NATIONAL MATH + SCIENCE INITIATIVE

AP CHEMISTRY

Multiple Choice

2016 EDITION
PRESENTER

Periodic Table of the Elements

1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 16.00	9 F 19.00	10 Ne 20.179
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.938	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 93.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.91	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 *La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.2	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.02	89 †Ac 227.03	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 § (269)	111 § (272)	112 § (277)						

§Not yet named

*Lanthanide Series:	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
†Actinide Series:	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

AP Chemistry Equations & Constants

Throughout the test the following symbols have the definitions specified unless otherwise noted.

L, mL	=	liter(s), milliliter(s)	mm Hg	=	millimeters of mercury
g	=	gram(s)	J, kJ	=	joule(s), kilojoule(s)
nm	=	nanometer(s)	V	=	volt(s)
atm	=	atmosphere(s)	mol	=	mole(s)

ATOMIC STRUCTURE

$E = h\nu$

$c = \lambda\nu$

E = energy

ν = frequency

λ = wavelength

Planck's constant, $h = 6.626 \times 10^{-34}$ J s

Speed of light, $c = 2.998 \times 10^{8}$ m s^{-1}

Avogadro's number $= 6.022 \times 10^{23}$ mol^{-1}

Electron charge, $e = -1.602 \times 10^{-19}$ coulomb

EQUILIBRIUM

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}, \text{ where } a\,A + b\,B \rightleftarrows c\,C + d\,D$$

$$K_p = \frac{(P_C)^c(P_D)^d}{(P_A)^a(P_B)^b}$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$K_w = [H^+][OH^-] = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$= K_a \times K_b$$

$$\text{pH} = -\log[H^+],\ \text{pOH} = -\log[OH^-]$$

$$14 = \text{pH} + \text{pOH}$$

$$\text{pH} = \text{p}K_a + \log\frac{[A^-]}{[HA]}$$

$$\text{p}K_a = -\log K_a,\ \text{p}K_b = -\log K_b$$

Equilibrium Constants

K_c (molar concentrations)

K_p (gas pressures)

K_a (weak acid)

K_b (weak base)

K_w (water)

KINETICS

$$\ln[A]_t - \ln[A]_0 = -kt$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

$$t_{1/2} = \frac{0.693}{k}$$

k = rate constant

t = time

$t_{1/2}$ = half-life

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$P_A = P_{total} \times X_A, \text{ where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + \ldots$$

$$n = \frac{m}{\boldsymbol{M}}$$

$$\text{K} = {}^\circ\text{C} + 273$$

$$D = \frac{m}{V}$$

$$KE \text{ per molecule} = \frac{1}{2} m v^2$$

Molarity, M = moles of solute per liter of solution

$$A = abc$$

P = pressure
V = volume
T = temperature
n = number of moles
m = mass
$\boldsymbol{M}$ = molar mass
D = density
KE = kinetic energy
v = velocity
A = absorbance
a = molar absorptivity
b = path length
c = concentration

Gas constant, $R = 8.314 \text{ J mol}^{-1} \text{K}^{-1}$
$= 0.08206 \text{ L atm mol}^{-1} \text{K}^{-1}$
$= 62.36 \text{ L torr mol}^{-1} \text{K}^{-1}$
1 atm = 760 mm Hg
= 760 torr
STP = 0.00 °C and 1.000 atm

THERMOCHEMISTRY/ ELECTROCHEMISTRY

$$q = mc\Delta T$$

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= -RT \ln K$$

$$= -nFE^\circ$$

$$I = \frac{q}{t}$$

q = heat
m = mass
c = specific heat capacity
T = temperature
S° = standard entropy
H° = standard enthalpy
G° = standard free energy
n = number of moles
E° = standard reduction potential
I = current (amperes)
q = charge (coulombs)
t = time (seconds)

Faraday's constant, F = 96,485 coulombs per mole of electrons

$$1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$$

EVERYTHING MULTIPLE CHOICE

Things to Know before the Exam

What I Absolutely Have to Know to Survive the AP Exam

The Multiple Choice section of the exam will test your knowledge of every topic you've studied in AP Chemistry (and maybe some you didn't). There will be questions that require you to analyze data, solve mathematical expressions (without a calculator – mental math is a must) and work with laboratory-based scenarios, and more…

MC Strategies

Be familiar with the format of the exam – that always makes you a better test taker.

- 60 Multiple Choice Problems (90 minutes): Roughly 90 sec. per question – some take more some less
- Numerical answer choices go from the least to the greatest (A to D).
- Numerical answer choices are aligned by the decimals (makes it easier to see the magnitude of the number as well as significant figures).
- Look for the work "approximate" – you don't have to be exact – make estimations to get the answer.
- Go through the MC once, answer all the questions you know and are easy for you. If you encounter a question you know but takes more time than normal MARK it with an ASTERISK (*) and move on – you can come back later.
  - All the MC questions are worth 1 point – if it is going to take you a long time to solve the problem move on and come back to it later.
- If you read a problem and have no idea – CIRCLE the number and move on.
- When you have gone through the test and answered all the questions that were "easy" go back and work on the ones you marked with an ASTERISK (*).
- If you still have time try to revisit the ones you CIRCLED – maybe you now remember something that you didn't the first time through.
- DO NOT PUT OFF bubbling your answer document – the last thing you want is a lot of correct answers on your paper but you ran out of time and didn't bubble them on the answer document.
- Read the "SET QUESTION" prompts carefully – these problems have a paragraph, a data set, a graph or a combination of these and then 3-4 questions that are related to the information provided. There is a lot of data and information provided in these prompts – be sure to read and note or annotate carefully.

Calculations Without a Calculator: *Mental Math is a Must!*

Be sure you can do "simple:" calculations quickly in your head – or estimate the calculations when the problem indicates "approximately"…

Example: The equilibrium constant for reaction A is 5.0×10^{5}. Determine the equilibrium constant for the reverse reaction.

$$\frac{1}{5.0\times10^{5}} == \frac{1}{5}\times10^{-5} = 0.2\times10^{-5} = 2\times10^{-6}$$

If you are asked to multiple or divide by 0.0075 – move the decimal 4 places to the right and work with "75" – be sure to move the decimal back 4 places when you are done.

Example: You are given 0.0075 moles of a substance with a molar mass of 110.1 grams/mol and asked to determine the umber of grams.

- Use 75 instead of 0.0075
- Split the problem in to parts
- $70 \times 110 = 7700$ and $5 \times 110 = 550$
- $7700 + 550 = 8250$
- Move the decimal back 4 places = 0.825 g

NATIONAL MATH + SCIENCE INITIATIVE

Practicing Mental Math

Approximately what mass of $CuSO_4 \bullet 5\,H_2O$ (250 g mol^{-1}) is required to prepare 250 mL of 0.10 *M* copper(II) sulfate solution?

(a) 4.0 g
(b) 6.2 g
(c) 34 g
(d) 85 g

Solution:

- $250 \times 0.10 = 25$ mmol
- 20 mmol × 250 g mol^{-1} = 5000 and 5 mmol × 250 g mol^{-1} =1250
- 5000 + 1250 = 6250
- B MUST be correct; move the decimal 3 places to the left (to make mmol = mol) = 6.25

How many moles of O_2 are needed to produce 142 grams of P_4O_{10} from monatomic phosphorus, P? (Molecular weight P_4O_{10} = 284)

(a) 0.500 mole
(b) 0.625 mole
(c) 1.25 mole
(d) 2.50 mole

Solution:

FIRST – note that for O_2 to form P_4O_{10} the ratio of O_2 to P_4O_{10} must be 5:1

ALSO – look for multiples when dealing with Molar Masses, etc… in a MC problem 142 is ½ of 284 – that sure make the problem easier to work!

$$\frac{142\text{ g}}{284\ \frac{\text{g}}{\text{mol}}} = 0.5\text{ mol }P_4O_{10} \times \frac{5\text{mol }O_2}{1\text{mol }P_4O_{10}} = 2.5\text{ mol }O_2$$

In a saturated solution of $Zn(OH)_2$ at 25°C, the value of $[OH^-]$ is 2.0 x 10^{-6} *M*. What is the value of the solubility-product constant, K_{sp}, for $Zn(OH)_2$ at 25°C?

(a) 4.0×10^{-18}
(b) 8.0×10^{-18}
(c) 1.6×10^{-17}
(d) 4.0×10^{-12}

Solution:

K_{sp} for $Zn(OH)_2 = [Zn^{2+}][OH^-]^2$

Since there are 2 OH^- ions for every 1 Zn^{2+} ion… then $[Zn^{2+}] = ½\,[OH^-] = 1.0 \times 10^{-6}$

$K_{sp} = [1.0 \times 10^{-6}][2.0 \times 10^{-6}]^2$ (REMEMBER – when you square an exponent you are really multiplying it by 2)

$K_{sp} = (1.0 \times 10^{-6})(4.0 \times 10^{-12}) = 4.0 \times 10^{-18}$

NATIONAL MATH + SCIENCE INITIATIVE

Practicing More Mental Math

Problem:
The atomic mass of copper is 63.55. Given that there are only two naturally occurring isotopes of copper, ^{63}Cu and ^{65}Cu, the natural abundance of the ^{65}Cu isotope must be *approximately*

(a) 90%
(b) 70%
(c) 50%
(d) 25%

Solution:
Be alert to when NO math is required to answer a quantitative problem – just look at the choices. If the average atomic mass is 63.55 and the 2 isotopes are Cu-63 and Cu-65, the Cu-65 isotope MUST be less than 50% abundant.

If you work it out the following takes a LOT of time that you shouldn't waste!
$63.55 = 65(x) + 63(1-x)$
$63.55 = 65x + 63 - 63x$
$0.55 = 2x$
$0.275 = x$
^{65}Cu is 27.5% abundant

Problem:
If 200. mL of 0.60 *M* $MgCl_2$ (*aq*) is added to 400. mL of distilled water, what is the concentration of Mg^{2+}(*aq*) in the resulting solution? Assume volumes are additive.

(a) 0.20 *M*
(b) 0.30 *M*
(c) 0.40 *M*
(d) 0.60 *M*

Solution:
Be alert to when LITTLE math is required to answer a quantitative problem – just look at the volumes – if you have [*M*] and dilute it, look for easy conversions (like half, a third, a fourth). Here the solution goes from 200. mL to 600 mL (200 + 400), which dilutes the solution by 1/3 therefore the 0.60 *M* solution is diluted to 0.20 *M*.

Problem:

$$H_2C_2O_4 + 2\ H_2O \rightleftharpoons 2\ H_3O^+ + C_2O_4^{2-}$$

Oxalic acid, $H_2C_2O_4$, is a diprotic acid with $K_1 = 5 \times 10^{-2}$ and $K_2 = 5 \times 10^{-5}$. Which of the following is equal to the equilibrium constant for the reaction represented above?

(a) 5×10^{-2}
(b) 5×10^{-5}
(c) 2.5×10^{-6}
(d) 5×10^{-10}

Solution:
When you have 2 *K*'s to get an overall K_{eq} you multiple them:
$K_1 \times K_2 = K_{eq}$
$(5 \times 10^{-2}) \times (5 \times 10^{-5}) = 25 \times 10^{-7}$ the only answer with 25 in the problem is C – no need to waste time adjusting the exponent to get 2.5×10^{-6}

NATIONAL MATH + SCIENCE INITIATIVE

Practicing Even More Mental Math

Problem:
If 87 grams of K_2SO_4 (molar mass 174 grams) is dissolved in enough water to make 250 milliliters of solution, what are the concentrations of the potassium and the sulfate ions?

	$[K^+]$	$[SO_4^{2-}]$
(a)	0.020 M	0.020 M
(b)	1.0 M	2.0 M
(c)	2.0 M	1.0 M
(d)	4.0 M	2.0 M

Solution:
Be alert to when LITTLE math is required to answer a quantitative problem.
First when K_2SO_4 dissolves you get 2 $[K^+]$ for every 1 $[SO_4^{2-}]$ – thus only C and D can be correct.
Look at the mass and the molar mass: 87 is ½ of 174, thus there are 0.5 moles of K_2SO_4 in 250 mL of solution

$$\frac{\left(\frac{1}{2}\text{ mol}\right)}{\left(\frac{1}{4}\text{ L}\right)} = 2M$$

therefore the $[SO_4^{2-}]$ = 2 *M* (and the $[K^+]$ = 4 *M*) thus D is correct.

Problem:
Green light has a wavelength of 5.50×10^2 nm. Which of the set ups below shows how to correctly calculate the energy of a photon of green light?

(a) $\dfrac{(6.63\times10^{-34})(3.0\times10^{17})}{(5.50\times10^{2})}$

(b) $\dfrac{(6.63\times10^{-34})(3.0\times10^{8})}{(5.50\times10^{2})}$

(c) $\dfrac{(6.63\times10^{-34})(5.50\times10^{2})}{(3.0\times10^{8})}$

(d) $(6.63\times10^{-34})(5.50\times10^{2})$

Solution:
Be ready for problems that you "set up" and don't have to solve. In this example you must realize that the wavelength is in nm and the speed of light is in m – so changing the speed of light from m to nm is essential – so look for a set up that plugs the correct variable in to the equation and one that uses the 10^9 conversion for m to nm…

$E = h\nu$ and $c = \lambda\nu$

$$E = \frac{hc}{\lambda}$$

$$E = \frac{(6.63\times10^{-34})(3.0\times10^{17})}{(5.50\times10^{2})}$$

NATIONAL MATH + SCIENCE INITIATIVE

Practicing Even More Mental Math Again

When a hydrate of X_2CO_3 (molar mass = 153 g mol^{-1}) is heated until all of the water is removed, it loses 54 percent of its mass. The formula of the hydrate is

(a) $X_2CO_3 \bullet 3\ H_2O$
(b) $X_2CO_3 \bullet 5\ H_2O$
(c) $X_2CO_3 \bullet 7\ H_2O$
(d) $X_2CO_3 \bullet 10\ H_2O$

Solution:
Some problems require you to estimate to make numbers more "user friendly" and you still have to work out the solution.
If the hydrate is 54% water it is 46% X_2CO_3. If you assume you have 100 g of the hydrate you have 46 grams of X_2CO_3 and 54 grams of H_2O

$$\frac{46\text{ g}}{153\ \frac{\text{g}}{\text{mol}}} \cong \frac{45\text{ g}}{150\ \frac{\text{g}}{\text{mol}}} \cong 0.3\text{ mol } X_2CO_3$$

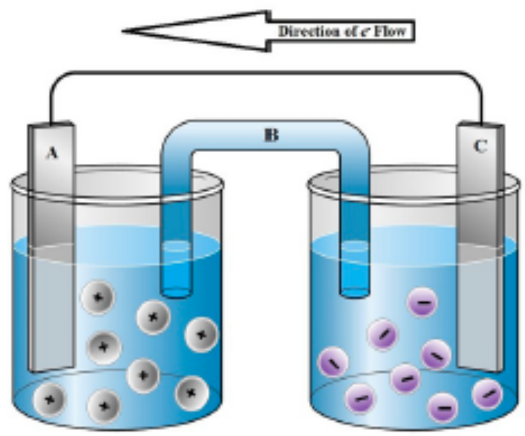
$$\frac{54\text{ g}}{18\ \frac{\text{g}}{\text{mol}}} 3\text{ mol } H_2O$$

$$\text{ratio of } \frac{H_2O}{X_2CO_3} = \frac{3}{0.3} = 10$$

Practicing Particulate Problems

When you have problems that give you a "particle representation" be sure you look closely at the representations and be sure you can distinguish between what is what, look for a "key" to art if given. If the representation is of a reaction, make sure the stoichiometric ratios are upheld, make sure atoms/molecules/etc… aren't missing unless you are told they are to be ignored.

Problem:



Which of the following statements applies to the change in mass of the electrodes involved in this electrochemical cell?

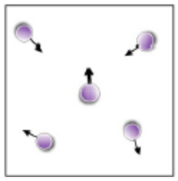
(a) Electrode A is the anode and it loses mass since metal atoms are being converted to metal ions.
(b) Electrode C is the anode and it gains mass since metal ions are being converted to metal atoms.
(c) Electrode A is the cathode and it gains mass since metal ions are being converted to metal atoms.
(d) Electrode C is the cathode and it loses mass since metal atoms are being converted to metal ions.

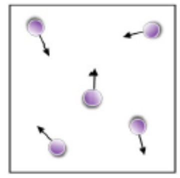
Solution:
In this representation the flow of the electrons is key. Once you know the electrons flow from the anode to the cathode you can answer the question. A is the cathode and it gains mass because ions in solution are reduced to metal atoms which adhere to the electrode. Be careful of "incorrect answers" that have correct information. Electrode C is the anode, however it loses mass because oxidation occurs at the anode (metals are ionized).

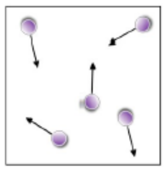
NATIONAL MATH + SCIENCE INITIATIVE

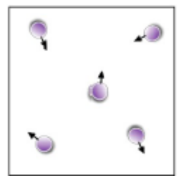
Practicing Particulate Problems

Problem:
Each of the following diagrams represents the same sample of hydrogen gas at a different Kelvin temperature. Which of the following diagrams corresponds to the hydrogen sample having the lowest temperature?

(a)


(c)


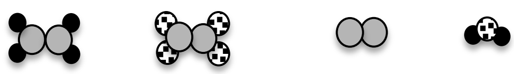
(b)


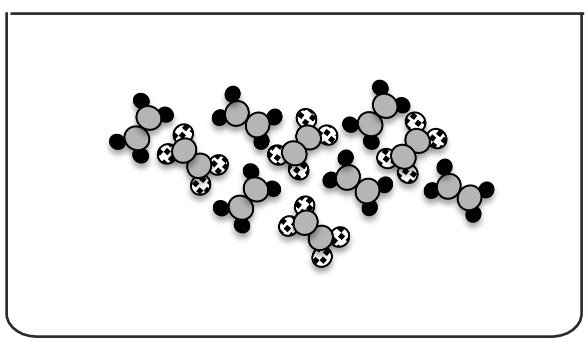
(d)


Solution:
(d) At the lowest temperature you are looking for the molecules with the lowest net motion represented by the smallest arrow.

The equation for the gaseous reaction between N_2H_4 and N_2O_4 is shown below.

$$2\ N_2H_4 + N_2O_4 \rightarrow 3\ N_2 + 4\ H_2O$$





Using the initial mixture of reactant molecules shown in the representation above, the number of water molecules produced in this reaction is

(a) 4
(b) 6
(c) 8
(d) 12

Solution:
12 water molecules are produced. 6 molecules of N_2H_4 and 4 molecules of N_2O_4 are present. They react in a 2:1 ratio thus the 6 molecules of N_2H_4 is the limiting reactant and the 4 molecules of N_2O_4 are present in excess.

$$6 \text{ molecules } N_2O_4 \times \frac{4 \text{ moles } H_2O}{2 \text{ moles } N_2O_4} = 12 \text{ molecules } H_2O$$