



NATIONAL MATH + SCIENCE INITIATIVE

AP CHEMISTRY

Laboratory Based Questions

2016 EDITION

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Periodic Table of the Elements

1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.012															9 F 19.00	10 Ne 20.179
11 Na 22.99	12 Mg 24.30															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					

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
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)

*Lanthanide Series:

†Actinide Series:

AP Chemistry Equations & Constants

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

L, mL = liter(s), milliliter(s)

g = gram(s)

nm = nanometer(s)

atm = atmosphere(s)

mm Hg = millimeters of mercury

J, kJ = joule(s), kilojoule(s)

V = volt(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 = 6.022×10^{23} mol⁻¹

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

EQUILIBRIUM

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

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

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

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

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

$$= K_a \times K_b$$

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

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

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

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

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

$$PV = nRT$$

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

$$P_{\text{total}} = P_A + P_B + P_C + \dots$$

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

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

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

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

Molarity, M = moles of solute per liter of solution

$$A = abc$$

P = pressure

V = volume

T = temperature

n = number of moles

m = mass

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

$$= 760 \text{ torr}$$

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

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



What I Absolutely Have to Know to Survive the AP Exam

If asked to do the following, it might indicate the question deals with laboratory questions:
Design an experiment; list measurements needed; show setup of calculations needed, use sample data to do calculations; interpret or draw graphs; explain the affect of error on the calculated value; use qualitative observations...

Parts of a Lab Question

You may not have done that exact experiment but you can use the knowledge gained doing other experiments to help account for certain observations.

You may be asked to describe how to do an experiment or to design an experiment.

- Materials: If they give you a list of equipment, don't think you have to use all of it.
- Procedure: Be sure to include important techniques like rinsing the buret with the solution before a titration or heating to constant mass.
- Data needed: The data needed are values that can be measured like initial and final temperatures. Writing all the mathematical equations needed to do the calculations will help you determine what data is needed.
- Calculations: A calculation is using what was measured like temperature change. Show the set up of the mathematical equations required for the calculations. Use sample data when appropriate.
- Graphs: Be sure you label the axes and other important points on your graph.
- Error Analysis: State whether the quantity will be too high, too low, or no change. Use equations to help you determine what change will occur and to support your answer.

Common Lab Procedure: Calorimetry

Calorimetry is used to determine the heat released or absorbed in a chemical reaction. A calorimeter can determine the heat of a solution reaction at constant pressure.

Techniques:

- Use a double Styrofoam cup with a plastic top and hole for the thermometer
- Determine the change in temperature accurately
- Measure solution volumes precisely
- Start with a dry calorimeter

Information to know about calorimetry:

- Heat capacity (C) = the amount of heat needed to raise the temperature of an object by one degree Celsius or Kelvin, $J/^{\circ}C$ or J/K .
- The heat capacity of 1 mol of a substance is called its molar heat capacity (Joules per mole per degree) $J/mol \cdot ^{\circ}C$ or $J/mol \cdot K$.
- Specific heat, c , also known as specific heat capacity, is defined as the amount of heat necessary to raise the temperature of 1.00 g of a substance by one degree. Units are (joules per gram per degree), $J/g \cdot ^{\circ}C$ or $J/g \cdot K$. You often use the specific heat capacity in analyzing gathered data then convert to molar heat capacity.

Assumptions often made during calorimetry: (Be able to answer error analysis questions about each assumption below)

- The density of dilute solutions is the same for water. $D = 1.0 \text{ g/mL}$
- The specific heat of the solutions is the same as that for water. $c = 4.184 \text{ J/g}^{\circ}C$
- The solutions react in their stoichiometric amounts.
- There is no loss of heat to the surroundings.

Equations:

- $q = mc\Delta T$ ($c = 4.184 \text{ J/g}^{\circ}C$)
- $q = \Delta H = mc\Delta T$, at constant pressure
- Use the density of the solution to convert from volume to mass for $q = mc\Delta T$



Common Lab Procedure: Titration

A titration is a laboratory procedure for quantitative analysis. In a titration two reagents are mixed, one with a known concentration & known volume [or a solid with a known mass] and one with an unknown concentration. There is some way to indicate when the two reagents have reacted completely (typically an indicator), and at the end of the titration the unknown solution's concentration can be calculated since you have accurately determined the volume of that solution required to complete the reaction.

Terms to know:

- Titrant – A solution of known concentration; it is often standardized
- Standardized solution – A solution in which the exact concentration is known.
- Indicator - A weak acid or base used in a titration to indicate the endpoint has been reached.
- Equivalence point – moles of acid = moles of base; point at which enough titrant has been added to completely react with the solution being analyzed.
- End point – the point at which the indicator changes color; important to pick an indicator with a pKa very close to the pH at the equivalence point.

Techniques:

Preparing the Buret:

1. Rinse a clean buret with distilled water and then the titrant (the solution that will be added to the flask).
2. Allow the titrant to drain through the buret so that the tip gets rinsed with titrant as well.
3. Discard the rinse solution. Fill it with the titrant. Remove air bubbles from the tip of the buret by draining several milliliters of titrant.

Preparing the Sample:

4. Pipet the desired volume of the solution to be analyzed into an Erlenmeyer flask. Record the exact volume. If the sample is a solid, weigh the desired mass, add the solid to an Erlenmeyer flask, and dissolve it in distilled water (the amount of water does matter since it doesn't change the moles of the solid). Be sure to record the exact mass of sample used.
5. Add the titrant to the flask until the equivalence point is reached. Calculate the volume of titrant added.
6. Change in color of a chemical indicator is usually used to signal the endpoint of the titration. The endpoint for this titration is reached when you reach a pale color that persists for several seconds.

Measured Data Required:

moles titrant = **moles** of substance analyzed @ equivalence point

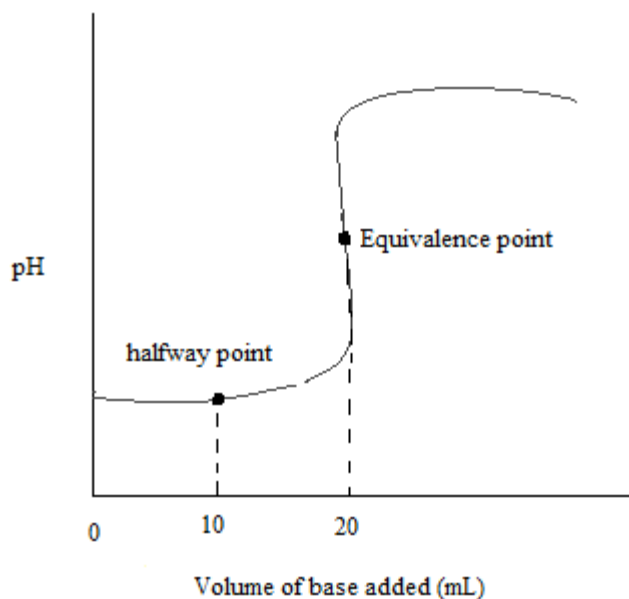
- mass of DRY substance analyzed OR accurately measured volume of solution analyzed [measure with a pipet OR buret]
- *initial* volume of titrant (substance of known molarity) and *final* volume of titrant (required to reach end point)
- Molarity of titrant

Calculation Hints:

- Substance analyzed is solution/liquid:
 - $M_1V_1 = M_2V_2$ @ equivalence point
 - Volume of titrant used to reach end point [difference between final and initial volumes]
 - $M_{\text{titrant}}V_{\text{of titrant added}} = \text{moles of titrant} = \text{moles of unknown}$
 - Molarity of unknown = $\frac{\text{moles of unknown}}{\text{Liters of unknown}}$



- Substance analyzed is solid:
 - Same as process as above
 - $M_{\text{titrant}} V_{\text{of titrant added}} = \text{moles of titrant} = \text{moles of unknown}$
 - Molecular weight of the unknown = $\frac{\text{mass of solid dissolved}}{\text{moles of unknown}}$

Graphs:

Common Lab Procedure: Gravimetric Analysis

One method for determining the amount of a given substance in solution is to form a precipitate that includes the substance. The precipitate is then filtered and dried. This process is called gravimetric analysis.

Techniques/Procedure:

1. Weigh sample
2. Form precipitate
3. Filter precipitate (A buchner funnel and aspirator can be used)
4. Dry precipitate (Be sure to dry to constant mass)
5. Weigh precipitate

For example if we wanted to determine the amount of chloride ions present in a given solid, we would weigh the solid sample, dissolve the sample in water, add an excess of silver nitrate solution to form the precipitate silver chloride. This precipitant would be filtered, and dried to constant mass. From the mass of silver chloride formed, we can determine the moles of silver chloride and the moles of chloride ion in the original sample.



Common Lab Procedure: Determining Molar Mass

Organize answer around calculations—paying special attention to what quantities are **measured** versus **calculated**!

$$\text{molar mass} = \frac{\text{mass of sample in grams}}{\text{moles of sample}}$$

Titration Data

- **moles** titrant = **moles** of substance analyzed @ equivalence point
- **Measured DATA** required:
 - mass of substance
 - *initial* volume of titrant (substance of known molarity) and *final* volume of titrant (required to reach end point)
 - Molarity of titrant
- **Calculations** required:
 - Molarity of titrant
 - Substance analyzed is solid:
 - $M_{\text{titrant}} V_{\text{titrant}} = \text{moles titrant}$
 - $\text{molar mass} = \frac{\text{g of solid analyzed}}{\text{moles of titrant used}}$

Vaporization of a Volatile Liquid

- $PV = nRT$ used to determine moles
- **Measured DATA** Required:
 - Pressure = atmospheric pressure unless collected over water
 - *initial* mass of flask
 - *final* mass of flask
 - Temperature of boiling water—don't assume 100°C
 - Volume of gas = fill flask with water and measure the volume of water in a graduated cylinder
- **Constants** needed:
 - If collected over water, the water vapor pressure at the experimental temperature.
- **Calculations** Required:
 - If the gas was collected over water $P_{\text{vapor}} = P_{\text{atmospheric/barometric}} - P_{\text{water vapor at certain temperature}}$
 - mass of sample = *final* mass of flask [includes vapors] – *initial* mass of flask

Common Lab Procedure: Colorimetric or Spectrophotometric Analysis

Colorimetric analysis is a quantitative analysis of a solution using color based on Beer's Law. Colorimetric analysis can be used to determine the concentration of an unknown solution, the rate constant of a reaction, the order of a reaction, etc.

Beer's Law is an expression that can be used to determine how much light passes through the solution. It also shows that concentration and absorbance are directly related.

$$A = \epsilon bc$$

- A = absorbance (measured with a colorimeter)
- ϵ = molar absorptivity (how much light will be absorbed by 1 cm of a 1 M solution of the chemical)
- b = path length of the cuvette in cm
- c = concentration in molarity



Lab Based Questions Cheat Sheet

Relationships

Calorimetry $q = \Delta H = mc\Delta T$ at constant pressure <ul style="list-style-type: none"> c = specific heat ΔT = change in temperature m = mass q = heat 	Beer's Law $A = \epsilon bc$ <ul style="list-style-type: none"> A = absorbance ϵ = molar absorptivity b = path length of the cuvette in cm c = concentration in molarity
Ideal Gas Law $PV = nRT$ <ul style="list-style-type: none"> V = volume in liters n = moles T = temperature in Kelvin P = pressure If collected using water displacement: $P_{\text{vapor}} = P_{\text{atmospheric/barometric}} - P_{\text{water vapor at certain temperature}}$	Other important relationships: @ Equivalence point $M_1V_1 = M_2V_2$ $\text{molar mass} = \frac{\text{mass of sample in grams}}{\text{moles of sample}}$ $\% \text{error} = \frac{\text{accepted} - \text{experimental}}{\text{accepted}} \times 100$

Connections

Electrochemistry: draw diagram of galvanic or electrolytic cell, qualitative observations that can be made at the cathode and anode, etc.	Stoichiometry: empirical formula of a compound, percent of an element in a compound, etc.
Thermodynamics: heat of reaction, molar heat capacity, etc.	Acids and Bases: standardizing a solution, drawing a titration curve, etc.
Qualitative Analysis: identifying a compound based on observations and tests	

Potential Pitfalls

Be aware there are quantities you **measure** [such as initial temperature and final temperature or initial pressure and final pressure, etc.] and terms you **calculate** using what you measured such as ΔT or ΔP

Be sure to include important steps in the procedure like “heat to constant mass,” “rinse the buret with distilled water and then the **solution** before titrating”, “dissolve the solid in about 100 mL of water and then add water to the 500 mL mark on the volumetric flask,” etc.

Writing the mathematical equations may help determine how an error affects the results. Use the equations to justify your error analysis.

If given a laboratory situation you have not specifically done, use the observations and the concepts you learned in your labs throughout the year to reason your way through the lab question.



- (iii) the molar volume of the gas (at STP)
- (d) What test can be done to prove which gas is produced?
- (e) What is the purpose of making the water level inside the test tube equal to the water level in the beaker?
- (f) If the vapor pressure of water is not used in the calculation, how will the molar volume of the gas at STP be affected? (higher, lower or the same) Explain.

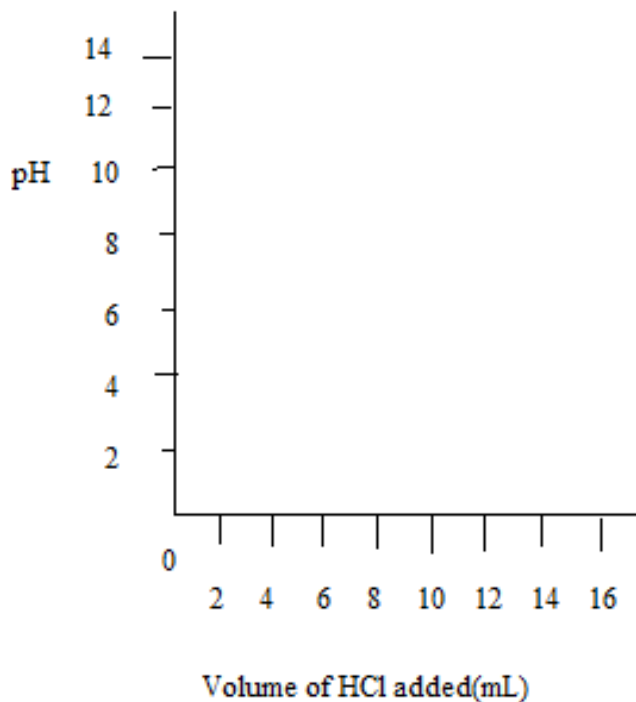


Another sample of hydrochloric acid was used to titrate a solution of calcium hydroxide.

- (g) Describe the steps needed to make 50.0 mL of a 0.50 M solution from the 6 M solution of hydrochloric acid, using a dropper, 5.0 mL pipet, 50.0 mL volumetric flask, and distilled water. Be sure to mathematically justify your process.
- (h) Write the balanced net ionic equation for the dissociation of $\text{Ca(OH)}_2(s)$ in aqueous solution, and write the equilibrium-constant expression for the dissolving Ca(OH)_2 .

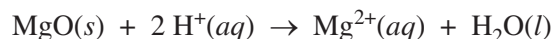
A 15.0 mL unknown solution of Ca(OH)_2 is titrated with a standardized 0.50 M solution of hydrochloric acid. It takes exactly 10.5 mL of hydrochloric acid to reach the equivalence point where the pH is 8.50.

- (i) Sketch the titration curve that shows the pH change as the volume of hydrochloric acid added increases from 0 to 16.0 mL. Be sure to label the equivalence point of the titration.





- (j) Calculate the concentration of $[\text{OH}]^-$ from the titration.

2013 AP[®] CHEMISTRY FREE-RESPONSE QUESTIONS

3. A student was assigned the task of determining the enthalpy change for the reaction between solid MgO and aqueous HCl represented by the net-ionic equation above. The student uses a polystyrene cup calorimeter and performs four trials. Data for each trial are shown in the table below.

Trial	Volume of 1.0 M HCl (mL)	Mass of MgO(s) Added (g)	Initial Temperature of Solution (°C)	Final Temperature of Solution (°C)
1	100.0	0.25	25.5	26.5
2	100.0	0.50	25.0	29.1
3	100.0	0.25	26.0	28.1
4	100.0	0.50	24.1	28.1

- (a) Which is the limiting reactant in all four trials, HCl or MgO? Justify your answer.
- (b) The data in one of the trials is inconsistent with the data in the other three trials. Identify the trial with inconsistent data and draw a line through the data from that trial in the table above. Explain how you identified the inconsistent data.

For parts (c) and (d), use the data from one of the other three trials (i.e., not from the trial you identified in part (b) above). Assume the calorimeter has a negligible heat capacity and that the specific heat of the contents of the calorimeter is $4.18 \text{ J}/(\text{g} \cdot \text{C}^\circ)$. Assume that the density of the $\text{HCl}(aq)$ is $1.0 \text{ g}/\text{mL}$.

- (c) Calculate the magnitude of q , the thermal energy change, when the MgO was added to the $1.0 \text{ M HCl}(aq)$. Include units with your answer.
- (d) Determine the student's experimental value of ΔH° for the reaction between MgO and HCl in units of $\text{kJ}/\text{mol}_{rxn}$.
- (e) Enthalpies of formation for substances involved in the reaction are shown in the table below. Using the information in the table, determine the accepted value of ΔH° for the reaction between $\text{MgO}(s)$ and $\text{HCl}(aq)$.

Substance	ΔH_f° (kJ/mol)
MgO(s)	-602
H ₂ O(l)	-286
H ⁺ (aq)	0
Mg ²⁺ (aq)	-467

- (f) The accepted value and the experimental value do not agree. If the calorimeter leaked heat energy to the environment, would it help account for the discrepancy between the values? Explain.

2011 AP[®] CHEMISTRY FREE-RESPONSE QUESTIONS (Form B)

Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be scored on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

5. A student is instructed to prepare 100.0 mL of 1.250 *M* NaOH from a stock solution of 5.000 *M* NaOH. The student follows the proper safety guidelines.
- (a) Calculate the volume of 5.000 *M* NaOH needed to accurately prepare 100.0 mL of 1.250 *M* NaOH solution.
- (b) Describe the steps in a procedure to prepare 100.0 mL of 1.250 *M* NaOH solution using 5.000 *M* NaOH and equipment selected from the list below.
- | | | | |
|-------------|------------------------|---|-------------------------|
| Balance | 25 mL Erlenmeyer flask | 100 mL graduated cylinder | 100 mL volumetric flask |
| 50 mL buret | 100 mL Florence flask | 25 mL pipet | 100 mL beaker |
| Eyedropper | Drying oven | Wash bottle of distilled H ₂ O | Crucible |
- (c) The student is given 50.0 mL of a 1.00 *M* solution of a weak, monoprotic acid, HA. The solution is titrated with the 1.250 *M* NaOH to the endpoint. (Assume that the endpoint is at the equivalence point.)
- (i) Explain why the solution is basic at the equivalence point of the titration. Include a chemical equation as part of your explanation.
- (ii) Identify the indicator in the table below that would be best for the titration. Justify your choice.

Indicator	p <i>K_a</i>
Methyl red	5
Bromothymol blue	7
Phenolphthalein	9

- (d) The student is given another 50.0 mL sample of 1.00 *M* HA, which the student adds to the solution that had been titrated to the endpoint in part (c). The result is a solution with a pH of 5.0.
- (i) What is the value of the acid-dissociation constant, *K_a*, for the weak acid? Explain your reasoning.
- (ii) Explain why the addition of a few drops of 1.250 *M* NaOH to the resulting solution does not appreciably change its pH.

2011 AP[®] CHEMISTRY FREE-RESPONSE QUESTIONS

2. A student is assigned the task of determining the mass percent of silver in an alloy of copper and silver by dissolving a sample of the alloy in excess nitric acid and then precipitating the silver as AgCl.

First the student prepares 50. mL of 6 M HNO₃.

- (a) The student is provided with a stock solution of 16 M HNO₃, two 100 mL graduated cylinders that can be read to ±1 mL, a 100 mL beaker that can be read to ±10 mL, safety goggles, rubber gloves, a glass stirring rod, a dropper, and distilled H₂O.
- Calculate the volume, in mL, of 16 M HNO₃ that the student should use for preparing 50. mL of 6 M HNO₃.
 - Briefly list the steps of an appropriate and safe procedure for preparing the 50. mL of 6 M HNO₃. Only materials selected from those provided to the student (listed above) may be used.
 - Explain why it is not necessary to use a volumetric flask (calibrated to 50.00 mL ±0.05 mL) to perform the dilution.
 - During the preparation of the solution, the student accidentally spills about 1 mL of 16 M HNO₃ on the bench top. The student finds three bottles containing liquids sitting near the spill: a bottle of distilled water, a bottle of 5 percent NaHCO₃(aq), and a bottle of saturated NaCl(aq). Which of the liquids is best to use in cleaning up the spill? Justify your choice.

Then the student pours 25 mL of the 6 M HNO₃ into a beaker and adds a 0.6489 g sample of the alloy. After the sample completely reacts with the acid, some saturated NaCl(aq) is added to the beaker, resulting in the formation of an AgCl precipitate. Additional NaCl(aq) is added until no more precipitate is observed to form. The precipitate is filtered, washed, dried, and weighed to constant mass in a filter crucible. The data are shown in the table below.

Mass of sample of copper-silver alloy	0.6489 g
Mass of dry filter crucible	28.7210 g
Mass of filter crucible and precipitate (first weighing)	29.3587 g
Mass of filter crucible and precipitate (second weighing)	29.2599 g
Mass of filter crucible and precipitate (third weighing)	29.2598 g

- Calculate the number of moles of AgCl precipitate collected.
- Calculate the mass percent of silver in the alloy of copper and silver.

2008 AP[®] CHEMISTRY FREE-RESPONSE QUESTIONS (Form B)

Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be graded on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

5. The identity of an unknown solid is to be determined. The compound is one of the seven salts in the following table.

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

Use the results of the following observations or laboratory tests to explain how each compound in the table may be eliminated or confirmed. The tests are done in sequence from (a) through (e).

- (a) The unknown compound is white. In the table below, cross out the two compounds that can be eliminated using this observation. Be sure to cross out these same two compounds in the tables in parts (b), (c), and (d).

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

- (b) When the unknown compound is added to water, it dissolves readily. In the table below, cross out the two compounds that can be eliminated using this test. Be sure to cross out these same two compounds in the tables in parts (c) and (d).

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

- (c) When $\text{AgNO}_3(aq)$ is added to an aqueous solution of the unknown compound, a white precipitate forms. In the table below, cross out each compound that can be eliminated using this test. Be sure to cross out the same compound(s) in the table in part (d).

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

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- (d) When the unknown compound is carefully heated, it loses mass. In the table below, cross out each compound that can be eliminated using this test.

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

- (e) Describe a test that can be used to confirm the identity of the unknown compound identified in part (d). Limit your confirmation test to a reaction between an aqueous solution of the unknown compound and an aqueous solution of one of the other soluble salts listed in the tables. Describe the expected results of the test; include the formula(s) of any product(s).

2008 AP® CHEMISTRY FREE-RESPONSE QUESTIONS

2. Answer the following questions relating to gravimetric analysis.

In the first of two experiments, a student is assigned the task of determining the number of moles of water in one mole of $\text{MgCl}_2 \cdot n \text{H}_2\text{O}$. The student collects the data shown in the following table.

Mass of empty container	22.347 g
Initial mass of sample and container	25.825 g
Mass of sample and container after first heating	23.982 g
Mass of sample and container after second heating	23.976 g
Mass of sample and container after third heating	23.977 g

- (a) Explain why the student can correctly conclude that the hydrate was heated a sufficient number of times in the experiment.
- (b) Use the data above to
- calculate the total number of moles of water lost when the sample was heated, and
 - determine the formula of the hydrated compound.
- (c) A different student heats the hydrate in an uncovered crucible, and some of the solid spatters out of the crucible. This spattering will have what effect on the calculated mass of the water lost by the hydrate? Justify your answer.

In the second experiment, a student is given 2.94 g of a mixture containing anhydrous MgCl_2 and KNO_3 . To determine the percentage by mass of MgCl_2 in the mixture, the student uses excess $\text{AgNO}_3(aq)$ to precipitate the chloride ion as $\text{AgCl}(s)$.

- (d) Starting with the 2.94 g sample of the mixture dissolved in water, briefly describe the steps necessary to quantitatively determine the mass of the AgCl precipitate.
- (e) The student determines the mass of the AgCl precipitate to be 5.48 g. On the basis of this information, calculate each of the following.
- The number of moles of MgCl_2 in the original mixture
 - The percent by mass of MgCl_2 in the original mixture