatures only
- (D) No temperature

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2017 Practice Exam #36

Q: Peptide - T when rxn is favored given dG dH dS

Questions X-Y refer to the following information.



Two molecules of the amino acid glycine join through the formation of a peptide bond, as shown above. The thermodynamic data for the reaction are listed in the following table.

ΔG_{298}°	ΔH_{298}°	ΔS_{298}°
+15 kJ/mol _{rxn}	+12 kJ/mol _{rxn}	-10 J/(K·mol _{rxn})

Under which of the following temperature conditions is the reaction thermodynamically favored?

- (A) It is only favored at high temperatures.
- (B) It is only favored at low temperatures.
- (C) It is favored at all temperatures.
- * (D) It is not favored at any temperature.

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

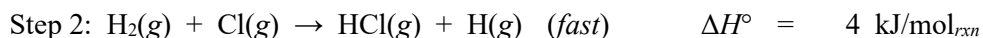
2017 Practice Exam #42

Q: HCl equil mechanism - reason for large value of K

Questions X-Y refer to the following information.



HCl(g) can be synthesized from H₂(g) and Cl₂(g) as represented above. A student studying the kinetics of the reaction proposes the following mechanism.



Which of the following statements identifies the greatest single reason that the value of K_p for the overall reaction at 298 K has such a large magnitude?

- (A) The activation energy for step 1 of the mechanism is large and positive.
- (B) The activation energy for step 2 of the mechanism is small and positive.
- (C) The value of ΔS° for the overall reaction is small and positive.
- * (D) The value of ΔH° for the overall reaction is large and negative.

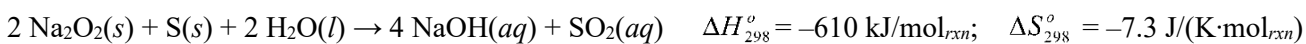
Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2016 Practice Exam #39

Q: Na₂O₂ + S - thermodynamic favorability driven by

Questions X-Y refer to the following information.

When water is added to a mixture of Na₂O₂(s) and S(s), a redox reaction occurs, as represented by the equation below.



Which of the following statements about the thermodynamic favorability of the reaction at 298 K is correct?

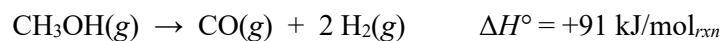
- (A) It is thermodynamically unfavorable.
- (B) It is thermodynamically favorable and is driven by ΔS° only.
- * (C) It is thermodynamically favorable and is driven by ΔH° only.
- (D) It is thermodynamically favorable and is driven by both ΔH° and ΔS° .

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2016 Practice Exam #46

Q: CH₃OH decomp - sign of entropy change

Questions X-Y refer to the following.



The reaction represented above goes essentially to completion. The reaction takes place in a rigid, insulated vessel that is initially at 600 K.

What can be inferred about ΔS° for the reaction at 600 K?

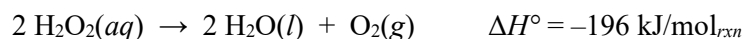
- (A) It must be positive, since the reaction is thermodynamically unfavorable at 600 K.
- (B) It must be negative, since there are more moles of products than reactants.
- * (C) It must be positive, since ΔG° is negative and ΔH° is positive.
- (D) It must be negative, since ΔG° is positive and ΔH° is positive.

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2015 Practice Exam #28

Q: H₂O₂ decomp - signs of free energy and entropy

Questions X-Y refer to the following information.



The decomposition of H₂O₂(aq) is represented by the equation above. A student monitored the decomposition of a 1.0 L sample of H₂O₂(aq) at a constant temperature of 300. K and recorded the concentration of H₂O₂ as a function of time. The results are given in the table below.

Time (s)	[H ₂ O ₂]
0	2.7
200.	2.1
400.	1.7
600.	1.4

The reaction is thermodynamically favorable. The signs of ΔG° and ΔS° for the reaction are which of the following?

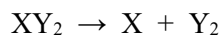
	ΔG°	ΔS°
(A)	Positive	Positive
* (B)	Negative	Positive
(C)	Positive	Negative
(D)	Negative	Negative

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

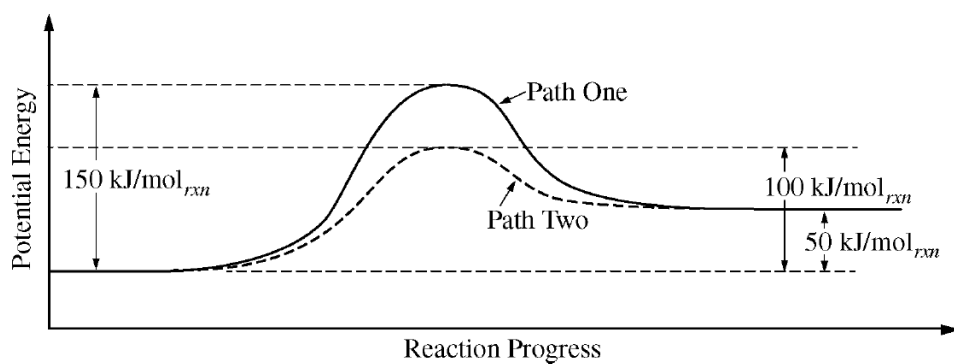
2014 Practice Exam #46

Q: Rxn energy profile - entropy change of reaction

Questions X-Y relate to the following information.



The equation above represents the decomposition of a compound XY_2 . The diagram below shows two reaction profiles (path one and path two) for the decomposition of XY_2 .



The reaction is thermodynamically favorable under standard conditions at 298 K. Therefore, the value of ΔS° for the reaction must be

- (A) equal to zero
- (B) equal to $\Delta H^\circ/298 \text{ K}$
- * (C) greater than $\Delta H^\circ/298 \text{ K}$
- (D) less than $\Delta H^\circ/298 \text{ K}$

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2013 Practice Exam #12

Q: Rxn is favored at high T but not low T - dS and dH

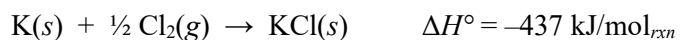
Which of the following reactions is not thermodynamically favored at low temperatures but becomes favored as the temperature increases?

	Reaction	ΔH° (kJ/mol _{rxn})	ΔS° (J/mol _{rxn} · K)
(A)	$2 \text{ CO}(g) + \text{O}_2(g) \rightarrow 2 \text{ CO}_2(g)$	-566	-173
* (B)	$2 \text{ H}_2\text{O}(g) \rightarrow 2 \text{ H}_2(g) + \text{O}_2(g)$	484	90.0
(C)	$2 \text{ N}_2\text{O}(g) \rightarrow 2 \text{ N}_2(g) + \text{O}_2(g)$	-164	149
(D)	$\text{PbCl}_2(s) \rightarrow \text{Pb}^{2+}(aq) + 2 \text{ Cl}^-(aq)$	23.4	-12.5

Topic
9.3 Gibbs Free Energy and Thermodynamic Favorability

2013 Practice Exam #37

Q: KCl enthalpy - driven by enthalpy or entropy



The elements K and Cl react directly to form the compound KCl according to the equation above. Refer to the information above and the table below to answer the questions that follow.

Process	ΔH° (kJ/mol _{rxn})
$\text{K}(s) \rightarrow \text{K}(g)$	v
$\text{K}(g) \rightarrow \text{K}^+(g) + e^-$	w
$\text{Cl}_2(g) \rightarrow 2 \text{Cl}(g)$	x
$\text{Cl}(g) + e^- \rightarrow \text{Cl}^-(g)$	y
$\text{K}^+(g) + \text{Cl}^-(g) \rightarrow \text{KCl}(s)$	z

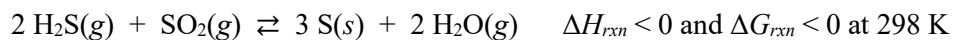
It is observed that the reaction producing KCl from its elements goes essentially to completion. Which of the following is a true statement about the thermodynamic favorability of the reaction?

- * (A) The reaction is favorable and driven by an enthalpy change only.
- (B) The reaction is unfavorable and driven by an entropy change only.
- (C) The reaction is favorable and driven by both enthalpy and entropy changes.
- (D) The reaction is unfavorable due to both enthalpy and entropy changes.

Topic
9.4 Thermodynamic and Kinetic Control

2023 Practice Exam (from AP Classroom)

Q: Activation energy of a reaction



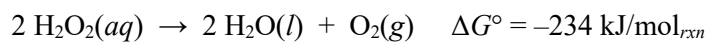
A 0.20 mol sample of $\text{H}_2\text{S}(g)$ and a 0.10 mol sample of $\text{SO}_2(g)$ are placed in a previously evacuated 10.0 L vessel at 298 K. Even though the reaction represented by the equation above is thermodynamically favorable, the formation of $\text{S}(s)$ was not observed. Which of the following best explains why $\text{S}(s)$ is not produced at 298 K?

- (A) At 298 K, some $\text{S}(s)$ must first be present for the reaction to occur.
- (B) At 298 K, the value of the equilibrium constant is less than 1.
- * (C) At 298 K, the energy of most molecular collisions is lower than the activation energy for the reaction.
- (D) At 298 K, the loss of entropy is too great to make molecular collisions likely to occur.

Topic
9.4 Thermodynamic and Kinetic Control

2021 Practice Exam (from AP Classroom)

Q: Delta G and stable reactant



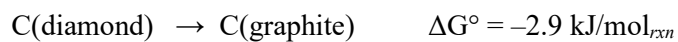
The value of ΔG° for the reaction represented above implies that the decomposition of $\text{H}_2\text{O}_2(aq)$ is thermodynamically favorable. However, $\text{H}_2\text{O}_2(aq)$ is typically stable for up to a year stored in a dark bottle at 298 K. The best explanation for this observation is that the decomposition reaction

- (A) is only thermodynamically favorable in the presence of a catalyst
- (B) occurs with an increase in entropy because $\text{O}_2(g)$ is a product
- (C) is reversible and $\text{H}_2\text{O}_2(aq)$ is produced almost as fast as it decomposes
- * (D) has a slow rate at 298 K because the activation energy is relatively high

Topic
9.4 Thermodynamic and Kinetic Control

2019 Practice Exam #40

Q: Why diamond doesn't convert to graphite at 298K



Which of the following best explains why the reaction represented above is not observed to occur at room temperature?

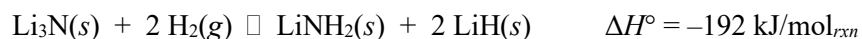
- (A) The rate of the reaction is extremely slow because of the relatively small value of ΔG° for the reaction.
- (B) The entropy of the system decreases because the carbon atoms in graphite are less ordered than those in diamond.
- * (C) The reaction has an extremely large activation energy due to strong three-dimensional bonding among carbon atoms in diamond.
- (D) The reaction does not occur because it is not thermodynamically favorable.

Topic
9.4 Thermodynamic and Kinetic Control

2018 Practice Exam #35

Q: H₂ storage - high rxn rate only at T above 200 C

Questions X-Y refer to the following information.



Because pure H₂ is a hazardous substance, safer and more cost effective techniques to store it as a solid for shipping purposes have been developed. One such method is the reaction represented above, which occurs at 200°C.

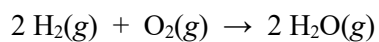
Which of the following is the most likely reason that the reaction occurs at a significant rate only if the temperature of the reaction mixture is greater than 200°C?

- (A) The reaction is exothermic.
- (B) ΔS° for the reaction is negative.
- * (C) The reaction has a high activation energy.
- (D) $\Delta G^\circ < 0$ when $T < 200^\circ\text{C}$.

Topic
9.4 Thermodynamic and Kinetic Control

2017 Practice Exam #48

Q: Why spark is needed for H₂ and O₂ to produce H₂O



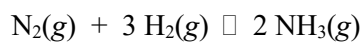
When H₂(g) and O₂(g) are mixed together in a rigid reaction vessel at 25°C, no reaction occurs. When the mixture is sparked, however, the gases react vigorously according to the equation above, releasing heat. Which of the following statements correctly explains why the spark is needed for the reaction to occur when the gases are originally at 25°C?

- (A) The reaction is not thermodynamically favorable at 25°C.
- (B) ΔH° for the reaction has a large positive value at 25°C.
- (C) ΔS° for the reaction has a large negative value at 25°C.
- * (D) The reaction has a large activation energy at 25°C.

Topic
9.4 Thermodynamic and Kinetic Control

2014 Practice Exam #37

Q: NH₃ synthesis - why favorable rxn is not observed



$$\Delta H_{298}^{\circ} = -92 \text{ kJ/mol}_{\text{rxn}}; \quad \Delta G_{298}^{\circ} = -33 \text{ kJ/mol}_{\text{rxn}}$$

Consider the reaction represented above at 298 K. When equal volumes of N₂(g) and H₂(g), each at 1 atm, are mixed in a closed container at 298 K, no formation of NH₃(g) is observed. Which of the following best explains the observation?

- (A) The N₂(g) and the H₂(g) must be mixed in a 1:3 ratio for a reaction to occur.
- * (B) A high activation energy makes the forward reaction extremely slow at 298 K.
- (C) The reaction has an extremely small equilibrium constant, so almost no product will form.
- (D) The reverse reaction has a lower activation energy than the forward reaction, so the forward reaction does not occur.

Topic
9.5 Free Energy and Equilibrium

2023 Practice Exam (from AP Classroom)

Q: K_{eq} from ΔH and ΔS

A reaction is known to have a negative value of ΔH° and a positive value of ΔS° . Which of the following statements correctly describes the equilibrium constant, K_{eq} , for this reaction?

- (A) K_{eq} will be less than 1 only at high temperatures.
- (B) K_{eq} will be less than 1 at all temperatures.
- (C) K_{eq} will be greater than 1 only at low temperatures.
- * (D) K_{eq} will be greater than 1 at all temperatures.

Topic
9.5 Free Energy and Equilibrium

2019 Practice Exam #33

Q: Sign on enthalpy + entropy - K decreases at high T

A student observes that the equilibrium constant for a reaction is greater than 1.0 at temperatures below 500 K but less than 1.0 at temperatures above 500 K. What can the student conclude about the values of ΔH° and ΔS° for the reaction? (Assume that ΔH° and ΔS° are independent of temperature.)

- (A) $\Delta H^\circ > 0$ and $\Delta S^\circ > 0$
- (B) $\Delta H^\circ > 0$ and $\Delta S^\circ < 0$
- (C) $\Delta H^\circ < 0$ and $\Delta S^\circ > 0$
- * (D) $\Delta H^\circ < 0$ and $\Delta S^\circ < 0$

Topic
9.5 Free Energy and Equilibrium

2019 Practice Exam #50

Q: FeO + C Coupled reactions - K and sign of delta G



The formation of Fe(s) and O₂(g) from FeO(s) is not thermodynamically favorable at room temperature. In an effort to make the process favorable, C(s) is added to the FeO(s) at elevated temperatures. Based on the information above, which of the following gives the value of K_{eq} and the sign of ΔG° for the reaction represented by the equation below at 1000 K?



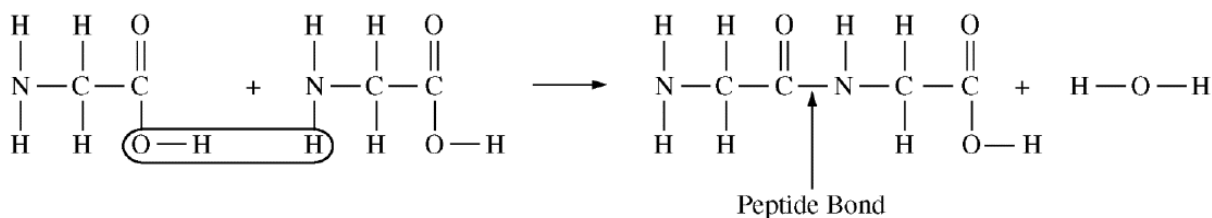
	K_{eq}	ΔG°
(A)	1×10^{-38}	Positive
(B)	1×10^{-38}	Negative
(C)	1×10^{26}	Positive
* (D)	1×10^{26}	Negative

Topic
9.5 Free Energy and Equilibrium

2017 Practice Exam #38

Q: Peptide - magnitude of K for the reaction

Questions X-Y refer to the following information.



Two molecules of the amino acid glycine join through the formation of a peptide bond, as shown above. The thermodynamic data for the reaction are listed in the following table.

ΔG_{298}°	ΔH_{298}°	ΔS_{298}°
+15 kJ/mol _{rxn}	+12 kJ/mol _{rxn}	-10 J/(K·mol _{rxn})

Based on thermodynamic data, which of the following is true at 298 K?

- (A) $K_{eq} = 0$
- * (B) $0 < K_{eq} < 1$
- (C) $K_{eq} = 1$
- (D) $K_{eq} > 1$

Topic
9.5 Free Energy and Equilibrium

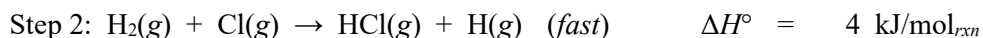
2017 Practice Exam #42

Q: HCl equil mechanism - reason for large value of K

Questions X-Y refer to the following information.



HCl(g) can be synthesized from H₂(g) and Cl₂(g) as represented above. A student studying the kinetics of the reaction proposes the following mechanism.



Which of the following statements identifies the greatest single reason that the value of K_p for the overall reaction at 298 K has such a large magnitude?

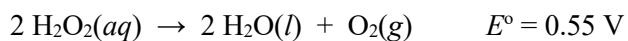
- (A) The activation energy for step 1 of the mechanism is large and positive.
- (B) The activation energy for step 2 of the mechanism is small and positive.
- (C) The value of ΔS° for the overall reaction is small and positive.
- * (D) The value of ΔH° for the overall reaction is large and negative.

Topic
9.5 Free Energy and Equilibrium

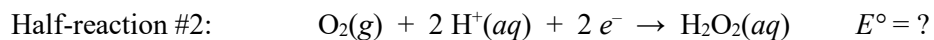
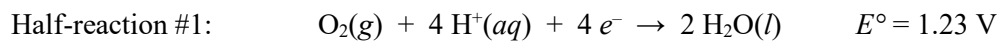
2016 Practice Exam #15

Q: H₂O₂ Ecell - sign of delta G and magnitude of K

Questions X-Y refer to the following information.



The equation and standard cell potential for the decomposition of H₂O₂(aq) in acidic solution at 25°C is given above. The reduction half-reactions for the process are listed below.



Which of the following is true for the decomposition of H₂O₂(aq) ?

(A) $\Delta G^\circ > 0$ and $K_{eq} > 1$

(B) $\Delta G^\circ > 0$ and $K_{eq} < 1$

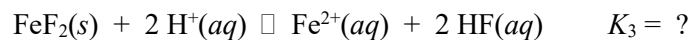
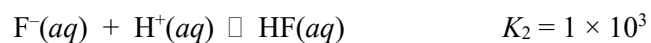
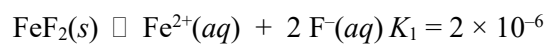
* (C) $\Delta G^\circ < 0$ and $K_{eq} > 1$

(D) $\Delta G^\circ < 0$ and $K_{eq} < 1$

Topic
9.5 Free Energy and Equilibrium

2014 Practice Exam #29

Q: Combining rxns - favorability from overall K value



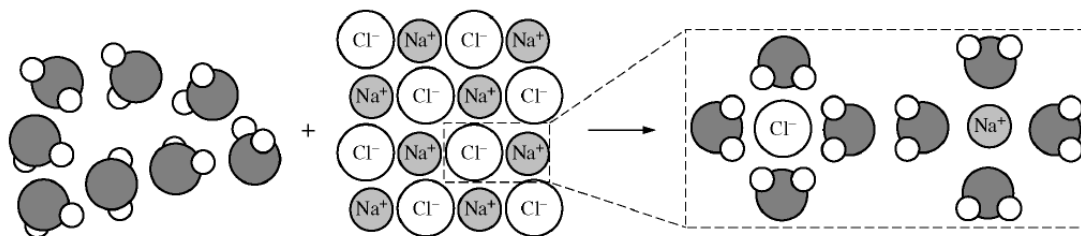
On the basis of the information above, the dissolution of $\text{FeF}_2(s)$ in acidic solution is

- (A) thermodynamically favorable, because $K_2 > 1$
- * (B) thermodynamically favorable, because $K_3 > 1$
- (C) not thermodynamically favorable, because $K_1 < 1$
- (D) not thermodynamically favorable, because $K_3 < 1$

Topic
9.6 Free Energy of Dissolution

2017 Practice Exam #34

Q: Signs on enthalpy and entropy for NaCl dissolution



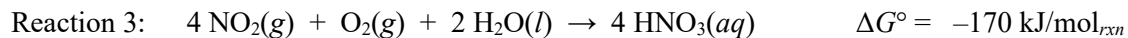
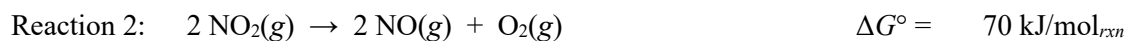
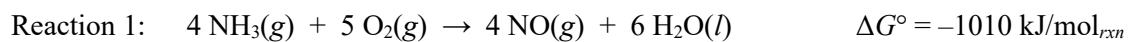
The process of dissolution of $\text{NaCl}(s)$ in $\text{H}_2\text{O}(l)$ is represented in the diagram above. Which of the following summarizes the signs of ΔH° and ΔS° for each part of the dissolution process?

	Breaking solvent–solvent interactions		Breaking solute–solute interactions		Forming solute–solvent interactions	
	ΔH°	ΔS°	ΔH°	ΔS°	ΔH°	ΔS°
* (A)	+	+	+	+	–	–
(B)	+	+	+	+	–	+
(C)	–	–	–	–	+	+
(D)	–	+	–	+	+	–

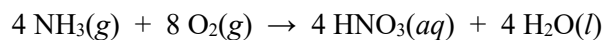
Topic
9.7 Coupled Reactions

2018 Practice Exam #38

Q: Given dG values for 3 rxns find overall dG value



Based on the values of ΔG° for the three reactions represented above, what is the value of ΔG° for the reaction represented below?



(A) $-1040 \text{ kJ/mol}_{rxn}$

(B) $-1110 \text{ kJ/mol}_{rxn}$

(C) $-1250 \text{ kJ/mol}_{rxn}$

* (D) $-1320 \text{ kJ/mol}_{rxn}$

Topic
9.8 Galvanic (Voltaic) and Electrolytic Cells

2023 Practice Exam (from AP Classroom)

Q: Ag and Ni galvanic cell

Half-Reaction	E° (V)
$\text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s)$	0.80
$\text{Ni}^{2+}(aq) + 2 e^- \rightarrow \text{Ni}(s)$	-0.25

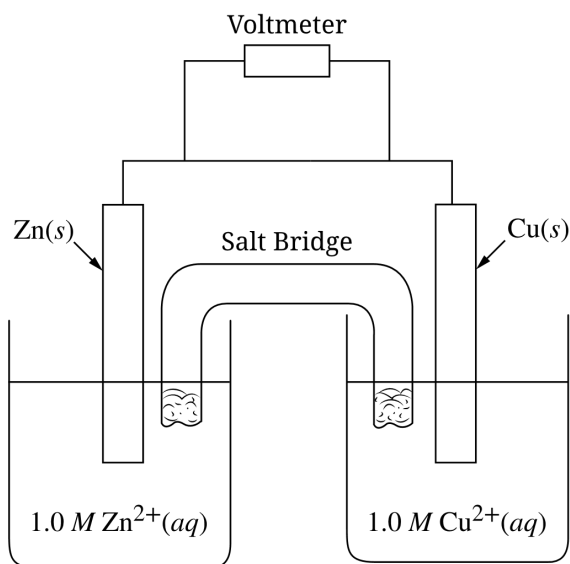
The standard reduction potentials of the half-reactions associated with a galvanic cell are listed in the table above. Which of the following statements identifies the electrode that increases in mass as the cell operates, and correctly explains why?

- * (A) The Ag electrode, because $\text{Ag}^+(aq)$ in the solution is reduced to form $\text{Ag}(s)$.
- (B) The Ag electrode, because Ag has a greater molar mass than Ni has.
- (C) The Ni electrode, because Ni is chemically more reactive than Ag is.
- (D) The Ni electrode, because $\text{Ni}^{2+}(aq)$ is reduced at a faster rate than $\text{Ag}^+(aq)$ is.

Topic
9.8 Galvanic (Voltaic) and Electrolytic Cells

2023 Practice Exam (from AP Classroom)

Q: Replace salt bridge with wire



Half-Reaction	E° (V)
$\text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s)$	0.80
$\text{Cu}^{2+}(aq) + 2e^- \rightarrow \text{Cu}(s)$	0.34
$\text{Zn}^{2+}(aq) + 2e^- \rightarrow \text{Zn}(s)$	-0.76

A student sets up a standard galvanic cell, as shown in the diagram, and measures a voltage of 1.10 V. Based on the standard reduction potentials in the table, which of the following will occur if the student makes a new standard cell but uses a silver wire in place of the salt bridge?

(A) The voltage will be greater than 1.10 V.

* (B) The voltage will be 0.

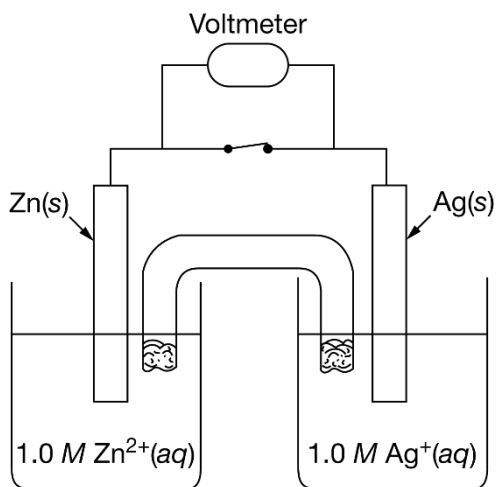
(C) The silver wire will become thinner.

(D) $\text{Zn}(s)$ and $\text{Cu}(s)$ will form on the silver wire.

Topic
9.8 Galvanic (Voltaic) and Electrolytic Cells

2021 Practice Exam (from AP Classroom)

Q: Best choice for salt bridge



Which of the following substances would be the best choice for filling the salt bridge in the galvanic cell shown above, and why?

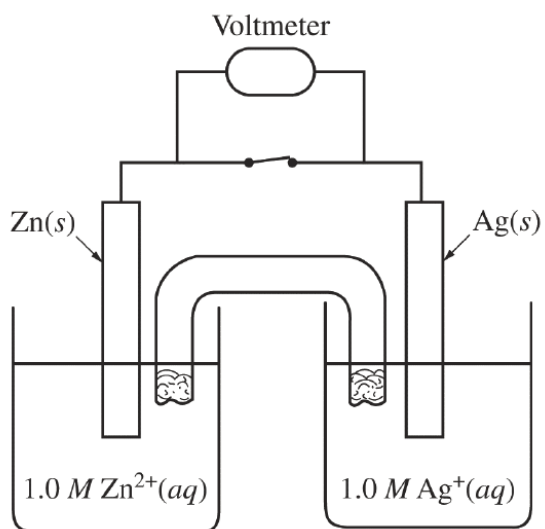
- (A) Distilled water, because it would avoid contaminating the solutions in the half-cells.
- (B) $1.0\text{ M HCl}(aq)$, because it would acidify the solutions and catalyze the overall cell reaction.
- (C) $1.0\text{ M CH}_3\text{OH}(aq)$, because it would increase the pH of the solutions and catalyze the overall cell reaction.
- * (D) $1.0\text{ M KNO}_3(aq)$, because the mobile ions would allow charge to flow between the half-cells.

Topic
9.8 Galvanic (Voltaic) and Electrolytic Cells

2019 Practice Exam #10

Q: Standard Zn-Ag Galvanic cell - overall reaction

Questions X-Y refer to the following information.



Standard reduction potentials for the half-reactions associated with the electrochemical cell shown above are given in the table below.

Half-Reaction	E° (V)
$\text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s)$	+ 0.80
$\text{Zn}^{2+}(aq) + 2 e^- \rightarrow \text{Zn}(s)$	- 0.76

Which of the following is the net ionic equation for the overall reaction that occurs as the cell operates?

- (A) $\text{Ag}(s) + \text{Zn}^{2+}(aq) \rightarrow \text{Ag}^{2+}(aq) + \text{Zn}(s)$
- (B) $\text{Ag}^+(aq) + \text{Zn}^{2+}(aq) + 3 e^- \rightarrow \text{AgZn}(s)$
- (C) $\text{Ag}^+(aq) + \text{Zn}(s) \rightarrow \text{Ag}(s) + \text{Zn}^{2+}(aq) + e^-$
- * (D) $2 \text{Ag}^+(aq) + \text{Zn}(s) \rightarrow 2 \text{Ag}(s) + \text{Zn}^{2+}(aq)$

Topic
9.8 Galvanic (Voltaic) and Electrolytic Cells

2013 Practice Exam #46

Not listed in the question bank

Questions X-Y refer to galvanic cells made from different combinations of the three half-cells described below.

Half-cell 1: strip of $\text{Al}(s)$ in $1.00\text{ M Al}(\text{NO}_3)_3(aq)$

Half-cell 2: strip of $\text{Cu}(s)$ in $1.00\text{ M Cu}(\text{NO}_3)_2(aq)$

Half-cell 3: strip of $\text{Fe}(s)$ in $1.00\text{ M Fe}(\text{NO}_3)_2(aq)$

Galvanic Cell	Half-cells	Cell Reaction	E° (V)
X	1 and 2	$2\text{ Al}(s) + 3\text{ Cu}^{2+}(aq) \rightarrow 2\text{ Al}^{3+}(aq) + 3\text{ Cu}(s)$	2.00
Y	1 and 3	$2\text{ Al}(s) + 3\text{ Fe}^{2+}(aq) \rightarrow 2\text{ Al}^{3+}(aq) + 3\text{ Fe}(s)$	1.22
Z	2 and 3	$\text{Fe}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{Cu}(s)$	?

In galvanic cells Y and Z, which of the following takes place in half-cell 3?

- (A) Reduction occurs in both cell Y and cell Z.
- (B) Oxidation occurs in both cell Y and cell Z.
- * (C) Reduction occurs in cell Y, and oxidation occurs in cell Z.
- (D) Oxidation occurs in cell Y, and reduction occurs in cell Z.

Topic
9.9 Cell Potential and Free Energy

2022 Practice Exam (from AP Classroom)

Q: Reaction with most positive cell potential

Reduction Half-Reaction	E° (V)
$\text{Ag}^+ + e^- \rightarrow \text{Ag}$	0.80
$\text{Sn}^{2+} + 2 e^- \rightarrow \text{Sn}$	-0.14
$\text{Fe}^{2+} + 2 e^- \rightarrow \text{Fe}$	-0.44
$\text{Zn}^{2+} + 2 e^- \rightarrow \text{Zn}$	-0.76

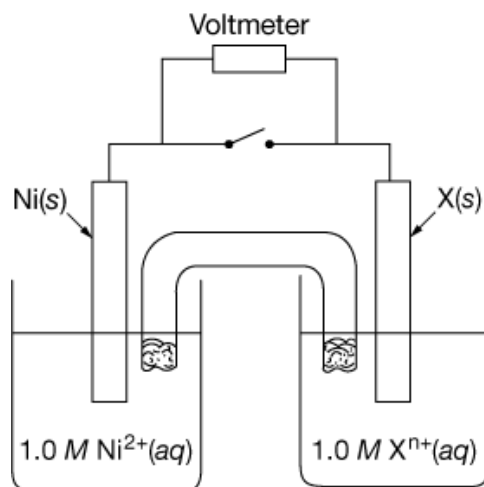
The standard reduction potentials of some half-reactions are given in the table above. Of the following equations, which represents the reaction that would be the basis of a cell with the most positive E_{cell}° ?

- * (A) $2 \text{Ag}^+ + \text{Sn} \rightarrow 2 \text{Ag} + \text{Sn}^{2+}$
- (B) $\text{Sn}^{2+} + 2 \text{Ag} \rightarrow \text{Sn} + 2 \text{Ag}^+$
- (C) $\text{Fe}^{2+} + \text{Zn} \rightarrow \text{Fe} + \text{Zn}^{2+}$
- (D) $\text{Zn}^{2+} + \text{Fe} \rightarrow \text{Zn} + \text{Fe}^{2+}$

Topic
9.9 Cell Potential and Free Energy

2021 Practice Exam (from AP Classroom)

Q: Element used in galvanic cell



In the galvanic cell shown above, the voltmeter connected across the electrodes shows a voltage of 0.52 V. Based on the standard reduction potentials given in the table below, which of the following is most likely the identity of the unknown element, X?

Half-Reaction	E° (V)
$\text{Rh}^{3+}(\text{aq}) + 3 e^- \rightarrow \text{Rh}(\text{s})$	0.76
$\text{Bi}^{3+}(\text{aq}) + 3 e^- \rightarrow \text{Bi}(\text{s})$	0.31
$\text{In}^+(\text{aq}) + e^- \rightarrow \text{In}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2 e^- \rightarrow \text{Ni}(\text{s})$	-0.24
$\text{Zn}^{2+}(\text{aq}) + 2 e^- \rightarrow \text{Zn}(\text{s})$	-0.76

(A) Rh

(B) Bi

(C) In

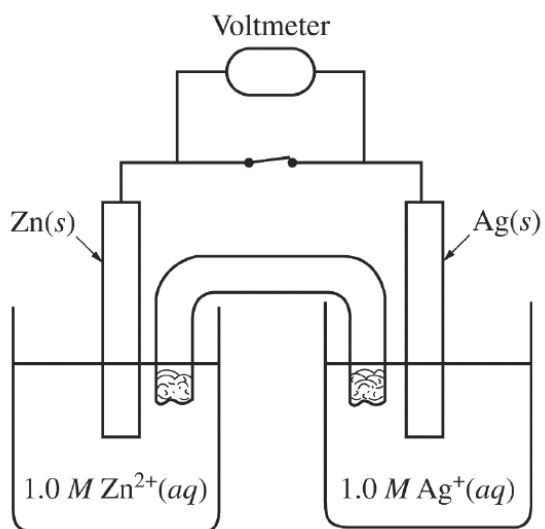
* (D) Zn

Topic
9.9 Cell Potential and Free Energy

2019 Practice Exam #11

Q: Standard Zn-Ag Galvanic cell - cell potential

Questions X-Y refer to the following information.



Standard reduction potentials for the half-reactions associated with the electrochemical cell shown above are given in the table below.

Half-Reaction	E° (V)
$\text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s)$	+ 0.80
$\text{Zn}^{2+}(aq) + 2 e^- \rightarrow \text{Zn}(s)$	- 0.76

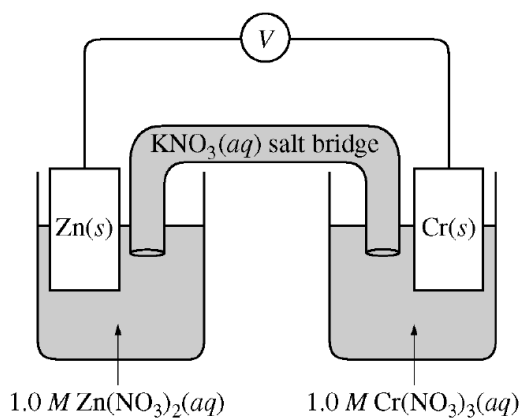
What is the value of E° for the cell?

- (A) 0.04 V
- (B) 0.84 V
- * (C) 1.56 V
- (D) 2.36 V

Topic
9.9 Cell Potential and Free Energy

2018 Practice Exam #8

Q: Ecell for Zn-Cr standard cell given half-reactions



The standard reduction potentials for the half-reactions related to the galvanic cell represented above are listed in the table below.

Half-Reaction	E° (V)
$\text{Cr}^{3+}(\text{aq}) + 3 e^- \rightarrow \text{Cr}(\text{s})$	-0.74
$\text{Zn}^{2+}(\text{aq}) + 2 e^- \rightarrow \text{Zn}(\text{s})$	-0.76

Which of the following gives the value of E°_{cell} for the cell?

(A) $E^\circ_{\text{cell}} = -1.50 \text{ V}$

(B) $E^\circ_{\text{cell}} = -0.80 \text{ V}$

(C) $E^\circ_{\text{cell}} = -0.02 \text{ V}$

* (D) $E^\circ_{\text{cell}} = +0.02 \text{ V}$

Topic
9.9 Cell Potential and Free Energy

2017 Practice Exam #31

Q: Mg^{2+} Cr^{3+} half-rxns - determine E_{cell} and ΔG

Half-Reaction	E° (V)
$\text{Mg}^{2+}(\text{aq}) + 2 e^- \rightarrow \text{Mg}(\text{s})$	- 2.37
$\text{Cr}^{3+}(\text{aq}) + 3 e^- \rightarrow \text{Cr}(\text{s})$	- 0.74

Based on the information in the table above, which of the following shows the cell potential and the Gibbs free energy change for the overall reaction that occurs in a standard galvanic cell?

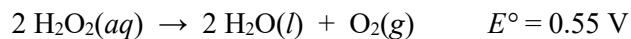
	E_{cell}° (V)	ΔG° (kJ/mol _{rxn})
(A)	+1.63	-157
* (B)	+1.63	-944
(C)	+5.63	-543
(D)	+5.63	-3262

Topic
9.9 Cell Potential and Free Energy

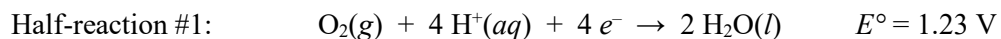
2016 Practice Exam #14

Q: H₂O₂ Ecell - reduction potential for O₂ + 2H⁺

Questions X-Y refer to the following information.



The equation and standard cell potential for the decomposition of H₂O₂(aq) in acidic solution at 25°C is given above. The reduction half-reactions for the process are listed below.



What is the standard reduction potential for half-reaction #2 represented above?

(A) -1.78 V

(B) -0.68 V

* (C) +0.68 V

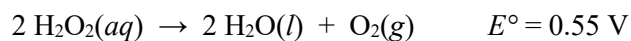
(D) +1.78 V

Topic
9.9 Cell Potential and Free Energy

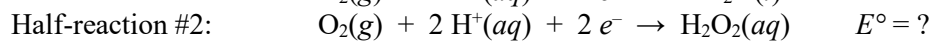
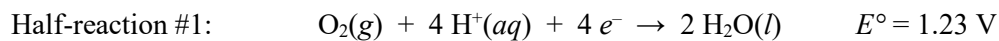
2016 Practice Exam #15

Q: H₂O₂ Ecell - sign of delta G and magnitude of K

Questions X-Y refer to the following information.



The equation and standard cell potential for the decomposition of H₂O₂(aq) in acidic solution at 25°C is given above. The reduction half-reactions for the process are listed below.



Which of the following is true for the decomposition of H₂O₂(aq) ?

(A) $\Delta G^\circ > 0$ and $K_{eq} > 1$

(B) $\Delta G^\circ > 0$ and $K_{eq} < 1$

* (C) $\Delta G^\circ < 0$ and $K_{eq} > 1$

(D) $\Delta G^\circ < 0$ and $K_{eq} < 1$

Topic
9.9 Cell Potential and Free Energy

2013 Practice Exam #45

Not listed in the question bank

Questions X-Y refer to galvanic cells made from different combinations of the three half-cells described below.

Half-cell 1: strip of $\text{Al}(s)$ in $1.00\text{ M Al(NO}_3)_3(aq)$

Half-cell 2: strip of $\text{Cu}(s)$ in $1.00\text{ M Cu(NO}_3)_2(aq)$

Half-cell 3: strip of $\text{Fe}(s)$ in $1.00\text{ M Fe(NO}_3)_2(aq)$

Galvanic Cell	Half-cells	Cell Reaction	E° (V)
X	1 and 2	$2\text{ Al}(s) + 3\text{ Cu}^{2+}(aq) \rightarrow 2\text{ Al}^{3+}(aq) + 3\text{ Cu}(s)$	2.00
Y	1 and 3	$2\text{ Al}(s) + 3\text{ Fe}^{2+}(aq) \rightarrow 2\text{ Al}^{3+}(aq) + 3\text{ Fe}(s)$	1.22
Z	2 and 3	$\text{Fe}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{Cu}(s)$	?

What is the standard cell potential of galvanic cell Z?

(A) 0.26 V

* (B) 0.78 V

(C) 2.34 V

(D) 3.22 V

Topic
9.10 Cell Potential Under Nonstandard Conditions

2013 Practice Exam #47

Q: Half cells - effect of increasing Fe^{3+} on voltage

Questions X-Y refer to galvanic cells made from different combinations of the three half-cells described below.

Half-cell 1: strip of $\text{Al}(s)$ in $1.00\text{ M Al}(\text{NO}_3)_3(aq)$

Half-cell 2: strip of $\text{Cu}(s)$ in $1.00\text{ M Cu}(\text{NO}_3)_2(aq)$

Half-cell 3: strip of $\text{Fe}(s)$ in $1.00\text{ M Fe}(\text{NO}_3)_2(aq)$

Galvanic Cell	Half-cells	Cell Reaction	E° (V)
X	1 and 2	$2\text{ Al}(s) + 3\text{ Cu}^{2+}(aq) \rightarrow 2\text{ Al}^{3+}(aq) + 3\text{ Cu}(s)$	2.00
Y	1 and 3	$2\text{ Al}(s) + 3\text{ Fe}^{2+}(aq) \rightarrow 2\text{ Al}^{3+}(aq) + 3\text{ Fe}(s)$	1.22
Z	2 and 3	$\text{Fe}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{Cu}(s)$	?

If the half-cell containing $1.00\text{ M Fe}(\text{NO}_3)_2(aq)$ in galvanic cells Y and Z is replaced with a half-cell containing $5.00\text{ M Fe}(\text{NO}_3)_2(aq)$, what will be the effect on the cell voltage of the two galvanic cells?

- (A) The voltage will increase in both cells.
- (B) The voltage will decrease in both cells.
- * (C) The voltage will increase in cell Y and decrease in cell Z.
- (D) The voltage will decrease in cell Y and increase in cell Z.

Topic
9.11 Electrolysis and Faraday's Law