CHEMISTRY PRACTICE TEST 2

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 your work, even if the answers are correct.

Question 1

The pH of a saturated aqueous solution of magnesium hydroxide is 10.17.

a. Calculate the molar concentration of hydroxide ion in the solution.
b. Write the equation for the dissociation of magnesium hydroxide in water and the corresponding K_{sp} expression.
c. Calculate the molar solubility of magnesium hydroxide in water.
d. Calculate the value of K_{sp} for magnesium hydroxide.
e. Calculate the molar concentration of magnesium ion at pH = 11.50.
f. Calculate the volume in milliliters of a 0.0150 M solution of hydrochloric acid needed to titrate 500.0 mL of saturated magnesium hydroxide solution.

Question 2

The standard reduction potentials of some selected half-reactions are given below.

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$E^\circ = +0.337$ V
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	$E^\circ = +0.000$ V
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	$E^\circ = +0.1359$ V
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(l)$	$E^\circ = +0.96$ V
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	$E^\circ = -0.28$ V

a. A piece of nickel and a piece of copper are placed into a hydrochloric acid solution.
   i. Predict whether nickel, copper, or both metals will react with hydrochloric acid.
   ii. Explain your answer(s) by writing the appropriate half-reactions and the overall net ionic equation(s) for the reaction(s) of the metal(s) with hydrochloric acid.
   iii. Calculate the cell voltage(s) for the overall reaction(s).
b. A piece of copper metal is placed into a solution of nitric acid.
   i. Write the net ionic equation.
   ii. Calculate the cell voltage.
   iii. Calculate the standard free energy change, ΔG°, for the process.
   iv. Calculate the equilibrium constant for the process at 25 °C.

Question 4

The formulas of four compounds are listed in the table along with the boiling points of two of the compounds.

Compound	Formula	Boiling Point
1	$CH_3CH_2CH_2CH_3$	
2	$CH_3CH_2CH_2OH$	97 °C
3	$CH_3CH_2OCH_3$	
4	$(CH_3)_2C=O$	57 °C

a. Which compounds are isomers? Justify your answer.
b. Consider Compound 4.
   i. Draw the Lewis structure and a space-filling model of Compound 4.
   ii. Predict the geometry around each carbon atom.
   iii. Identify the hybridization of each carbon atom in Compound 4.
   iv. Is Compound 4 polar or nonpolar? Explain.
   v. What kinds of intermolecular forces exist between molecules of Compound 4?
c. Explain why Compound 2 boils at a higher temperature than Compound 4.
d. Arrange the four compounds in order of increasing boiling point (lowest to highest). Justify your answer.

Question 5

a. Which element, potassium or chlorine, is more likely to have the higher first ionization energy? Explain using electron configurations, Coulomb's law, and effective nuclear charge.
b. Explain the following statements: The ionic radius of potassium is smaller than its atomic radius. The ionic radius of chlorine is larger than its atomic radius.

Question 6

Consider the following equilibrium systems:

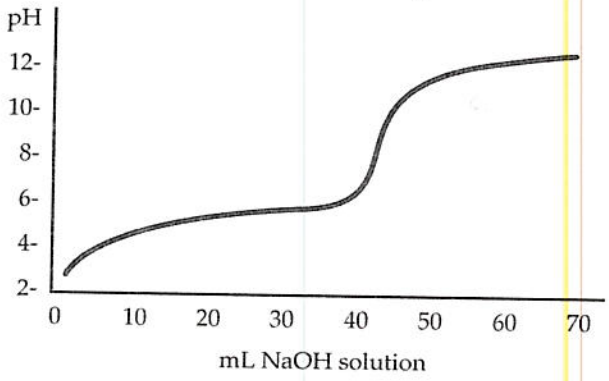
a. $(NH_4)_2CO_3(s) \leftrightarrows 2NH_3(g) + H_2O(g) + CO_2(g)$ $K_p = 0.250$ at 350 °C.
   i. Is the value of K_c at 350 °C greater than, less than, or equal to the value of K_p for this reaction? Explain your answer.
   ii. Predict the sign of ΔS for the reaction. Justify your answer with evidence.
   iii. Calculate the value of K_p for:
   $2NH_3(g) + H_2O(g) + CO_2(g) \leftrightarrows (NH_4)_2CO_3(s)$
   iv. Calculate the value of K_p for:
   $4NH_3(g) + 2H_2O(g) + 2CO_2(g) \leftrightarrows 2(NH_4)_2CO_3(s)$

c. One product of the reaction of copper with nitric acid, nitrogen monoxide, reacts with oxygen in the air to produce nitrogen dioxide. The enthalpy of combustion of nitrogen monoxide is −56.53 kJ/mol. The standard enthalpy of formation, $\Delta H°_f$, for nitrogen dioxide is 33.84 kJ/mol. The standard free energy of formation, $\Delta G°_f$, for nitrogen dioxide is 51.84 kJ/mol.
   i. Write and balance an equation for the reaction of nitrogen monoxide with oxygen.
   ii. Calculate the standard heat of formation for nitrogen monoxide.
   iii. Calculate the standard entropy for nitrogen dioxide at 25 °C. Be sure to specify the units.

d. In a separate experiment involving an electrolysis cell, how many grams of nickel metal can be plated onto an inert electrode in 30.0 min at 3.50 A?

Question 3

Using a pH meter, the titration of 50.0 mL of an unknown acid solution with 0.115 M NaOH was carried out in the laboratory. The following titration curve was constructed from the data obtained from the experiment.



a. Does the graph represent the titration of a weak or strong acid? Explain.
b. Estimate the approximate pH at the equivalence point.
c. Estimate the approximate concentration of the acid. Show your calculations.
d. Estimate the approximate K_a of the acid. Mathematically justify your answer.
e. Clearly indicate the areas on the graph where the solution behaves as a buffer.
f. Which of the following indicators would be best suited to accurately determine the end point of the titration? What color change would signal the endpoint? Explain your reasoning.

Bromcresol green, $pK_a = 4.5$ (yellow to blue)
Thymol blue, $pK_{a_1} = 2$ (red to yellow), $pK_{a_2} = 8.5$ (yellow to blue)
Alizarin, $pK_a = 6.5$ (yellow to red)
Phenol red, $pK_a = 7.5$ (yellow to red)

b. $Cu^{2+}(aq) + CO_3^{2-}(aq) \leftrightarrows CuCO_3(s) \quad K_c = 4.3 \times 10^{+9}$
State the effect on the solubility of solid copper(II) carbonate (increase, decrease, or stay the same) when the following changes are made. In each case, explain your reasoning using a balanced chemical equation when appropriate.
   i. Water is added to the container.
   ii. Gaseous hydrogen chloride is allowed to dissolve in the solution.
   iii. Solid sodium carbonate is added to the solution.

Question 7

In the laboratory, you are to determine the identity of a pure unknown white solid.

a. A 19.2 g sample of the volatile compound decomposes upon heating to yield 6.80 g of ammonia, 8.80 g of carbon dioxide, and the only other product is water. Calculate the empirical formula of the compound in the form: $C_wH_xN_yO_z$.
b. When a sample of the compound is dissolved in water and made basic with sodium hydroxide, wetted pH paper held above the solution indicates a pH of about 9 and the solution gives off a distinct smell of ammonia.
Write and balance a net ionic equation for the reaction of sodium hydroxide with the compound that explains this result.
c. When another sample is dissolved in water and made acidic with hydrochloric acid, the solution effervesces. Write and balance a net ionic equation that could explain this result.
d. Based on your answers to Parts b and c, rearrange the simplest formula you determined in Part a to identify the compound. Name the compound.
e. Use principles of intermolecular forces and polarity to explain why effervescence was observed in Part c but not in Part b.