Autumn 2012 / 2013

Exam Code(s)  
Exam(s)  
1st Engineering

Module Code(s)  
Module(s)  
CH140  
Engineering Chemistry

External Examiner(s)  
Professor Tim Gallagher
Internal Examiner(s)  
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INSTRUCTIONS:  
Answer Four questions:

Question one must be attempted
Three other questions must be attempted
Separate Answer Books are not required for each section.
All questions carry 25 marks distributed as shown.

Leave the front page of the Answer Book blank and clearly list on it the numbers of the questions attempted.

Duration  
2hrs

No. of Pages  
6 (including this front page)

Department(s)  
Chemistry

Requirements  
None

All questions carry equal marks,
Molar volume at STP= 22.4 dm$^3$, Avogadro’s Number $6.02 \times 10^{23}$,
R=$0.08206 \text{ dm}^3 \text{ atm/mol K}$
Section A

1. **Answer each of the following [by indicating the correct answer in your answer book]:**

   (i) All of the following are properties of antimony. Which one is not a physical property?
   
   (a) It is a solid at room temperature.
   (b) It has both yellow and gray forms (allotropes) in the solid state.
   (c) It burns in an atmosphere of chlorine.
   (d) It is one of the few substances that expands upon freezing.
   (e) The gray form melts at 631°C.  

   [2 Marks]

   (ii) If a sample of propane, C₃H₈, contains a total of 6.0 × 10³ atoms of carbon, how many molecules of propane are in the sample?
   
   (a) 6.0 × 10³
   (b) 2.0 × 10³
   (c) 8.0 × 10³
   (d) 1.1 × 10⁴
   (e) 3.0 × 10³  

   [2 Marks]

   (iii) What element has the electron configuration 1s² 2s² 2p⁶ 3s² 3p⁴?
   
   (a) C
   (b) S
   (c) Ti
   (d) Si

   [2 Marks]

   (iv) What is the name of Fe(OH)₃?
   
   (a) iron hydroxide
   (b) iron trihydroxide
   (c) iron (III) hydroxide
   (d) iron (II) hydroxide
   (e) none of these

   [2 Marks]

   (v) A compound is known to contain only carbon, hydrogen, and oxygen. If the complete combustion of a 0.150 g sample of this compound produces 0.225 g of CO₂ and 0.0614 g of H₂O, what is the empirical formula of this compound?
   
   (a) C₃H₄
   (b) CH₄O
   (c) C₃HO₃
   (d) C₃H₈O₃
   (e) C₅H₇O₅

   [2 Marks]

   (vi) Which combination of name and formula below is correct?
   
   (a) sodium acetate, CH₃COONa
   (b) lithium oxide, LiO₂
   (c) iron(iv) chloride, FeCl₃
   (d) potassium hydrogen sulfate, K₂PO₄

   [2 Marks]

   …Question continues overleaf
(vii) The original method of making ammonia was to react calcium cyanamide with water according to the following reaction.

\[ \text{CaCN}_2(s) + 
\text{H}_2\text{O}(l) \rightarrow \text{CaCO}_3(s) + \text{NH}_3(g) \]

Which of the following is the most correct set of stoichiometric coefficients to balance this equation?

(a) 1, 3, 1, 2  
(b) 4, 2, 6, 2  
(c) 2, 6, 2, 4  
(d) 1, 1, 1, 1  

[2 Marks]

(viii) Which equation below illustrates the reaction of an acid in aqueous solution?

(a) \[ \text{NaOH}(aq) \rightarrow \text{Na}^+(aq) + \text{OH}^-(aq) \]  
(b) \[ \text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightarrow \text{NH}_4^+(aq) + \text{OH}^-(aq) \]  
(c) \[ \text{HNO}_3(aq) + \text{H}_2\text{O}(l) \rightarrow \text{H}_3\text{O}^+(aq) + \text{NO}_3^-(aq) \]  
(d) \[ \text{HCl}(aq) + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{Cl}^+(aq) + \text{OH}^-(aq) \]  

[2 Marks]

(ix) In which of the following is the oxidation number of the underlined element given incorrectly?

oxidation number

(a) \[ \text{K}_2\text{Cr}_2\text{O}_7 \quad +6 \]  
(b) \[ \text{NaAl(OH)}_4 \quad +3 \]  
(c) \[ \text{NaHSO}_3 \quad +4 \]  
(d) \[ (\text{NH}_4)_2\text{SO}_4 \quad +6 \]  
(e) \[ \text{HIO}_4 \quad +5 \]  

[2 Marks]

(x) If the pressure of a confined gas sample doubled, while the volume was held constant, what happened to the temperature?

(a) It halved.  
(b) It went up by a factor of four.  
(c) It doubled.  
(d) Cannot be determined with information given.  

[2 Marks]

(xi) How many milliliters of 0.812 M \( \text{HCl} \) would be required to titrate 1.33 g of \( \text{NaOH} \) to the equivalence point?

\[ \text{NaOH}(aq) + \text{HCl}(aq) \rightarrow \text{NaCl}(aq) + \text{H}_2\text{O}(l) \]

(a) 25.6 mL  
(b) 41.0 mL  
(c) 34.2 mL  
(d) 20.7 mL  

[2 Marks]

(xii) Calculate \( \Delta G^\circ \) for the following reaction,

\[ \text{C(diamond)} + \text{O}_2(g) \rightarrow \text{CO}_2(g) \]

given that \( \Delta G^\circ[\text{CO}_2(g)] = -394.4 \text{ kJ/mol} \) and \( \Delta G^\circ[\text{C(diamond)}] = +2.9 \text{ kJ/mol} \).

(a) -397.3 kJ  
(b) -394.4 kJ  
(c) 397.3 kJ  
(d) 394.4 kJ  

[3 Marks]
2. **Answer each of the following:**

(i) Explain by reference to their electronic configuration what compound will be formed by the reaction of potassium and sulfur. Also outline the type of bonding that will be present in the compound formed. **[6 marks]**

(ii) \[ \text{Zn(s)} + 2 \text{AgBr (aq)} \rightarrow \text{ZnBr}_2 \text{(aq)} + 2 \text{Ag(s)} \]
In the equation above identify the oxidation states of all species and what is oxidised and reduced in the reaction. **[4 Marks]**

(iii) Draw how a cell could be constructed on the basis of the reaction above. **[4 Marks]**

(iv) If the direction of the reaction shown above is the spontaneous reaction identify the anode and cathode and which direction electrons will flow within the cell. **[3 Marks]**

(v) How long would it take to deposit 50.0 g of iron (from \( \text{Fe}^{3+} \)) at the cathode of the Iron-plating cell operating at a current of 5.00 A? (1 Mole electrons = 1 Faraday=96500 coulombs and Q in coulombs=I x t) **[4 Marks]**

(vi) Give a brief description of the process of electrolysis. **[4 Marks]**

3. **Answer each of the following:**

(i) A student has to make up 230 mL of a 0.4 M Na\(_2\)CO\(_3\) solution. How much Na\(_2\)CO\(_4\) should they weigh out? **[5 Marks]**

(ii) To the solution above was added 200 mL of 0.9M H\(_2\)SO\(_4\) and the acid and base react according to the equation \( \text{H}_2\text{SO}_4 + \text{Na}_2\text{CO}_3 \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O} + \text{CO}_2 \)
Answer the following (showing all calculations).
(a) How many moles of acid are added? **[5 Marks]**

(b) Which reagent is in excess? **[5 Marks]**

(c) What is the concentration of the reagent that was in excess at the end of the reaction? **[5 Marks]**

(d) What is the pH of the solution at the end of the reaction? **[5 marks]**
4. **Answer each** of the following:

(i) Name each molecule and indicate the functional group present in the molecules above (i)-(vi): [2 x 6 marks]

(ii) A vessel containing a sample of gas is at 3.2 atm pressure, 100 °C and has a volume of 4 dm³. What pressure would be present when the temperature is changed to 35°C and the volume to 3.5 dm³? [5 marks]

(iii) Calculate the number of moles of gas in the sample above. If the sample of gas has a mass of 36.8g what is the compounds molecular mass? [5 marks]

(iv) Explain why glass is transparent [3 Marks]

5. **Answer each** of the following:

\[
N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -111 \text{ kJ mol}^{-1}
\]

(i) Write out an expression for \( K_{eq} \) for the reaction above. [3 Marks]

(ii) From the information above discuss what conditions of pressure and temperature should be used for this reaction [8 Marks]

(iii) What is entropy? [3 Marks]

(iv) Discuss what factors effect whether a reaction is spontaneous or not. [3 Marks]

(v) Explain how a catalyst alters the rate of reaction [4 Marks]

\[
2 \text{H}_2\text{O}_2(aq) \xrightarrow{\text{I}^-(aq) \text{ cat}} 2\text{H}_2\text{O}(l) + \text{O}_2(g)
\]

(vi) A student studies the reaction above and determines that the rate of the reaction is first order in \( \text{H}_2\text{O}_2 \) and also in \( \text{I}^- \). What is the rate equation? [4 Marks]