2000 **REVIEW #1**

K_c & K_p

$$2H_2S_{(g)} \rightleftharpoons 2H_{2(g)} + S_{2(g)}$$

When heated, hydrogen sulfide gas decomposes according to the equation above. A 3.40 g sample of $H_2S_{(g)}$ is introduced into an evacuated rigid 1.25 L container. The sealed container is heated to 483 K and 3.72×10^{-2} mol of $S_{2(g)}$ is present at equilibrium.

a. Write the expression for the equilibrium constant, K_c, for the decomposition reaction represented above.
b. Calculate the equilibrium concentration, in mol L^{1-}, of the following gases in the container at 483 K.
    i. $H_{2(g)}$
    ii. $H_2S_{(g)}$
c. Calculate the value of the equilibrium constant, K_c, for the decomposition reaction at 483 K.
d. Calculate the partial pressure of $S_{2(g)}$ in the container at 483 K.
e. For the reaction $H_{2(g)} + \frac{1}{2}S_{2(g)} \rightleftharpoons H_2S_{(g)}$ at 483 K, calculate the value of the equilibrium constant, K_c.

2001 **REVIEW #2**

K_{sp}

Answer the following questions relating to the solubility of the chlorides of silver and lead.

a. At 10°C , 8.9×10^{-5} g of $AgCl_{(s)}$ will dissolve in 100. mL of water.
    i. Write the equation for the dissociation of $AgCl_{(s)}$ in water.
    ii. Calculate the solubility, in mol L^{1-}, of $AgCl_{(s)}$ in water at 10°C.
    iii. Calculate the value of the solubility-product constant, K_{sp}, for $AgCl_{(s)}$ at 10°C.
b. At 25°C, the value of K_{sp} for $PbCl_{2(s)}$ is 1.6×10^{-5} and the value of K_{sp} for $AgCl_{(s)}$ is 1.8×10^{-10}.
    i. If 60.0 mL of 0.0400*M* $NaCl_{(aq)}$ is added to 60.0mL of 0.0300*M* $Pb(NO_3)_{2(aq)}$, will a precipitate form? Assume that volumes are additive. Show calculations to support your answer.
    ii. Calculate the equilibrium value of $[Pb^{2+}{}_{(aq)}]$ in 1.00 L of saturated $PbCl_2$ solution to which 0.250 moles of $NaCl_{(s)}$ have been added. Assume that no volume change occurs.
    iii. If 0.100*M* $NaCl_{(aq)}$ is added slowly to a beaker containing both 0.120*M* $AgNO_{3(aq)}$ and 0.150*M* $Pb(NO_3)_{2(aq)}$ at 25°C, which will precipitate first, $AgCl_{(s)}$ or $PbCl_{2(s)}$? Show calculations to support your answer.

1998 **REVIEW #3**

K_{sp}

Solve the following problem related to the solubility equilibria of some metal hydroxides in aqueous solution.

a. The solubility of $Cu(OH)_{2(s)}$ is 1.72×10^{-6} gram per 100 milliliters of solution at 25°C.
    i. Write the balanced chemical equation for the dissociation of $Cu(OH)_{2(s)}$ at 25°C.
    ii. Calculate the solubility (in moles per liter) of $Cu(OH)_{2(s)}$ at 25°C.
    iii. Calculate the value of the solubility-product constant, K_{sp}, for $Cu(OH)_2$ at 25°C.
b. The value of the solubility-product constant, K_{sp}, for $Zn(OH)_{2(s)}$ is 7.7×10^{-17} at 25°C.
    i. Calculate the solubility (in moles per liter) of $Zn(OH)_2$ at 25°C in a solution with a pH of 9.35.
    ii. At 25°C, 50.0 milliliters of 0.100-molar $Zn(NO_3)_2$ is mixed with 50.0 milliliters of 0.300-molar NaOH. Claculate the molar concentration of $Zn^{2+}{}_{(aq)}$ in the resulting solution once equilibrium has been established. Assume that volumes are additive.

1998 **REVIEW #4**

Le Châtelier's Principle

$$C_{(s)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + H_{2(g)} \quad \Delta H° = +131 \text{ kJ}$$

A rigid container holds a mixture of graphite pellets ($C_{(s)}$), $H_2O_{(g)}$, and $H_{2(g)}$ at equilibrium. State whether the number of moles of $CO_{(g)}$ in the container will increase, decrease, or remain the same after each of the following disturbances is applied to the original mixture. For each case, assume that all other variables remain constant except for the given disturbance. Explain each answer with a short statement.

a. Additional $H_{2(g)}$ is added to the equilibrium mixture at constant volume.
b. The temperature of the equilibrium mixture is increased at constant volume.
c. The volume of the container is decreased at constant temperature.
d. The graphite pellets are pulverized.

1996 **REVIEW #5**
Acid-Base
K_a & K_b

$$HOCl \rightleftharpoons OCl^{1-} + H^{1+}$$

Hypochlorous acid, HOCl, is a weak acid commonly used as a bleaching agent. The acid-dissociation constant, K_a, for the reaction represented above is 3.2×10^{-8}.

a. Calculate the $[H^{1+}]$ of a 0.14-molar solution of HOCl.
b. Write the correctly balanced net ionic equation for the reaction that occurs when NaOCl is dissolved in water and calculate the numerical value of the equilibrium constant for the reaction.
c. Calculate the pH of a solution made by combining 40.0 milliliters of 0.14-molar HOCl and 10.0 milliliters of 0.56-molar NaOH.
d. How many millimoles of solid NaOH must be added to 50.0 milliliters of 0.20-molar HOCl to obtain a buffer solution that has a pH of 7.49? Assume that the addition of the solid NaOH results in a negligible change in volume.
e. Household bleach is made by dissolving chlorine gas in water, as represented below.

$$Cl_{2(g)} + H_2O_{(l)} \rightarrow H^{1+} + Cl^{1-} + HOCl_{(aq)}$$

Calculate the pH of such a solution if the concentration of HOCl in the solution is 0.065-molar.

1999 **REVIEW #6**
Acid-Base
K_a & K_b

In aqueous solution, ammonia reacts as represented above. In 0.0180*M* NH_3(aq) at 25°C, the hydroxide ion concentration, $[OH^{1-}]$, is $5.60 \times 10^{-4}M$. In answering the following, assume that the temperature is constant at 25°C and that the volumes are additive.

a. Write the equilibrium-constant expression for the reaction represented above.
b. Determine the pH of 0.0180*M* NH_3(aq).
c. Determine the value of the base ionization constant, K_b, for $NH_{3(aq)}$.
d. Determine the percent ionization of NH_3 in 0.0180*M* $NH_{3(aq)}$.
e. In an experiment, a 20.0 mL sample of 0.0180*M* $NH_{3(aq)}$ was placed in a flask and titrated to the equivalence point and beyond using 0.0120*M* $HCl_{(aq)}$.
    i. Determine the volume of 0.0120*M* $HCl_{(aq)}$ that was added to reach the equivalence point.
    ii. Determine the pH of the solution in the flask after a total of 15.0 mL of 0.0120*M* $HCl_{(aq)}$ was added.
    iii. Determine the pH of the solution in the flask after a total of 40.0 mL of 0.0120*M* $HCl_{(aq)}$ was added.

1989
Reaction quiz **REVIEW #7**

Give the formulas to show the reactants and product for FIVE of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

a. Solutions of zinc sulfate and sodium phosphate are mixed.
b. Solutions of silver nitrate and lithium bromide are mixed.
c. A stream of chlorine gas is passed through a solution of cold, dilute sodium hydroxide.
d. Excess hydrochloric acid solution is added to a solution of potassium sulfite.
e. A solution of tin(II) chloride is added to an acidified solution of potassium permanganate.
f. A solution of ammonium thiocyanate is added to a solution of iron(III) chloride.
g. Samples of boron trichloride gas and ammonia gas are mixed.
h. Carbon disulfide vapor is burned in excess oxygen.

1997 **REVIEW #8**
Reaction quiz

Give the formulas to show the reactants and product for FIVE of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

a. Excess potassium hydroxide solution is added to a solution of aluminum nitrate.
b. A solution of sodium bromide is added to an acidified solution of potassium bromate.
c. Sulfur dioxide gas is bubbled into distilled water.
d. Phosphorus trihydride gas is bubbled into liquid boron trichloride.
e. Hydrogen gas is passed over hot iron(II) oxide powder.
f. Solid potassium amide is added to distilled water.
g. A strip of magnesium metal is heated strongly in pure nitrogen gas.
h. A solution of nickel chloride is added to a solution of sodium sulfide.

1985 **REVIEW #9**
Reaction quiz

Give the formulas to show the reactants and product for FIVE of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

a. Sodium metal is added to water.
b. Dilute sulfuric acid is added to a solution of lithium hydrogen carbonate.
c. Ethanol and formic acid (methanoic acid) are mixed and warmed.
d. Excess concentrated potassium hydroxide solution is added to a precipitate of zinc hydroxide.
e. The gases boron trifluoride and ammonia are mixed.
f. A solution of tin(II) chloride is added to a solution of iron(III) sulfate.
g. Phosphorus(V) oxytrichloride is added to water.
h. An acidified solution of sodium permanganate is added to a solution of sodium sulfite.

1992 **REVIEW #10**
Reaction quiz

Give the formulas to show the reactants and product for FIVE of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

a. An excess of sodium hydroxide solution is added to a solution of magnesium nitrate.
b. Solid lithium hydride is added to water.
c. Solutions of ammonia and hydrofluoric acid are mixed.
d. A piece of aluminum metal is added to a solution of silver nitrate.
e. A solution of potassium iodide is electrolyzed.
f. Solid potassium oxide is added to water.
g. An excess of nitric acid solution is added to a solution of tetramminecopper(II) sulfate.
h. Carbon dioxide gas is bubbled through water containing a suspension of calcium carbonate.

1993 **REVIEW #11**
Reaction quiz

Give the formulas to show the reactants and product for FIVE of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

a. A strip of copper is immersed in dilute nitric acid.
b. Potassium permanganate solution is added to an acidic solution of hydrogen peroxide.
c. Concentrated hydrochloric acid is added to solid manganese(II) sulfide.
d. Excess chlorine gas is passed over hot iron filings.
e. Water is added to a sample of solid magnesium nitride.
f. Excess sulfur dioxide gas is bubbled through a dilute solution of potassium hydroxide.
g. Excess concentrated ammonia solution is added to a suspension of silved chloride.
h. Solutions of tri-potassium phosphate and zinc nitrate are mixed.

1997 **REVIEW #12**
Thermodynamics
For the gaseous equilibrium represented below, it is observed that greater amounts of PCl_3 and Cl_2 are produced as the temperature is increased.

$$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$$

a. What is the sign of $\Delta S°$ for the reaction? Explain.
b. What change, if any, will occur in $\Delta G°$ for the reaction as the temperature is increased? Explain your reasoning in terms of thermodynamics principles.
c. If He gas is added to the original reaction mixture at constant volume and temperature, what will happen to the partial pressure of Cl_2? Explain.
d. If the volume of the reaction mixture is decreased at constant temperature to half the original volume, what will happen to the number of moles of Cl_2 in the reaction vessel? Explain.

1999 **REVIEW #13**
Thermodynamics
Answer the following questions in terms of thermodynamic principles and concepts of kinetic molecular theory.

a. Consider the reaction represented below, which is spontaneous at 298 K.
$CO_{2(g)} + 2NH_{3(g)} \rightarrow CO(NH_2)_{2(s)} + H_2O_{(l)} \quad \Delta H°_{298} = -134$ kJ
   i. For the reaction, indicate whether the standard entropy change, $\Delta S°_{298}$, is positive, or negative, or zero. Justify your answer.
   ii. Which factor, the change in enthalpy, $\Delta H°_{298}$, or the change in entropy, $\Delta S°_{298}$, provide the principal driving force for reaction at 298 K. Explain.
   iii. For the reaction, how is the value of the standard free energy change, $\Delta G°$, affected by an increase in temperature? Explain.

b. Some reactions that are predicted by their signs of $\Delta G°$ to be spontaneous at room temperature do not proceed at a measurable rate at room temperature.
   i. Account for this apparent contradiction.
   ii. A suitable catalyst increases the rate of such a reaction. What effect does the catalyst have on $\Delta G°$ for the reaction? Explain.

1996 **REVIEW #14**
Thermodynamics

$$C_2H_{2(g)} + 2H_{2(g)} \rightarrow C_2H_{6(g)}$$

Information about the substances involved in the reaction represented above is summarized in the following tables.

Substance	$S°$ ($\frac{J}{mol \cdot K}$)	$\Delta H_f^°$ (kJ/mol)
$C_2H_{2(g)}$	200.9	226.7
$H_{2(g)}$	130.7	0
$C_2H_{6(g)}$	-----	-84.7

Bond	Bond Energy (kJ/mol)
C – C	347
C = C	611
C – H	414
H – H	436

a. If the value of the standard entropy change, $\Delta S°$, for the reaction is -232.7 joules per mole ▪ Kelvin, calculate the standard molar entropy, $S°$, of C_2H_6 gas.
b. Calculate the value of the standard free-energy change, $\Delta G°$, for the reaction. What does the sign of $\Delta G°$ indicate about the reaction above?
c. Calculate the value of the equilibrium constant, K, for the reaction at 298K?
d. Calculate the value of the C ≡ C bond energy in C_2H_2 in kilojoules per mole.

1998 **REVIEW #15**
Thermodynamics

$$C_6H_5OH_{(s)} + 7O_{2(g)} \rightarrow 6CO_{2(g)} + 3H_2O_{(l)}$$

When a 2.000-gram sample of pure phenol, $C_6H_5OH_{(s)}$, is completely burned according to the equation above, 64.98 kilojoules of heat is released. Use the information in the table below to answer the questions that follow.

Substance	Standard Heat of Formation, $\Delta H_f^°$, at 25°C (kJ/mol)	Absolute Entropy, $S°$, at 25°C ($\frac{J}{mol \cdot K}$)
$C_{(graphite)}$	0.00	5.69
$CO_{2(g)}$	-393.5	213.6
$H_{2(g)}$	0.00	130.6
$H_2O_{(l)}$	-285.85	69.91
$O_{2(g)}$	0.00	205.0
$C_6H_5OH_{(s)}$	?	144.0

a. Calculate the molar heat of combustion of phenol in kilojoules per mole at 25°C.
b. Calculate the standard heat of formation, $\Delta H_f^°$, of phenol in kilojoules per mole at 25°C.
c. Calculate the value of the standard free-energy change, $\Delta G°$, for the combustion of phenol at 25°C.
d. If the volume of the combustion container is 10.0 liters, calculate the final pressure in the container when the temperature is changed to 110. °C. (Assume no oxygen remains unreacted and that all products are gaseous.)

1996 **REVIEW #16**
Electrochemistry

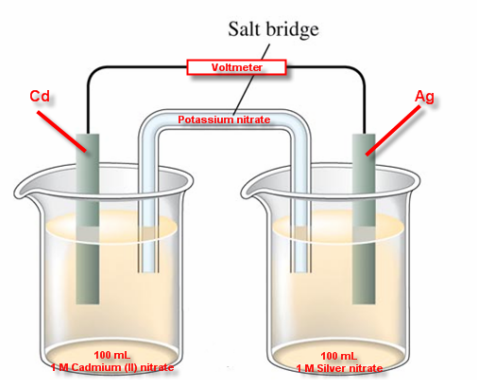
$$Sr_{(s)} + Mg^{2+} \rightleftharpoons Sr^{2+} + Mg_{(s)}$$

Consider the reaction represented above that occurs at 25°C. All reactants and products are in their standard states. The value of the equilibrium constant, K_{eq}, for the reaction is 4.2×10^{17} at 25°C.

a. Predict the sign of the standard cell potential, $E°$, for a cell based on the reaction. Explain your prediction.
b. Identify the oxidizing agent for the spontaneous reaction.
c. If the reaction were carried out at 60°C instead of 25°C, how would the cell potential change? Justify your answer.
d. How would the cell potential change if the reaction were carried out at 25°C with a 1.0-molar solution of $Mg(NO_3)_2$ and a 0.10-molar solution of $Sr(NO_3)_2$? Explain.
e. When the cell reaction in (d) reaches equilibrium, what is the cell potential?

1998 **REVIEW #17**
Electrochemistry

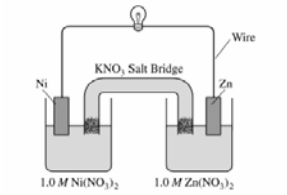
Answer the following questions regarding the electrochemical cell shown to the right.



a. Write the net-ionic equation for the spontaneous reaction that occurs as the cell operates, and determine the cell voltage.
b. In which direction do anions flow in the salt bridge as the cell operates? Justify your answer.
c. If 10.0 mL of 3.0-molar $AgNO_3$ solution is added to the half-cell on the right, what will happen to the cell voltage? Explain.
d. If 1.0 gram of solid NaCl is added to each half-cell, what will happen to the cell voltage? Explain.
e. If 20.0 mL of distilled water is added to both half-cells, the cell voltage decreases. Explain.

2001 **REVIEW #18**
Electrochemistry

Answer the following questions that refer to the galvanic cell shown in the diagram to the right. (A table of standard reduction potentials is printed on the green insert and on page 4 of the booklet with the pink cover.)



a. Identify the anode of the cell and write the half-reaction that occurs there.
b. Write the net ionic equation for the overall reaction that occurs as the cell operates and calculate the value of the standard cell potential, E^{o}_{cell}.
c. Indicate how the value of E_{cell} will be affected if the concentration of $Ni(NO_3)_{2(aq)}$ was changed from 1.0*M* to 0.10*M* and the concentration of $Zn(NO_3)_{2(aq)}$ remained at 1.0*M*. Justify your answer.
d. Specify whether the value of K_{eq} for the cell reaction is less than 1, greater than 1, or equal to 1. Justify your answer.

1997 **REVIEW #19**
Electrochemistry

In an electrolytic cell, a current of 0.250 ampere is passed through a solution of a chloride of iron, producing $Fe_{(s)}$ and $Cl_{2(g)}$.

a. Write the equation for the half-reaction that occurs at the anode.
b. When the cell operates for 2.00 hours, 0.521 grams of iron are deposited at one electrode. Determine the formula or the chloride of iron in the original solution.
c. Write the balanced equation for the overall reaction that occurs in the cell.
d. How many liters of $Cl_{2(g)}$, measured at 25°C and 750 mmHg, are produced when the cell operates as described in part (b)?
e. Calculate the current that would produce chlorine gas from the solution at a rate of 3.00 grams per hour.

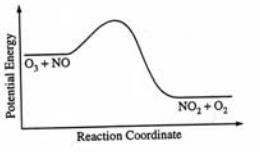
2000 **REVIEW #20**
Electrochemistry

Answer the following questions that relate to electrochemical reactions.

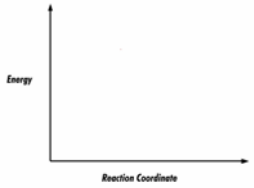
a. Under standard conditions at 25°C , $Zn_{(s)}$ reacts with $Co^{2+}_{(aq)}$ to produce $Co_{(s)}$.
   i. Write the balanced equation for the oxidation half reaction.
   ii. Write the balanced net-ionic equation for the overall reaction.
   iii. Calculate the standard potential, $E°$, for the overall reaction at 25°C.
b. At 25°C , H_2O_2 decomposes according to the following equation.
   $2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$ $\quad E°=0.55$ V
   i. Determine the value of the standard free energy change, $\Delta G°$, for the reaction at 25°C.
   ii. Determine the value of the equilibrium constant, K_{eq}, for the reaction at 25°C.
   iii. The standard reduction potential, $E°$, for the half reaction
   $O_{2(g)} + 4H^{1+}_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$
   has a value of 1.23 V. Using this information in addition to the information given above, determine the value of the standard reduction potential, $E°$, for the half reaction below.
   $O_{2(g)} + 2H^{1+}_{(aq)} + 2e^- \rightarrow H_2O_{2(aq)}$
c. In an electrolytic cell, $Cu_{(s)}$ is produced by the electrolysis of $CuSO_{4(aq)}$. Calculate the maximum mass of $Cu_{(s)}$ that can be deposited by a direct current of 100. amperes passed through 5.00 L of 2.00*M* $CuSO_{4(aq)}$ for a period of 1.00 hour.

1998 **REVIEW #21**
Kinetics
Answer the following questions regarding the kinetics of chemical reactions

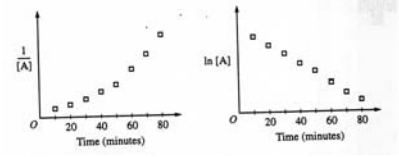
a. The diagram to the right shows the energy pathway for the reaction $O_3 + NO \rightarrow NO_2 + O_2$. Clearly label the following directly on the diagram.
   i. The activation energy (E_a) for the forward reaction.
   ii. The enthalpy change (ΔH) for the reaction.



b. The reaction $2N_2O_5 \rightarrow 4NO_2 + O_2$ is first order with respect to N_2O_5.
   i. Using the axes at right, complete the graph that represents the change in $[N_2O_5]$ over time as the reaction proceeds.
   ii. Describe how the graph in (i) could be used to find the reaction rate at a given time, *t*.
   iii. Considering the rate law and the graph in (i), describe how the value of the rate constant, *k*, could be determined.
   iv. If more N_2O_5 were added to the reaction mixture at constant temperature, what would be the effect on the rate constant, *k*? Explain.



c. Data for the chemical reaction $2A \rightarrow B + C$ were collected by measuring the concentration of A at 10-minute intervals for 80 minutes. The following graphs were generated from the analysis of the data.
   Use the information in the graphs above to answer the following.



   i. Write the rate-law expression for the reaction. Justify your answer.
   ii. Describe how to determine the value of the rate constant for the reaction.

1997 **REVIEW #22**
Kinetics

$$2\ A + B \rightarrow\ C + D$$

The following results were obtained when the reaction represented above was studied at 25°C.

Experiment	Initial [A]	Initial [B]	Initial Rate of Formation of C (mol L^{-1} min^{-1})
1	0.25	0.75	4.3×10^{-4}
2	0.75	0.75	1.3×10^{-3}
3	1.50	1.50	5.3×10^{-3}
4	1.75	??	8.0×10^{-3}

a) Determine the order of the reaction with respect to A and B. Justify your answer.
b) Write the rate law for the reaction. Calculate the value of the rate constant, specifying units.
c) Determine the initial rate of change of [A] in Experiment 3.
d) Determine the initial value of [B] in Experiment 4.
e) Identify which of the reaction mechanisms represented below is consistent with the rate law developed in part (b). Justify your choice.

1	$A + B \rightarrow C + M$	Fast
	$M + A \rightarrow D$	Slow
2	$B \rightleftharpoons M$	Fast equilibrium
	$M + A \rightarrow C + X$	Slow
	$A + X \rightarrow D$	Fast
3	$A + B \rightleftharpoons M$	Fast equilibrium
	$M + A \rightarrow C + X$	Slow
	$X \rightarrow D$	Fast

1996 **REVIEW #23**
Kinetics
The reaction between NO and H_2 is believed to occur in the following three-step process.

$NO + NO \rightleftharpoons N_2O_2$ (fast)
$N_2O_2 + H_2 \rightarrow N_2O + H_2O$ (slow)
$N_2O + H_2 \rightarrow N_2 + H_2O$ (fast)

(a) Write a balanced equation for the overall reaction.
(b) Identify the intermediates in the reaction. Explain your reasoning.
(c) From the mechanism represented above, a student correctly deduces that the rate law for the reaction is rate = $k[NO]^2[H_2]$. The student then concludes that (1) the reaction is third-order and (2) the mechanism involves the simultaneous collision of two NO molecules and an H_2 molecule. Are conclusions (1) and (2) correct? Explain.
(d) Explain why an increase in temperature increases the rate constant, *k*, given the rate law in (c).

1999 **REVIEW #24**
Kinetics

$$2NO_{(g)} + Br_{2(g)} \rightarrow 2\ NOBr_{(g)}$$

A rate study of the reaction represented above was conducted at 25°C. The data that were obtained are shown in the table below.

Experiment	Initial [NO] (mol L^{-1})	Initial [Br_2] (mol L^{-1})	Initial Rate of Appearance of NOBr (mol L^{-1} s^{-1})
1	0.0160	0.0120	3.24×10^{-4}
2	0.0160	0.0240	6.38×10^{-4}
3	0.0320	0.0060	6.42×10^{-4}

(a) Calculate the initial rate of disappearance of $Br_{2(g)}$ in experiment 1.

(b) Determine the order of the reaction with respect to each reactant, $Br_{2(g)}$ and NO(*g*). In each case, explain your reasoning.

(c) For the reaction,
  i. write the rate law that is consistent with the data, and
  ii. calculate the value of the specific rate constant, *k*, and specify units.

(d) The following mechanism was proposed for the reaction:

$Br_{2(g)} + NO_{(g)} \rightarrow NOBr_{2(g)}$ *slow*

$NOBr_{2(g)} + NO_{(g)} \rightarrow 2\ NOBr_{(g)}$ *fast*

Is this mechanism consistent with the given experimental observations? Justify your answer.

1996 **REVIEW #25**
Bonding/Structure/IMF
Explain each of the following observations in terms of the electronic structure and/or bonding of the compounds involved.

(a) At ordinary conditions, HF (normal boiling point = 20°C) is a liquid, whereas HCl (normal boiling point = -114°C) is a gas.
(b) Molecules of AsF_3 are polar, whereas molecules of AsF_5 are nonpolar.
(c) The N–O bonds in the NO_2^{1-} ion are equal in length, whereas they are unequal in HNO_2.
(d) For sulfur, the fluorides SF_2, SF_4, and SF_6 are known to exist, whereas for oxygen only OF_2 is known to exist.

1997 **REVIEW #26**
Bonding/Structure/IMF
Consider the molecules PF_3 and PF_5

(a) Draw the Lewis electron-dot structures for PF_3 and PF_5 and predict the molecular geometry of each.
(b) Is the PF_3 molecule polar, or is it nonpolar? Explain.
(c) On the basis of bonding principles, predict whether each of the following compounds exists. In each case, explain your prediction.
  i. NF_5
  ii. AsF_5

1999 **REVIEW #27**
Bonding/Structure/IMF
Answer the following questions using principles of chemical bonding and molecular structure.

(a) Consider the carbon dioxide molecule, CO_2, and the carbonate ion, CO_3^{2-}.
  i. Draw the complete Lewis electron-dot structure for each species.
  ii. Account for the fact that the carbon-oxygen bond length in CO_3^{2-} is greater than the carbon-oxygen bond length in CO_2.
(b) Consider the molecules CF_4 and SF_4.
  i. Draw the complete Lewis electron-dot structure for each molecule.
  ii. In terms of molecular geometry, account for the fact that the CF_4 molecule is nonpolar, whereas the SF_4 molecule is polar.

1997 **REVIEW #28**
Bonding/Structure/IMF
Explain each of the following observations using principles of atomic structures and/or bonding.

(a) Potassium has a lower first-ionization energy than lithium.
(b) The ionic radius of N^{3-} is larger than that of O^{2-}.
(c) A calcium atom is larger than a zinc atom.
(d) Boron has a lower first-ionization energy than beryllium.

2000 **REVIEW #29**

Bonding/Structure/IMF

Answer the following question about the element selenium, Se (atomic number 34).

(a) Samples of natural selenium contain six stable isotopes. In terms of atomic structure, explain what these isotopes have in common, and how they differ.

(b) Write the complete electron configuration (e.g., $1s^2 2s^2$… etc.) for a selenium atom in the ground state. Indicate the number of unpaired electrons in the ground-state atom, and explain your reasoning.

(c) In terms of atomic structure, explain why the first ionization energy of selenium is

i. Less than that of bromine (atomic number 35), and

ii. Greater than that of tellurium (atomic number 52).

(d) Selenium reacts with fluorine to form SeF_4. Draw the complete Lewis electron-dot structure for SeF_4 and sketch the molecular structure. Indicate whether the molecule is polar or nonpolar, and justify your answer.

2003 **REVIEW #30**

Bonding/Structure/IMF

Compound Name	Compound Formula	ΔH^o_{vap} (kJ mol^{-1})
Propane	$CH_3CH_2CH_3$	19.0
Propanone	CH_3COCH_3	32.0
1-propanol	$CH_3CH_2CH_2OH$	47.3

Using the information in the table above, answer the following questions about organic compounds.

(a) For propanone,

i. draw the complete structural formula (showing all atoms and bonds);

ii. predict the approximate carbon-to-carbon-to-carbon angle.

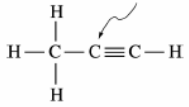
(b) For each pair of compounds below, explain why they do not have the same value for their standard heat, ΔH^o_{vap}. (You must include specific information about <u>both</u> compounds in each pair.)

i. Propane and propanone

ii. Propanone and 1-propanol

(c) Draw the complete structural formula for an isomer of the molecule you drew in part (a) (i).

(d) Given the structural formula for propyne below,



i. indicate the hybridization of the carbon atom indicated by the arrow in the structure above;

ii. indicate the total number of sigma (σ) bonds and the total number of pi (π) bonds in the molecule.

1998 **REVIEW #31**

Colligative properties

An unknown compound contains only three elements C, H, and O. A pure sample of the compound is analyzed and found to be 65.60 percent C and 9.44 percent H by mass.

a) Determine the empirical formula of the compound.

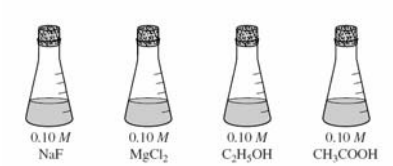
b) A solution of 1.570 grams of the compound in 16.08 grams of camphor is observed to freeze at a temperature 15.2 Celsius degrees below the normal freezing point for camphor. Determine the molar mass and apparent molecular formula of the compound. (The molal freezing-point depression constant, K_f, for camphor is 40.0 kg ▪ K ▪ mol^{-1}.)

c) When 1.570 grams of the compound is vaporized at 300°C and 1.00 atmosphere, the gas occupies a volume of 577 milliliters. What is the molar mass of the compound based on this result?

d) Briefly describe what occurs in solution that accounts for the difference between the results obtained in parts (b) and (c).

1999 **REVIEW #32**

Colligative properties



Answer the following questions, which refer to the 100 mL samples of aqueous solutions at 25°C in the stoppered flasks shown above.

a) Which solution has the lowest electrical conductivity? Explain

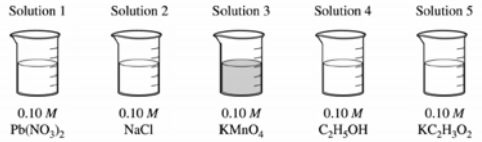
b) Which solution has the lowest freezing point? Explain.

c) Above which solution is the pressure of the water vapor greatest? Explain.

d) Which solution has the highest pH? Explain.

2001 **REVIEW #33**

Colligative properties



Answer the questions below that relate to the five aqueous solutions at 25°C shown above.

a) Which solution has the highest boiling point? Explain.

b) Which solution has the highest pH? Explain.

c) Identify a pair of the solutions that would produce a precipitate when mixed together. Write the formula of the precipitate.

d) Which solution could be used to oxidize the $Cl^{1-}_{(aq)}$ ion? Identify the product of the oxidation.

e) Which solution would be the <u>least</u> effective conductor of electricity? Explain.

1996 **REVIEW #34**

Acid-Base (Lab)

A 0.500-grams sample of a weak, nonvolatile acid, HA, was dissolved in sufficient water to make 50.0 milliliters of solution. The solution was then titrated with a standard NaOH solution. Predict how the calculated molar mass of HA would be affected (too high, too low, or not affected) by the following laboratory procedures. Explain each of your answers.

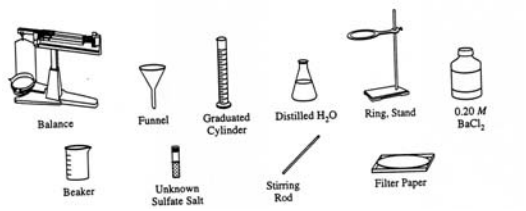
a. After rinsing the buret with distilled water, the buret is filled with the standard NaOH solution; the weak acid HA is titrated to its equivalence point.

b. Extra water is added to the 0.500-gram sample of HA.

c. An indicator that changes color at pH 5 is used to signal the equivalence point.

d. An air bubble passes unnoticed through the tip of the buret during the titration.

1997 **REVIEW #35**
Lab



An experiment is to be performed to determine the mass percent of sulfate in an unknown soluble sulfate salt. The equipment shown above is available for the experiment. A drying oven is also available.

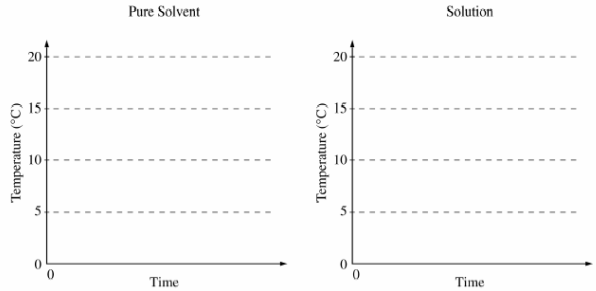
a) Briefly list the steps needed to carry out this experiment.
b) What experimental data need to be collected to calculate the mass percent of sulfate in the unknown?
c) List the calculations necessary to determine the mass percent of sulfate in the unknown.
d) Would 0.20-molar $MgCl_2$ be an acceptable substitute for the $BaCl_2$ solution provided for this experiment? Explain.

2000 **REVIEW #36**
Lab

The molar mass of an unknown solid, which is nonvolatile and a nonelectrolyte, is to be determined by the freezing point depression method. The pure solvent used in the experiment freezes at 10°C and has a known molal freezing-point depression constant, K_f. Assume that the following materials are also available.

- Test tubes
- Beaker
- Stirrer
- Stopwatch
- Pipet
- Graph paper
- Thermometer
- Hot-water bath
- Balance
- Ice

(a) Using the two sets of axes provided below, sketch cooling curves for (i) the pure solvent and for (ii) the solution as each is cooled from 200°C to 0.0°C.



(b) Information from these graphs may be used to determine the molar mass of the unknown solid.
  i. Describe the measurements that must be made to determine the molar mass of the unknown solid by this method.
  ii. Show the setup(s) for the calculation$_{(s)}$ that must be performed to determine the molar mass of the unknown solid from experimental data.
  iii. Explain how the difference(s) between the two graphs in part (a) can be used to obtain information needed to calculate the molar mass of the unknown solid.

(c) Suppose that during the experiment a significant but unknown amount of solvent evaporates from the test tube. What effect would this have on the calculated value of the molar mass of the solid (i.e., too large, too small, or no effect)? Justify you answer.

(d) Show the setup for the calculation of the percentage error in a student's result if the student obtains a value of 126 g mol^{-1} for the molar mass of the solid when the actual value is 120. g mol^{-1}.

1998 **REVIEW #37**

Lab

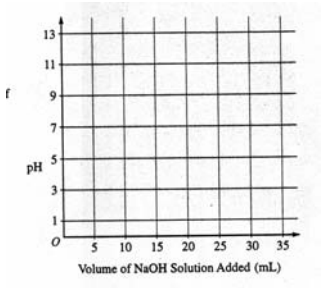
An approximately 0.1-molar solution of NaOH is to be standardized by titration. Assume that the following materials are available.

- Clean, dry 50 mL buret
- 250 mL Erlenmeyer flask
- Wash bottle filled with distilled water
- Analytical balance
- Phenolphthalein indicator solution
- Potassium hydrogen phthalate, KHP, a pure solid monoprotic acid (to be used as the primary standard)

(a) Briefly describe the steps you would take, using materials listed above, to standardize the NaOH solution.

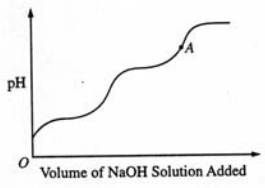
(b) Describe (i.e., set up) the calculations necessary to determine the concentration of the NaOH solution.

(c) After the NaOH solutions has been standardized, it is used to titrate a weak monoprotic acid, HX. The equivalence point is reached when 25.0 mL of NaOH solution has been added. In the space provided at the right, sketch the titration curve, showing the pH changes that occur as the volume of NaOH solution added increases from 0.0 to 35.0 mL. Clearly label the equivalence point on the curve.



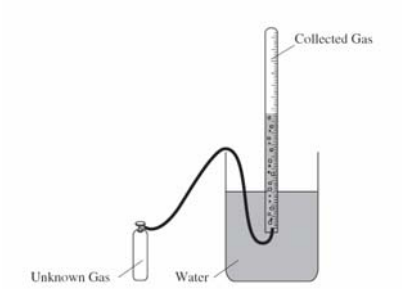
(d) Describe how the value of the acid-dissociation constant, K_a, for the weak acid HX could be determined from the titration curve in part (c).

(e) The graph to the right shows the results obtained by titrating a different weak acid, H_2Y, with the standardized NaOH solution. Identify the negative ion that is present in the highest concentration at the point in the titration represented by the letter A on the curve.



1999 **REVIEW #38**

Lab



A student performs an experiment to determine the molar mass of an unknown gas. A small amount of the pure gas is released from a pressurized container and collected in a graduated tube over water at room temperature, as shown in the diagram above. The collection tube containing the gas is allowed to stand for several minutes, and its depth is adjusted until the water levels inside and outside the tube are the same. Assume that:

- the gas is not appreciably soluble in water
- the gas collected in the graduated tube and the water are in thermal equilibrium
- a barometer, a thermometer, an analytical balance, and a table of the equilibrium vapor pressure of water at various temperatures are also available.

(a) Write the equation(s) needed to calculate the molar mass of the gas

(b) List the measurements that must be made in order to calculate the molar mass of the gas.

(c) Explain the purpose of equalizing the water levels inside and outside the gas collection tube.

(d) The student determines the molar mass of the gas to be 64 g mol^{-1}. Write the expression (set-up) for calculating the percent error in the experimental value, assuming that the unknown gas is butane (molar mass 58 g mol^{-1}). Calculations are not required.

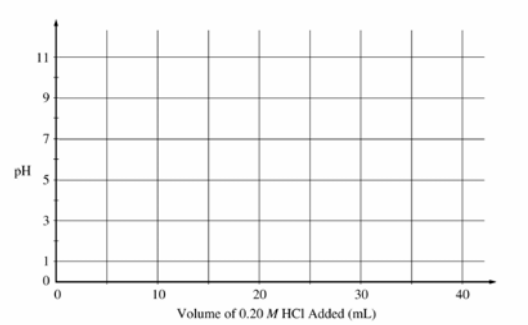
(e) If the student fails to use information from the table of the equilibrium vapor pressures of water in the calculation, the calculated value for the molar mass of the unknown gas will be smaller than the actual value. Explain.

2000 **REVIEW #39**
Lab

A volume of 30.0 mL of 0.10 *M* $NH_{3(aq)}$ is titrated with 0.20 *M* $HCl_{(aq)}$. The value of the base-dissociation constant, K_b, for NH_3 in water is 1.8×10^{-5} at 25 °C.

a) Write the net-ionic equation for the reaction of $NH_{3(aq)}$ with $HCl_{(aq)}$.

b) Using the axes provided below, sketch the titration curve that results when a total of 40.0 mL of 0.20 *M* $HCl_{(aq)}$ is added dropwise to the 30.0 mL volume of 0.10 *M* $NH_{3(aq)}$.



c) From the table below, select the most appropriate indicator for the titration. Justify your choice.

Indicator	pK_a
Methyl Red	5.5
Bromothymol Blue	7.1
Phenolphthalein	8.7

d) If equal volumes of 0.10 *M* $NH_{3(aq)}$ and 0.10 *M* $NH_4Cl_{(aq)}$ are mixed, is the resulting solution acidic, neutral, or basic? Explain.