**AP Chemistry Final Exam 2015**

**Chemistry**

**Section II**

**7 Constructed-Response Questions**

**(Time-105 minutes)**

**YOU MAY USE YOUR CALCULATOR FOR SECTION II**

**Directions:** Questions 1,2, and 3 are long constructed-response questions that should require 20 minutes each to answer. Questions 4,5,6, and 7 are short constructed-response questions that should require about seven minutes each to answer. Read each question carefully and write your response in the space provided following each question. 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. Specific answers are preferable to broad, diffuse responses. For calculations, clearly show the method used and the steps involved in arriving at your answers. If is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not.

I. Students are assigned the task of identifying the concentration and identity of the contents of a jar labeled simply "solution of a base." Based on a physical property of the solution, the group suspects that the base might be ammonia. They decide to titrate 40.0 mL samples of the base with 0.10 molar HNO3. The students titrate three such samples with the HNO3, using three different indicators. The indicators are:

 A. Phenolphthalein, range 8.3 - 10.

 B. Methyl orange, range 3.2 - 4.5

 C. bromthymol blue range 6- 7.5.

The data was listed in the following chart:

|  |  |  |
| --- | --- | --- |
| Indicator | mL 0.10 M HNO3 at end point | mL base |
| methyl orange | 19.9 | 40.0 |
| bromthymol blue | 20.1 | 40.0 |
| phenolphthalein | ??? | 40.0 |

The quantity of HNO3 required to reach the endpoint (the first permanent appearance of the acidic color of the indicator) is significantly different using phenolphthalein, while very similar for the other two indicators.

A. What is the molarity of the base based on the titrations with methyl orange and bromthymol blue?

B. If the unknown base is actually aqueous NaOH, what is the pH of the base solution?

C. Using a piece of pH paper, the **actual** pH of the base solution is found to be 11.

 i. Why is the the value based on the phenolphthalein titration significantly different from the value calculated with the other two indicators?

 ii. Would the molarity of the base calculated from the phenolphthalein titration be greater or less than the molarity calculated in part A? Justify your answer.

D. The titration is repeated, once again using 40.0 mL of the base , but this time using a pH meter, read at 5 mL intervals. The results are shown below:

|  |  |
| --- | --- |
| **Volume of 0.10 M acid (mL) added to 40.0 mL of base** | **pH** |
| 0 | 11.0 |
| 5.0 | 9.7 |
| 10.0 | 9.3 |
| 15.0 | 8.8 |
| 20.0 | 4.3 |
| 25.0 | 2.1 |
|  |  |

 (i) The actual Kb of NH3 is 1.8 x 10-5 . Using the calculated molarity from part A, and the initial pH of 11.0, perform a calculation to indicate whether the unknown base is actually likely to be aqueous ammonia.

 ii. If the unknown base has an actual Kb of 1.8 x 10-5, calculate the **theoretical**

 pH after the addition of 10.0 mL of the acid.

 (iii) Assuming that the base is ammonia, what is the theoretical pH of the solution at the equivalence point?

II. Values of ΔGof, ΔHof, and So can be obtained for ions, by comparing them to the values for H+ ion, which are all assigned as zero. A value of So for the OH- ion can be calculated experimentally using the following data:

 ΔGof of H2O(l) = -237 kJ.mol ΔGof of H+ = 0

 ΔHof of H2O(l) = -286 kJ/mol ΔHof of H+ = 0

 So of H2O(l) = 69.9 J/mol K So of H+ = 0 (note that the So value is in Joules, not kilojoules)

 To determine ΔHo for the ionization of water, H2O(l) ⭢ H+(aq) + OH-(aq) Students did the following: 50.0 mL of 2.00 molar NaOH and 50.0 mL of 2.00 molar HCl came to the same temperature in separate beakers. When the solutions were mixed in an insulated coffee cup, the temperature of the solutions increased by 13.3oC.

 A. What is the net ionic equation for the reaction of HCl(aq) with NaOH(aq) ?

 B. Assuming that the solutions have a density of 1.00 g/mL, and a specific heat of 4.18 J/g°, how much heat, in joules, was produced by the reaction?

 C. What is the calculated value of Δ H for the neutralization reaction, in kJ/mol rxn?

 D. What is ΔH° for the ionization of water, H2O(l) ⭢ H+(aq) + OH-(aq) ?

 E. Based on the listed equilibrium constant for the ionization of water, calculate the

 value of Δ G° for the ionization of water, in kJ/mol.

 F. Calculate the value of ΔS° for the ionization of water

 G. Based on the value obtained in part F, and the thermodynamic values given at the top of the page, calculate the value of So for the OH-(aq) ion.

III. A 5.00 gram sample of a solid mixture known to contain some chromium(III) oxide was analyzed as follows:

 The entire sample was dissolved in nitric acid. When the solution is made basic with NaOH, and treated with H2O2, all of the chromium is part of the yellow chromate ion, CrO42- . The resulting solution has a volume of 100.0 mL.

 A. How many moles of electrons must be transferred to the peroxide from the chromium oxide to produce 1.00 mole of chromate ion?

 B. 25.0 mL of the solution are treated with excess AgNO3 until all of the chromate

 ion has been precipitated as Ag2CrO4. The dried precipitate has a mass of 0.568 grams.

 i. How many grams of Cr were there in the precipitate?

 ii. What was the molarity of CrO42- ion in the original 100. mL sample?

 iii. Assuming that all of the Cr in the solid sample were in the form of Cr2O3, how many grams of Cr2O3 were present in the original 5.00 gram sample?

 iv. What is the % by mass of Cr2O3 in the original sample?

 C. A second analysis is performed using a spectrophotometer. Chromate ion absorbs at a wave length of 370 nm. A 0.10 molar solution of Na2CrO4 is prepared. It produces an absorbance of 0.85 properly tested with the spectrophotometer, at that wave length.

 i. What is the frequency of the light used to test the solution?

 ii. A sample from the original 100. mL solution is tested in the same spectrophotometer at the same wave length, with an identical cuvette. It produces an

 absorbance of 0.60. Based on these data, what is the molarity of chromate ion in the solution?

 iii. Which of the two values for the molarity of chromate ion in the solution is likely to be more accurate - the one obtained in part C ii, or the one obtained in part B ii? Justify your answer.

4. The following compounds all show the same molecular geometry.

XeF2 BeI2 ICl2−

 (a) For each of these species, describe the **electron** geometry .

 (b) Draw a Lewis dot structure of the ICl2− ion.

 (c) What is the formal charge on the iodine, based on your Lewis structure?

5. II. Propene, C3H6 (g) , reacts with HCl (g) to produce 2-chloropropane, C3H7Cl(g) as illustrated below: C3H6(g) + HCl(g) → C3H7Cl(g)



1. Find ΔH° for this reaction at 298 K.

|  |  |
| --- | --- |
| **Bonds** | **Bond Energies (kJ/mol)** |
| C-C | 348 |
| C=C | 614 |
| C-H | 413 |
| H-Cl | 431 |
| C-Cl | 328 |

1. Using the table below, answer questions (i)- (ii).

|  |  |
| --- | --- |
| **Compounds** | **Standard Molar Entropy ( J/mol-K)** |
| HCl (g) | 187 |
| C3H6 (g) | 267 |
| C3H7Cl (g) | 304 |

 (i) Find ΔS°. Include units.

 (ii) Find ΔG°. Include units.

6.

 (a) When an aqueous solution of HBr is added to a solution of H2O2, oxygen gas is rapidly produced. This reaction occurs through the following steps:

 2H+(aq) + 2 Br-(aq) + H2O2(aq) → Br2(aq) + 2 H2O (ℓ)

 Br2(aq) + H2O2(aq) → 2 Br- (aq) + 2 H+ (aq) + O2(g)

 (i) Write the balanced net equation for the reaction that is taking place.

 (ii) Identify the intermediate in this mechanism.

(b) The conversion of ozone into O2 may involve a two step mechanism.

 1. O3 (g) → O2 (g) + O(g)

 2. O3(g) + O(g) → 2 O2(g)

 (i) Assume that when this reaction occurs at room temperature, a graph of ln[O3] vs. time produces a straight line.

If this is the case, which of the two steps is the rate determining step? Explain.

 (ii) How could you use the graph described in part (i) to determine the rate constant for the reaction?

7. Fe3+(aq) + e- → Fe2+ (aq) E° = +0.77 volts

 Fe2+(aq) + 2 e- → Fe(s) E° = −0.44 volts.

 Two half cells are constructed. One cell contains a strip of pure Fe immersed in

 1.00 molar Fe(NO3)2 . The second cell contains a strip of Pt (an inert electrode)

 in a 1.00 molar solution of Fe(NO3)3 .

 (a) Draw a labeled diagram that shows how the two half cells might be connected to produce a steady current. Identify the **cathode** in your diagram.

 (b) Write a balanced equation for the spontaneous reaction that occurs in the cell.

 (c) Calculate the E° for the reaction shown in part (b).