**NAME:**_____

**GENERAL CHEMISTRY**
**CHEM. 111 SEC. 020**
**FINAL EXAM**

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**2nd Session Summer, 2003**

Answer all the questions. DO NOT write on this examination paper; use the blank sheets at the end of the exam for your answers. Credit will not be given for numerical calculations unless all relevant calculations are shown. Questions that require graphing can be answered using the graph paper supplied or if you have a graphing calculator, you may use that. If you use a graphing calculator, you need to state in your answer the equation(s) of the graph(s) you used. Please give answers to numerical question to 3 significant figures.

1. a) Determine the oxidation number of all the elements in the following compounds, elements and ions.
   i) $Fe^{3+}$
   ii) $S_2O_3^{2-}$
   iii) Ca
   iv) $N_2O_5$

**3 points**

b) Balance the following equation:

$$Cr_2O_7^{2-} + Fe^{2+} + H_3O^{+} \rightarrow Cr^{3+} + Fe^{3+} + H_2O$$

**8 points**

2. 57.6g of copper(II) nitrate are dissolved in water to make 370mL of solution. The density of the solution is 1.127g.mL$^{-1}$. Calculate:

a)
   i) The molarity of the solution.
   ii) The molarity of the copper ions.
   iii) The molarity of the nitrate ions.

b)
   i) The Wt% of copper (II) nitrate.
   ii) The Wt% of copper ions.
   iii) The Wt% of nitrate ions.

**10 points**

3. a) 31.7g of glucose ($C_6H_{12}O_6$) is dissolved in water to produce 125mL of solution whose density is 1.273g.mL at 20$^o$C. The vapor pressure of pure water at 20$^o$C is 17.25 mmHg. Calculate the vapor pressure of the solution.

**5 points**

b) 10.71g of an unknown compound is dissolved in 155g of water to make a solution. The freezing point of the solution is -1.607$^o$C. Given that the freezing point depression constant for water is 1.86$^o$C.m$^{-1}$. Calculate the molecular weight of the compound.

**5 points**

c) The unknown compound in 3b above is one of the following compounds. Identify the compound. Credit will not be given without an explanation.

- $Cu(SO_4)_2$
- $C_3H_6O$
- $Fe_2(SO_4)_3$
- $Al(NO_3)_3$
- NaCl

**5 points**

4. a) For the following reaction at 25$^o$C:

$$NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$$

Calculate:

i) The enthalpy of the reaction.
ii) The Gibbs Free Energy of the reaction.
iii) The entropy of the reaction.

**10 points**

b) Is the reaction in 4(a) above spontaneous or non-spontaneous? Credit will not be given without an explanation.

**2 points**

c) If the reaction in 4(a) above were performed at 1000$^o$C, is the reaction spontaneous or non-spontaneous?

**3 points**

5. a) For the following reaction using Brønsted Lowry acid base theory identify:

$$HIO_{3(l)} + H_2O_{(l)} \leftrightarrow H_3O^{+}{}_{(aq)^{+}}\ IO^{-}_{3(aq)}$$

i) The acid
ii) The base
iii) The conjugate acid
iv) The conjugate base

**4 points**

b) For the reaction in 5(a) above:

i) Write the equilibrium expression for ka the acid dissociation constant.

**2 points**

ii) If Sodium Iodate ($NaIO_3$) was added to the solution in 5(a) above, how would this effect the equilibrium? Credit will not be given without an explanation.

**2 points**

iii) The reaction in 5(a) above is exothermic, if I cooled the reaction down, how would this effect the equilibrium? Credit will not be given without an explanation.

**2 points**

iv) If potassium iodide is added to the solution in 5(a) above, how would this effect the equilibrium? Credit will not be given without an explanation.

**2 points**

c) A 0.015M solution of nitric acid is prepared. Calculate the pH and pOH of the solution.

**5 points**

6. a) Explain how two of the following intermolecular forces arise:

i) London dispersion forces
ii) Hydrogen bonding
v) Dipole-Dipole interaction
vi) Ion-Dipole interaction

**5 points**

b) Explain very carefully the trend in boiling points of the following elements and compounds.

| **Substance** | **Boiling Point $^{o}$C** |
|---|---|
| Ar | -186 |
| $CH_4$ | -164 |
| HCl | -85 |
| $C_2H_5OH$ | 78 |
| $H_2O$ | 100 |

**10 points**

7. a) The following data were obtained for the reaction:

$$\underset{\text{(azomethane)}}{H_3C - N = N - CH_{3(g)}} \rightarrow N_{2(g)} + \underset{\text{(ethane)}}{C_2H_{3(g)}}$$

| **Time(s)** | **Conc. Azomethane moles.L$^{-1}$** |
|---|---|
| 0 | $2.84 \times 10^{-3}$ |
| 100 | $2.20 \times 10^{-3}$ |
| 150 | $1.93 \times 10^{-3}$ |
| 200 | $1.70 \times 10^{-3}$ |
| 250 | $1.50 \times 10^{-3}$ |
| 300 | $1.32 \times 10^{-2}$ |

i) Calculate the initial rate of the reaction.
ii) Calculate the rate of reaction after 175 s.
iii) If the reaction is 1$^{st}$ order, calculate the rate constant for the reaction.
iv) If the reaction is 1$^{st}$ order, calculate the half-life of azomethane in this reaction.

**10 points**

b) For the reaction:

$$NO_{2(g)} + CO_{(g)} \rightarrow NO_{(g)} + CO_{2(g)}$$

The mechanism is thought to be:

$$NO_{2(g)} + NO_{2(g)} \rightarrow NO_{(g)} + NO_{3(g)} \qquad \text{Slow}$$

$$NO_{3(g)} + CO_{(g)} \rightarrow NO_{2(g)} + CO_{2(g)} \qquad \text{Fast}$$

What is the rate law for this reaction?

**3 points**

c) Define or explain the following:

i) Activation energy
ii) 2$^{nd}$ Law of Thermodynamics
iii) Lattice site
iv) Lewis acid

**4 points**

## USEFUL INFORMATION

### 1ST order reaction

$$\log\left[\frac{[A_o]}{[A_t]}\right] = \frac{kt}{2.303}$$

$A_o$ = Initial concentration
$A_t$ = Concentration after time t
k = Rate constant of the reaction
t = Time

$$t_{\frac{1}{2}} = \frac{0.693}{k}$$

$t_{\frac{1}{2}}$ = Half-life
k = Rate constant

### Thermodynamics

$$\Delta G = \Delta H - T\Delta S$$

Activation Energy

$$\log k = \log A - \frac{Ea}{2 \cdot 303\, RT}$$

k = rate constant
A = constant
Ea = activation energy
R = gas constant 8.314 $J.mole^{-1}.K^{-1}$
T = Temperature in K

### Dipole Movement

$\mu = Qr$

$\mu$ = dipole moment
Q = charge on the atoms
r = distance between charges on atoms (bond length)

absolute charge on e = $1.60218 \times 10^{-19}$ C (Coulombs)
1 Debye = $3.34 \times 10^{-30}$ C.m.

### Raoult's Law

$P_{solution} = P^o_{solvent} \times X_{solvent}$

**Freezing Point Depression**

$\Delta T = K_f\, m$

$K_f$ water = $1.86^{o}C.m^{-1}$

**Osmotic Pressure**

$\Pi = M R T$

$\Pi$ = Osmotic Pressure

R = Gas Constant = $0.0821.ats.L.mole^{-1}.k^{-1}$
T = Temperature K
M = Molarity

## ANSWERS

1. a)

   i) Fe +3
   ii) S +2, O -2
   iii) Ca 0
   iv) N + S, O -2

   b)

   $Cr_2O_7^{2-} + 6\,Fe^{2+} + 14H_3O^- \rightarrow 2Cr^{3+} + 6Fe^{3+} + 21H_2O$

2. a)

   i) 0.830M
   ii) $[Cu^{2+}] = 0.830M$
   iii) $[NO_3^-] = 1.66M$

   b)

   i) Wt. % $Cu(NO_3)_2 = 13.8\%$
   ii) Wt. % $Cu^{2+} = 4.68\%$
   iii) Wt. % $NO_3^- = 9.12\%$

3. a) $P_{soln} = 16.8mmHg$
   b) $79.9g \cdot mole^{-1}$
   c) $Fe_2(SO_4)_3$

4. a)

   i) $\Delta H^o = -177kJ$
   ii) $\Delta G^o = -90.0kJ$
   iii) $\Delta S^o = -285J \cdot k^{-1}$

   b) The reaction is spontaneous

   c) The reaction is non-spontaneous

5. a)

   i) $HIO_3$
   ii) $H_2O$
   iii) $H_3O^+$
   iv) $IO_3^-$

   b) i) $K_a = \dfrac{[H_3O^+][IO_3^-]}{[HIO_3]}$

   ii) Equilibrium will shift to the left
   iii) Equilibrium will shift to the right
   iv) No effect

c) Strong acid
pH = 1.80 pOH = 12.2

6. a)

i) When two atoms or molecules come close to one another, their atomic or molecular orbitals become distorted due to the repulsion of the two negatively charged orbitals. This induces a small dipole in the atoms or molecules which gives rise to a small attractive forces which are known as London Dispersion Forces.

ii) Hydrogen bonding arises when hydrogen is bonded to a small very electronegative element. A force is then apparent between the hydrogen on one molecule and the small electronegative element on a different molecule.

iii) When two atoms of differing electronegatives are bonded together the molecular orbitals forming the bond between the two atoms become distorted towards the more electronegative atom. This causes a dipole to form in the molecule so that one molecule now attract another molecule with a similar dipole. These are termed Dipole-Dipole interactions.

vi) This is an interaction which takes place between a molecule with a permanent dipole and an ion.

b) In Argon we have only induced Dipole-Dipole or London Dispersion Forces between different atoms. The forces are very weak so it has a very low boiling point. In Methane ($CH_4$) again we only have Dipole-Dipole interaction. However, the electrons in Methane are less tightly bound to the atoms than in Argon, so the orbital distortion is a little larger and hence the forces are a little bigger so that despite methane having a lower molecular weight than Argon its boiling point is higher. In hydrogen chloride we have Dipole-Dipole interaction which are stronger than London Dispersion Forces. Hence even though hydrogen chloride and Argon have similar molecular weights, the boiling point of hydrogen chloride is much higher. Ethanol ($C_2H_5OH$) has a molecular weight similar to argon and hydrogen chloride however, it has a hydrogen bonded to oxygen (i.e. small electronegative element) so it has the possibility of hydrogen bonding hence its much higher boiling point. Water though its molecular weight is similar to methane has the highest boiling point as it like ethanol has the possibility of hydrogen bonding. Its boiling point is a little higher than ethanol despite its much lower molecular weight as it has the possibility of multiple hydrogen bonds.

7. a) Draw a graph of [Azomethane] vs Time

i) $7.69 \times 10^{-6}$ moles $L^{-1} \cdot s^{-1}$ (Draw a tangent to the graph at time = 0, the slope is the initial rate.)

ii) $4.38 \times 10^{-6}$ moles $L^{-1} \cdot s^{-1}$ (Draw a tangent to the graph at time = 175s, the slope is the rate.)

iii) $2.41 \times 10^{-3}$ moles $s^{-1}$

iv) 288 s.

b)

Rate = $k[NO_2]^2$

c)

i) This is the minimum energy the reactants need in order to react.

ii) The entropy of the universe increases is a spontaneous process and remains unchanged in an equilibrium process.

iii) A lattice site is a position in a crystal structure at which an atom, molecule or ion is located.

iv) A Lewis acid is any substance that can accept a pair of electrons.