CHEMISTRY PRACTICE TEST 1

Section II

90 minutes

You may use a calculator for this section.

Directions: Answer each of the following questions, clearly showing the methods you use and the steps involved at arriving at the answers. Partial credit will be given for work shown and little or no credit will be given for not showing numerical work, even if the answers are correct.

Question 1

a. The acid ionization constants for the triprotic acid, phosphoric acid, are $K_{a_1} = 7.5 \times 10^{-3}$, $K_{a_2} = 6.2 \times 10^{-8}$, and $K_{a_3} = 4.2 \times 10^{-13}$.

   i. Write three ionic equations, one for each of the successive ionizations of the three protons of phosphoric acid. Clearly indicate which equilibrium constant corresponds to each ionic equation.

   ii. Calculate the number of grams of sodium dihydrogen phosphate dihydrate needed to prepare 1.00 L of a 0.250 molar solution.

   iii. Write a net ionic equation for the hydrolysis of aqueous sodium phosphate and calculate the value of the corresponding equilibrium constant for the reaction.

b. The acid ionization constant, K_a, for acetic acid is 1.8×10^{-5}. Exactly 41.00 g of sodium acetate is added to water to make 1.00 L of solution. Calculate:

   i. the pH of the solution.

   ii. the percent ionization of the acetate in the solution.

c. Calculate the pH of a solution resulting from mixing 200.0 mL of the solution prepared in Part b with 200.0 mL of 0.200 M hydrochloric acid.

d. Calculate the number of milliliters of 1.00 M hydrochloric acid or 1.00 M sodium hydroxide (specify which and justify your answer) that needs to be added to 82.00 g of sodium acetate to obtain a buffer having a pH of 4.44.

Question 2

Mercury(II) chloride reacts with oxalate ion according to the following equation:

$$2HgCl_2(aq) + C_2O_4^{2-}(aq) \rightarrow 2Cl^-(aq) + 2CO_2(g) + Hg_2Cl_2(s)$$

The initial rate of the reaction was determined for several concentrations of the reactants and the following rate data were obtained for the appearance of chloride ion:

Experiment	$[HgCl_2]$(mol L^{-1})	$[C_2O_4^{2-}]$(mol L^{-1})	Rate (mol $L^{-1}s^{-1}$)
1	0.144	0.132	5.63×10^{-5}
2	0.144	0.396	5.10×10^{-4}
3	0.072	0.396	2.51×10^{-4}
4	0.288	0.132	1.13×10^{-4}

a. Write the rate law for this reaction.
b. Calculate the rate constant and specify its units.
c. What is the reaction rate when the concentration of both reactants is 0.150 M?
d. What is the rate of disappearance of oxalate ion when $[C_2O_4^{2-}] = 0.10$ M and $[HgCl_2] = 0.20$ M?
e. Is the overall equation likely to be an elementary step? Explain.
f. Which species is oxidized in the reaction and which is reduced?

Question 3

The empirical and molecular formulas of a hydrocarbon are determined by combustion analysis.

a. Combustion of a 1.214 g sample of a hydrocarbon results in 4.059 g of carbon dioxide and 0.9494 g of water.
   i. How many moles of carbon are contained in the sample?
   ii. How many moles of H are contained in the sample?
   iii. What is the empirical formula of the hydrocarbon?
b. The mass spectrum of the hydrocarbon shows a parent peak at 184 mass units.
   i. Predict the molar mass of the hydrocarbon.
   ii. What is the molecular formula of the hydrocarbon?
   iii. Write and balance a chemical equation for the complete combustion of the hydrocarbon.

Question 4

In an experiment, a hydrocarbon and carbon tetrachloride were each found not to dissolve in water.

a. Draw the Lewis structure and a line-angle representation for carbon tetrachloride and make a sketch of a space-filling model.
b. What is the molecular geometry of carbon tetrachloride and what are the bond angles in the molecule?
c. Does the molecule have any polar bonds? Explain. Is the molecule polar? Explain.

d. Explain the fact that carbon tetrachloride does not dissolve in water.
e. What principal intermolecular force(s) is(are) acting in the carbon tetrachloride solution of the hydrocarbon?

Question 5

Consider the following equilibrium system:

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g) \quad \Delta H = +176\ kJ/mol$$

State the effect on the number of grams of solid ammonium chloride present at equilibrium (increase, decrease, or stay the same) and, in each case, explain your reasoning, when:

a. the partial pressure of ammonia is increased.
b. the temperature is increased.
c. the products are passed through liquid water.
d. the volume of the container is decreased.

Question 6

The first ionization energy of potassium is $+419\ kJ/mol$. The electron affinity of chlorine is $-349\ kJ/mol$. Electron affinity is the energy change that occurs when an electron is added to a gaseous atom.

a. Define first ionization energy and write a thermochemical equation that represents the first ionization energy of potassium.
b. Write a thermochemical equation that represents the electron affinity of chlorine.
c. Write the sum of the reactions you wrote in Parts a and b and calculate the heat of the reaction in the gas phase. Specify if the reaction is endothermic or exothermic.
d. The reaction between potassium metal and chlorine gas to produce solid potassium chloride is highly exothermic ($\Delta H = -435\ kJ/mol$).
   i. Write the formation reaction of potassium chloride.
   ii. Besides the ionization of potassium, what forces must be overcome in the formation of potassium chloride?
   iii. Explain why this reaction releases so much energy.
e. Predict whether the formation of calcium chloride would be more or less exothermic than the formation of potassium chloride. Explain the basis of your prediction.

Question 7

A 5.0 g sample of sodium chloride is added to 10.0 mL of water at 20 °C. Upon mixing, the salt dissolves and the temperature of the mixture is measured. The experiment is repeated with ammonium chloride and again with calcium chloride. The data in the table summarize the results:

Experiment	Salt	T_1	T_2
1	NaCl	20 °C	20 °C
2	NH_4Cl	20 °C	5 °C
3	$CaCl_2$	20 °C	35 °C

a. Predict the signs of ΔG, ΔS, and ΔH for each of the three experiments. Explain your reasoning.

b. Consider the dissolution of ammonium chloride in water.

   i. Write a thermochemical equation, including the heat term, for the dissolution of ammonium chloride.

   ii. Discuss the nature and relative magnitudes of the bonds and intermolecular forces that break and those that form when ammonium chloride dissolves in water.

   iii. What is the driving force for the change? Use the equation, $\Delta G = \Delta H - T\Delta S$, to explain your reasoning.

c. Is there a temperature at which an equilibrium will be established for the dissolution of ammonium chloride? Justify your answer.