Chemistry 3A

Semester One Examination, 2010

Answers and Solutions

MULTIPLE CHOICE ANSWER SHEET

1. [A] [B] [C] [D]
2. [A] **[B]** [C] [D]
3. [A] [B] **[C]** [D]
4. [A] [B] **[C]** [D]
5. [A] **[B]** [C] [D]

6. [A] [B] **[C]** [D]
7. [A] **[B]** [C] [D]
8. [A] **[B]** [C] [D]
9. [A] [B] **[C]** [D]
10. [A] **[B]** [C] [D]

11. [A] [B] **[C]** [D]
12. **[A]** [B] [C] [D]
13. [A] [B] [C] **[D]**
14. [A] [B] **[C]** [D]
15. [A] [B] [C] **[D]**

16. **[A]** [B] [C] [D]
17. **[A]** [B] [C] [D]
18. [A] **[B]** [C] [D]
19. **[A]** [B] [C] [D]
20. **[A]** [B] [C] [D]

21. [A] **[B]** [C] [D]
22. [A] [B] [C] **[D]**
23. [A] [B] **[C]** [D]
24. [A] [B] [C] **[D]**
25. **[A]** [B] [C] [D]

________/ 25 marks

PART 2 (60 marks)

Answer **ALL** questions in Part 2 in the spaces provided below.

Question 26.

Give fully balanced equations for the reactions which occur (if at all) in the following experiments.
Use **ionic equations** where appropriate. In each case describe observations such as colour changes, precipitate formation (give the colour), or gas evolution (give the colour or describe as colourless) resulting from the chemical reaction.

a) A dilute solution of hydrochloric acid is added to solid zinc oxide.

Equation $ZnO(s) + 2H^{+}(aq) \leftrightarrow Zn^{2+}(aq) + H_2O(l)$

[2 marks]

Observation white powder is mixed with colourless liquid to produce colourless liquid

[2 marks]

b) A solution of sodium carbonate is added to a solution of copper(II) nitrate.

Equation $CO_3^{2-}(aq) + Cu^{2+}(aq) \leftrightarrow CuCO_3(s)$

[2 marks]

Observation colourless liquid is added to blue clear liquid to produce a green solid (ppte)

[2 marks]

c) A dilute solution of potassium hydrogen carbonate is added to a dilute solution of sulphuric acid.

Equation $HCO_3^{-}(aq) + H^{+}(aq) \leftrightarrow H_2O\ (l) + CO_2(g)$

[2 marks]

Observation colourless solution is added to colourless solution to produce effervescing of a colourless odourless gas

[2 marks]

Question 27.

Yellow iron(III) ions and colourless thiocyanate ions establish equilibrium in aqueous solution as shown in the equation below:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons aq)$$

The iron(III) thiocyanate ($FeSCN^{2+}$) complex ion shown on the right hand side of the equation is dark red.

With reference to the above, certain changes are then imposed on the system at equilibrium.
Clearly state what you would observe after each change is made and apply Le Chatelier's Principle to account for each observation in the spaces allocated below.

(a) Some concentrated colourless sodium thiocyanate (NaSCN) solution is added.

Observation : the system gets darker red

[1 mark]

Explanation :

As SCN^- is added to the system the stress on the system is relieved partially by a reaction that uses up this added substance. Therefore more $FeSCN^{2+}$ is produced, and Fe^{3+} is used up.

[2 marks]

(b) A small amount of concentrated potassium nitrate solution is added.

Observation : there is no change, the solution might lighten slightly due to dilution

[1 mark]

Explanation :
The addition of potassium nitrate does not alter the position of equilibrium because it does not react with anything in the system. There may be a little lightening as the colourless solution dilutes the mixture.

[2 marks]

Question 28.

Using carefully drawn diagrams, thoroughly **explain** the difference in shape and polarity between BF_3 molecules and PF_3 molecules.

BF_3 is non octet and forms a trigonal planar (symmetrical) shape due to equal repulsions between bonding pairs.

Since the BF_3 has no dipole moment because the molecule is symmetrical there will be no polarity.

PF_3 has one pair of non bonded electrons and three pairs of bonded electrons that forms pyramidal shape due to bonding pair – bonding pair repulsions weaker than non bonding pair – bonding pair repulsions.

Thus with the extra electrons on the chlorine atoms we will find that the molecule will have a dipole.
4 of the above points = 4 marks

[4 marks]

Question 29.

Explain the difference between the terms "electronegativity" and "ionisation energy".

Ionisation activity is the energy required to remove electrons from an atom.

This may be used to determine how metallic or non metallic the substance is.

Electronegativity is the property of an atom to attract electrons to its nucleus.

It may be used to determine the polarity of a bond – ionic bonds are due to very large differences in electronegativity whilst covalent bonds have less different electronegativities which enable electrons to be more equally shared.

Three of the above points = 3 marks

[3 marks]

Question 30.

This question relates to the following reaction:

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)} \qquad \Delta H = +180\ \text{kJ mol}^{-1}$$

Complete the table by predicting and explaining the effect on the position of equilibrium of the following imposed changes. (simply stating Le Chatelier's principle does not constitute an explanation)

Imposed change	**Affect on equilibrium position** to right, to left, or no change	**Explanation**
Increased Temperature	Right	Energy is used up in the forward reaction
Reduce the volume of the reaction vessel	No change	The number of molecules in the reactants is equal to the number of molecules produced in the products. As there is no lessening of the imposed stress there will be no change.
Remove some of the NO(g)	Right	More NO will be formed to reestablish equilibrium. This reaction will be that which produces NO.

[6 marks]

Question 31.

(a) Write the equilibrium constant expression for the following reaction.

$$Co(H_2O)_6{}^{2+}{}_{(aq)} + 4Cl^-{}_{(aq)} \rightleftharpoons CoCl_4{}^{2-}{}_{(aq)} + 6H_2O_{(l)}$$

$$K = \frac{[CoCl_4^{2-}]}{[Co(H_2O)_6^{2+}]\times[Cl^-]^4}$$

Each error (-1) mark

[2 marks]

(b) Describe the effect on the position of equilibrium when

(i) K is very small eg K = 10^{-3}

Reactants are favoured at equilibrium because these concentrations are larger making K smaller.

[2 marks]

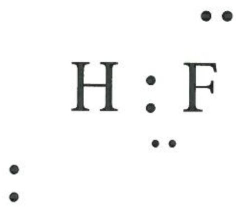
(ii) K is small eg K = 1

At equilibrium products and reactants will be in almost equal quantities so neither will be favoured thus K will be nearer 1.

[2 marks]

Question 32.

Complete the table below by drawing correct Lewis (electron dot) diagrams, indicating whether the substance is polar or non polar and describe the type of bonding of the particle shown.

Formula	Lewis (electron dot) diagram	Polar or non polar	Type of bonding of particle shown
H_2S		polar	Dipole forces
HF	 	polar	Hydrogen bonding
NO_3^-		Non polar (but charged)	ionic

[9 marks]

Question 33.

a) Explain why sodium chloride dissolves in water whilst in kerosene or petrol (non polar substances) sodium chloride is relatively insoluble. [3 marks]

Na^+ ions and Cl^- ions are attracted to the strong dipoles of the water molecules which are able to remove these ions from the crystal lattice [1 mark] dispersed/diffused throughout the water and thus are considered dissolved in the water. [1mark]

Weak attractions between Na^+ and Cl^- ions do not allow breaking of the crystal lattice so dissolving does not occur. [1 mark]

b) Explain why iodine (I_2) is soluble in ethanol (CH_3CH_2OH), very soluble in carbon tetrachloride (CCl_4) but slightly soluble in water. [3 marks]

Iodine has weak dispersion forces between its molecules which are closer in magnitude to the forces in ethanol and CCl_4. The forces between water molecules are large and these will tend to favour attraction between these dipole forces than with those of iodine. Thus very little dissolving will occur. [2 marks]

The weaker forces between CCl_4 and iodine will favour dissolving as the forces are similar and thus he solubility will be greater.. [1 mark]

Question 34

Complete the following table that describes the type of bonding and properties of the substance. The first row has been done for you

Substance	Bonding between atoms	Bonding between molecules (if present)	Property of substance due to bonding	Reason why bonding is responsible for property.
Water	Covalent	Hydrogen bonding	Excellent solvent of salts.	Strong attractive forces due to dipoles.
Graphite	Covalent	Van derWaals (dispersion)	lubricant	Strong bonds between atoms in sheet, weak dispersion forces between sheets allow movement
Copper	Metallic	none	Conductor Malleable	Delocalised electrons

[8 marks]

END OF PART 2

PART 3 (40 marks)

Answer **ALL** questions in Part 3. The calculations are to be set out in detail in this Question/Answer Booklet. Marks will be allocated for correct working, correct equations and clear setting out, even if you cannot complete the problem. Note that if an incomplete answer is given only partial marks will be awarded.
When questions are divided into sections, clearly distinguish each section using (a), (b), and so on. Express your final numerical answers to three (3) significant figures where appropriate, and provide units where applicable. Information which may be necessary for solving the problems is located on the separate Chemistry Data Sheet.

Question 35.

In an laboratory experiment solutions were added together without reacting.
150.0 mL of 0.100 mol L^{-1} magnesium nitrate, 100.0 mL of 0.0500 mol L^{-1} potassium nitrate and 100 mL of 0.0500 mol L^{-1} iron (III) nitrate were added with water to make 5.00 L of solution.

[Density of solution 1.00 kg L^{-1}]

(a) Find the final concentration of ferric (Fe^{3+}) ions in mol L^{-1}. [2 marks]

(b) Find the final concentration of nitrate (NO_3^-) ions in parts per million (ppm) [4 marks]

(c) Find the concentration of magnesium (Mg^{2+}) ions in grams per litre (g L^{-1}). [3 marks]

(a)

$Fe(NO_3)_{3(s)} \rightarrow Fe^{3+}_{(aq)} + 3NO^-_{3(aq)}$

$n(Fe^{3+}) = c \times v = 0.0500 \times 0.100 = 0.00500$ mol [1]

$v_{final} = 5.00$ L

$c(Fe^{3+}) = \frac{n}{V} = \frac{0.00500}{5.00 L}$

$= 0.00100$ M (mol L^{-1}) [1]

(2 total)

b) $Mg(NO_3)_2 \rightarrow Mg^{2+} + 2NO_3^-$

$KNO_3 \rightarrow K^+ + NO_3^-$

$Fe(NO_3)_3 \rightarrow Fe^{3+} + 3NO_3^-$

mass water $= 5.00\,L \times 1.00\,kg\,L^{-1} = 5.00\,kg$

moles NO_3^- Mg : $n(NO_3^-) = 2 \times 0.150 \times 0.100$

$= 3.00 \times 10^{-2}$ mol

K : $n(NO_3^-) = 1 \times 0.100 \times 0.0500$ [1]

$= 5.00 \times 10^{-3}$ mol

Fe : $n(NO_3^-) = 3 \times 0.100 \times 0.0500$ [1]

$= 1.5 \times 10^{-2}$ mol

$n_{TOTAL} = 5.00 \times 10^{-2}$ mol

$m(NO_3^-) = 14.01 + 3 \times 16.00 = 62.01$ g [1]

ppm $= \frac{5.00 \times 10^{-2} \times 62.01}{5.00}$ g/kg

$= 6.2 \times 10^{-1} \times 10^{3}$ mg/kg (4 total)

$= 6.2 \times 10^{2}$ ppm [1]

c) $n(Mg^{2+}) = c \times V = 0.100 \times 0.150 = 1.50 \times 10^{-2}$ mol [1]

$m(Mg^{2+}) = 1.50 \times 10^{-2} \times 24.31 = 3.65 \times 10^{-1}$ g [1]

$c(Mg^{2+}) = \frac{m}{V} = \frac{3.65 \times 10^{-1}}{5.00} = 7.29 \times 10^{-2}\,g\,L^{-1}$ [1]

3 total

Question 36.

Chromium metal occurs mainly as the green mineral chromite, $Fe_2O_3.Cr_2O_3$. Chromium is extracted from chromite by heating the mineral in air with sodium carbonate to form sodium chromate according to the following balanced equation:

$$2Fe_2O_3.Cr_2O_3 + 4Na_2CO_3 + 3O_2(g) \rightarrow 2Fe_2O_3 + 4Na_2CrO_4(s) + 4CO_2(g)$$

(a) Calculate the mass of sodium carbonate needed to react with 1.00 tonne of chromite. [Hint: 1 tonne = 10^3 kg or 10^6 g.] [5 marks]

(b) What volume of oxygen gas measured at 30.0°C and 98.0 kPa pressure is required for the reaction in (a) above? [5 marks]

(a) $n(Na_2CO_3) = \frac{4}{2} n(\text{Chromite})$ [1]

$M(\text{Chromite}) = 2\times55.85 + 3\times16.00 + 2\times52.00 + 3\times16.00$

$= 311.7$ g/mol [1]

$n(\text{chromite}) = \frac{m}{M} = \frac{10^6}{311.7} = 3.208\times10^3$ mol [1]

$n(Na_2CO_3) = \frac{4}{2}\times3.208\times10^3$ mol

$M(Na_2CO_3) = 2\times22.99 + 12.01 + 3\times16.00$

$= 105.99$ g mol^{-1} [1]

$m(Na_2CO_3) = \frac{4}{2}\times3.208\times10^3\times105.99$ (5 total)

$= 6.8\times10^5$ g [1]

(b) $n(O_2) = \frac{3}{2} n(\text{chromite})$ [1]

$= \frac{3}{2}\times3.208\times10^3 = 4.8\times10^3$ mol [1]

$V = \frac{nRT}{P}$ [1] $= \frac{4.8\times10^3\times8.315\times(273.1+30.0)}{98.0}$ [1]

$= 1.238\times10^5$ L [1]

(5 total)

Question 37.

In a laboratory experiment to prepare highly insoluble mercury(I) bromide, a student added 150.0 mL of 0.0502 mol L^{-1} mercury(I) nitrate solution to 250.0 mL of 0.0203 mol L^{-1} potassium bromide solution.

Note: mercury(I) = Hg_2^{2+}

(a) Write the correct, balanced **reversible** equation for this reaction. [2 marks]

(b) Show which reactant is the limiting reagent in this experiment. [4 marks]

(c) Determine the theoretical mass of mercury(I) bromide the student would obtain. [4 marks]

(d) Why is the amount of mercury(I) bromide a "theoretical" mass? [1 mark]

(a) $Hg_2Br_{2(s)} \rightleftharpoons Hg_{2\,(aq)}^{2+} + 2Br^-_{(aq)}$ {−1 per error} [2]

OR

$Hg_2(NO_3)_{2\,(aq)} + 2KBr_{(aq)} \rightleftharpoons Hg_2Br_{2(s)} + 2KNO_{3\,(aq)}$

(b) $SR = \frac{n(Hg_2(NO_3)_2)}{n(KBr)} = \frac{1}{2} = 0.5$ [1]

$n(Hg_2(NO_3)_2) = c \times v = 0.0502 \times 0.150 = 7.53 \times 10^{-3}$ mol [1]

$n(KBr) = c \times v = 0.0203 \times 0.250 = 5.075 \times 10^{-3}$ mol [1]

$AR = \frac{n(Hg)}{n(KBr)} = \frac{7.53 \times 10^{-3}}{5.025 \times 10^{-3}} = 1.49$

$\therefore$ KBr is LR and Hg_2^{2+} in excess [1]

(c) $m(Hg_2Br_2) = \frac{1}{2} n(Br^-)$ [1]

$= \frac{1}{2} \times 5{\cdot}075 \times 10^{-3}$ mol

$=$

$M(Hg_2Br_2) = 2 \times 200{\cdot}6 + 2 \times 79{\cdot}90$

$= \underline{561{\cdot}0 \text{ g mol}^{-1}}$ [1]

$m(Hg_2Br_2) = \frac{1}{2} \times 5{\cdot}075 \times 10^{-3} \times 561{\cdot}0$ [1]

$= \underline{1{\cdot}42 \text{ g}}$ [1]

d) Note eventhough Hg_2Br_2 is highly insoluble there will be undissolved Hg_2^{2+} and Br^- ions in solution (ie at equilibrium). [1]

[11 marks]

Read the information below to complete the Question 38 on page 28.

The **Contact Process** is a process involving the catalytic oxidation of sulfur dioxide, SO_2, to sulfur trioxide, SO_3. The sulfur trioxide, SO_3, is added to water to produce sulfuric acid, H_2SO_4.

Step 1
Solid sulfur, S(s), is burned in air to form sulfur dioxide gas, SO_2 at 1000°C.

$$S(s) + O_2(g) \leftrightarrow SO_2(g) \qquad \Delta H = \text{-ve}$$

Step 2
The mixture of sulfur dioxide and air is heated to 450°C and subjected to a pressure of 101.3 - 202.6 kPa (1 – 2 atmospheres) in the presence of vanadium (V) oxide) to produce sulfur trioxide, $SO_3(g)$, with a yield of 98%.

$$2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g) \qquad \Delta H = -99 \text{ kJ mol}^{-1}$$

Any unreacted gases from the above reaction are recycled back into the above reaction.

Step 3
Sulfur trioxide, $SO_3(g)$ is dissolved in 98% (18M) sulfuric acid, H_2SO_4, to produce disulfuric acid or pyrosulfuric acid, also known as fuming sulfuric acid or oleum, $H_2S_2O_7$.

$$SO_3(g) + H_2SO_4\,(l) \leftrightarrow H_2S_2O_7\,(l) \qquad \Delta H = \text{-ve}$$

This is done because when water is added directly to sulfur trioxide to produce sulfuric acid

$$SO_3(g) + H_2O(l) \leftrightarrow H_2SO_4(l) \qquad \Delta H = -170 \text{ kJ mol}^{-1}$$

the reaction is slow and tends to form a mist in which the particles refuse to coalesce.

Step 4
Water is added to the disulfuric acid, $H_2S_2O_7$, to produce sulfuric acid, H_2SO_4

$$H_2S_2O_7(l) + H_2O(l) \leftrightarrow 2H_2SO_4(l) \qquad \Delta H = \text{-ve}$$

Steps 3 and 4 are performed at the lowest temperature possible (70 - 90°C).

It is suggested that you write between 1½ and 2 pages to answer the following question.

Question 38.

During the manufacture of sulphuric acid described on page 27,
- a) indicate whether equilibrium was present during specific reactions,
- b) use Le Chatelier's Principle, and
- c) Collision Theory to **explain** why certain conditions were used to **maximise** the yield of product in each reaction.

[10 marks]

Marks were awarded thus:

3 marks for indicating whether equilibrium was present during specific reactions

Students need to **show evidence** for this – they cannot assume that equilibrium existed.

Evidence

Step 1 equilibrium could occur – no evidence except for a reversible reaction, equilibrium expression possible

Step 2 equilibrium definitely – closed system, high pressure, 98% yield equilibrium expression possible

Step 3 equilibrium most likely – closed system, reversible reaction, equilibrium expression possible

Step 4 equilibrium possible – closed system, reversible reaction, no equilibrium expression possible

Three pieces of evidence are required to get three marks.

Use of Le Chatelier's Principle required equilibrium to be present. If students did not mention this at all they missed out on a mark.

Step 1

LCP effect of high temp on yield due to exo reaction; pressure not an issue as number of particles on both sides equal, steady state addition of S and O_2 causes reaction to proceed.

CT high temp increases RR

Step 2

LCP high temp effect on exo reaction lowered yield (98%)

High pressure effect on yield – promote reaction increased yield ie 3volumes to 2

Catalyst no effect – equilibrium attained quicker.

CT see catalyst above – lowered Ea gives faster reaction

Gases - give high reaction rate, high P maximises interactions

Stoich ratio of reacting gases

SEE NEXT PAGE

Step 3
Possibly at equilibrium

LCP reaction must occur at high pressure (ie 1 volume to zero vol) for SO3 gas to produce oleum

Lower temperature to produce higher yield (exo reaction)

CT reaction rate important here

Note alternative reaction is used **not** the direct reaction

Step 4

Not necessarily at equilibrium thus LCP not a consideration.

6 marks for sections b) and c)