Chemistry 12 2009 Semester II Solutions

Part 1

1	2	3	4	5	6	7	8	9	10
d	d	b	a	b	d	a	c	d	c
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
b	a	c	a	c	c	b	b	d	c
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
a	c	a	a	d	c	d	b	c	b

PART 2 **(70 marks = 35 % of paper)**

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1. Write equations for any reactions that occur in the following procedures. If no reaction occurs write 'no reaction'.
   In each case, describe **in full** what you would observe, including any
   - Colours
   - Odours
   - Precipitates (give the colour)
   - Gases evolved (give the colour or describe as colourless)

   If no change is observed, you must state this as the observation.

(a) Solid copper (II) oxide is reacted with dilute hydrochloric acid.

Equation $CuO + 2H^+ \rightarrow Cu^{2+} + H_2O$

Observation Black solid dissolves to form blue solution

(3 marks)

(b) Zinc granules are added to a solution of iron (II) nitrate.

Equation $Zn + Fe^{2+} \rightarrow Zn^{2+} + Fe$

Observation Grey solid reacts with green solution forming grey solid and colourless solution

(3 marks)

(c) Concentrated ammonia solution is added to a suspension of silver sulfide.

Equation $Ag_2S + 4NH_3 \rightarrow 2Ag(NH_3)_2^+ + S^{2-}$

Observation Black solid dissolves to form a colourless solution

(3 marks)

(d) A solution of magnesium nitrate is added to a solution of potassium phosphate.

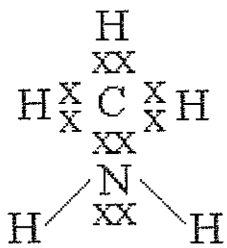
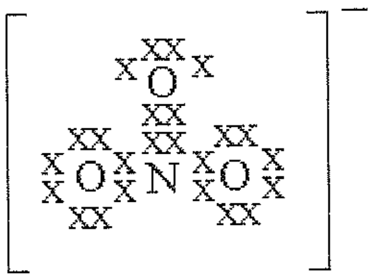
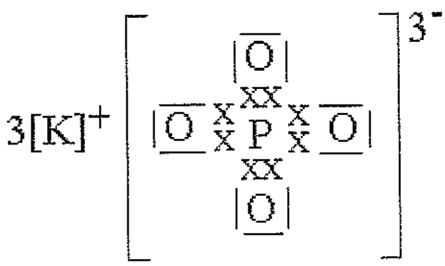
Equation $2Mg^{2+} + 3PO_4^{3-} \rightarrow Mg_3(PO_4)_2$

Observation Colourless solution forms a white precipitate

(3 marks)

2. For each species listed in the table below, draw the structural formula, representing all valence shell electron pairs either as : or –

[for example, water $H:\ddot{\underset{\cdot\cdot}{O}}:H$ or $H-\ddot{\underset{\cdot\cdot}{O}}-H$ or $H-\overline{\underline{O}}-H$ and so on]

Species	Electron-dot diagram
Methanamine CH_3NH_2	
Nitrate ion NO_3^-	
Potassium phosphate K_3PO_4	

(6 marks)

3. For each of the following pairs of substances describe a chemical test and observation by which you could distinguish between the substances listed. You must indicate which of the substances gives rise to the observation. No equations are necessary.

Substances	What you would do	What you would see
2-methyl-2-propanol 3° and 2-propanol 2°	Warm with acidified $KMnO_4$ solution	2 methyl-2-propane 2-propanol decolourises
Propanoic acid and propanone	Add marble chips	Propanic acid forms bubbles and colourless gas

(6 marks)

4. Hypochlorous acid HClO is a weak acid and barium hydroxide solution $Ba(OH)_2$ is a strong base. When chemically equivalent amounts of these solutions are mixed barium hypochlorite is formed. Explain why this salt solution is basic.

$Ba(ClO)_2 \rightarrow Ba^{2+} + 2OCl^-$

$OCl^- + H_2O \rightleftharpoons HOCl + OH^-$

Therefore basic

(3 marks)

5. A compound commonly used in soaps is sodium stearate, $NaC_{17}H_{35}COO$. The cleaning action of soap is very much reduced in acidic conditions because the stearate ions react to form stearic acid, $C_{17}H_{35}COOH$.

(a) Write an equation to show the formation of this acid.

$C_{17}H_{35}COO^- + H^+ \rightarrow C_{17}H_{35}OOH$

(b) Explain why stearic acid molecules are not as effective in their cleaning action as stearate ions.

Ions form ion-dipole attractions with water
Acid will form H-bonds that are not as strong, therefore less able to mix the hydrophobic particles in dirt.

(4 marks)

6. An impure sample of copper contains iron and silver impurities. For the electrowinning of copper from this sample, describe and explain:

(a) what happens to the copper.

Dissolves at anode
Departed at cathode

(b) what happens to the iron.

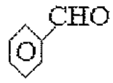
Goes into electrolyte solution
$Fe \rightarrow Fe^{2+} + 2e^-$ $E° = +0.44$ V

(c) what happens to the silver.

Falls to bottom of cell
Not oxidised at anode $E° = -0.80$ V

(6 marks)

7. Identify by name or formula an example of each of the following.

Description	Name or Formula
An aromatic aldehyde	
A compound which is a liquid at room temperature and whose molecules are hydrogen bonded together	NH_3
A substance that can be used as a primary standard in redox titrations	$H_2C_2O_4$
A secondary alcohol	2-propanol
A positively charged complex ion	$Ag(NH_3)^{2+}$
A solution that will dissolve aluminium oxide but not iron (III) oxide	NaOH
A gas which forms a basic solution in water	Ammonia
The major product of the Contact Process	SO_3 or H_2SO_4

(8 marks)

8. Both osmium (I) acetate and osmium (III) acetate are soluble in water. Use the following observations to help you make an estimate of the Standard Reduction Potential for the half-reaction

$$Os^{3+} + 2e^- \rightarrow Os^+$$

Observations
Osmium (I) acetate solution decolourises bromine water but does not turn iron (III) sulfate solution green.
When osmium (III) acetate solution is added to potassium iodide solution a brown colour is produced.

The value of E^o lies between +0.77 (0.8) V and +1.07 V.

(2 marks)

9. A series of solutions of hydrochloric acid with different concentrations was prepared and tested with the indicator, erythrosin. The results of the experiment are set out below.

pH	Indicator colour
1	Yellow
2	Yellow
3	Orange
4	Red

On the basis of these results, what can be concluded about the suitability of erythrocin for titrations involving hydrochloric acid and sodium carbonate solution? Justify your answer with equations.

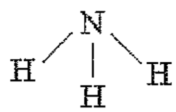
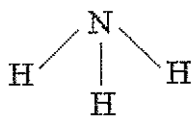
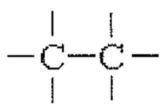
Suitable. End point in acidic range.

Titration equiv point is acidic

$CO_2 + H_2O \rightarrow H_2CO_3$ acidic at end point

(4 marks)

10. Write a structural formula to represent an example of each of the following.

A non-polar molecule that contains only polar bonds	O = C = O
A polar molecule that contains only polar bonds	
A polar molecule that will hydrogen bond with water	
A non-polar molecule that contains at least one non-polar bond	

(4 marks)

11. In the chemical equilibrium system:

$$Fe^{3+} (aq) + SCN^- (aq) \Leftrightarrow FeSCN^{2+} (aq)$$

The Fe^{3+} ions are brown, SCN^- ions are colourless and the $FeSCN^{2+}$ ions are deep red. Their concentration in the equilibrium mixture can be estimated by the intensity of their colour.

The concentration of Fe^{3+} in this solution can be reduced by the addition of fluoride ions which form a series of colourless complex ions in solution.

$$Fe^{3+} + F^- \rightarrow FeF^{2+}$$

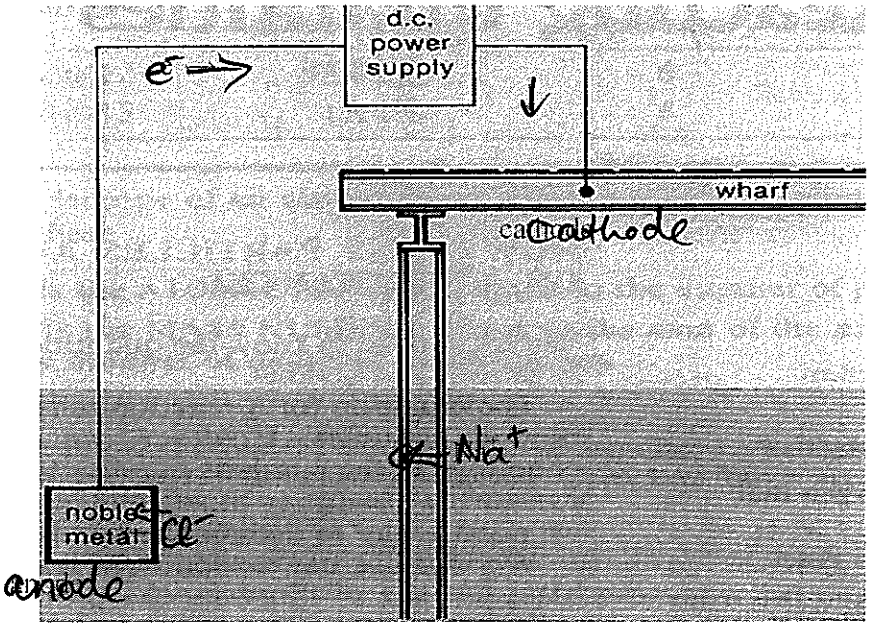
$$Fe^{3+} + 2F^- \rightarrow FeF_2^+$$

A solution was prepared by mixing KSCN solution with $Fe(NO_3)_3$ solution and it was then divided into four portions in petri dishes. The dishes were treated differently as shown in the table below. Describe how each dish would appear, compared to dish 1 and explain your answer in each case.

Dish	**Action**	**Observation (compared to dish 1)**	**Explanation**
Dish 1	No change	Same	No answer required
Dish 2	KSCN crystals added	More red Less brown (1mk)	→ reduce to [SCN^-]
Dish 3	$Fe(NO_3)_3$ crystals added	More brown More red (1mk)	↑ [Fe^{3+}] → ↑ [$FeSCN^{2+}$] (3mk for both answers above)
Dish 4	NaF crystals added	Less brown Less red (1mk)	↓ [Fe^{3+}] → ↓ [$FeSCN^{2+}$] (2mk)

(8 marks)

12. Shown below is a diagrammatic representation of a steel wharf which is protected from corrosion by application of an emf between the wharf and a lump of noble metal (probably copper).



On the diagram indicate

(a) the direction of electron flow.

(b) the direction of the flow of sodium ions in the sea water.

(c) the direction of the flow of chloride ions in the sea water.

(d) the anode.

(e) the cathode.

(f) Write the equation for the reaction at the anode.

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ or $2Cl^- \rightarrow Cl_2 + 2e^-$

(g) Write the equation for the reaction at the cathode.

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ OR $2H_2O + O_2 + 4e^- \rightarrow 4OH^-$

(7 marks)

PART THREE

1. acid $\rightarrow 2H^+$

a) $1.616 - 1.152 = 0.464$ g (1 mark)

$\% \text{ water} = \frac{0.464}{1.616} \times 100 = 28.7\%$ (1 mark)

b) (2NaOH) + $H_2X \rightarrow 2H_2O + 2Na^+$

c = 1.1100 M

v = 23.70 mL

n = cv

= 0.002607

(1 mark)

$^nH_2 = \frac{1}{2} \times {}^nNaOH$

$= \frac{1}{2} \text{ X } 0.002607 = 0.001303$ mol in 20 mL

$^nH_2X = 0.001303 \times \frac{500}{20}$

= 0.03259 mol in 500 mL

(1 mark)

$n = \frac{\textbf{mass}}{\textbf{molar mass}}$

$0.03259 = \frac{\textbf{4.1}}{\textbf{molar mass}}$

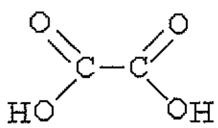
$\Rightarrow$ molar mass = 126 (1 mark)

c) molar mass anhydrous acid

mass $\frac{71.3}{100} \times 4.1 = 2.923$ g (1 mark)

$0.03259 = \frac{\textbf{2.923}}{\textbf{molar mass}}$ (1 mark)

$\Rightarrow$ molar mass = 90g

d) 

$$\begin{array}{r} 24 \\ 62 \\ 2 \\ \hline 90 \end{array}$$

(1 mark)

2. $Sb \rightarrow H_3SbO_4$

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

v = 44.25 mL

c = 0.2000 M

n = cv

= (0.2) (0.04425) = 0.00885 mol (1 mark)

$^{n}I_2 = \frac{1}{2} \times nS_2O_3^{2-} = \frac{1}{2} \times 0.00885$

$= 0.004425$ (1 mark)

$^{n}H_2SbO_4 = \frac{2}{1} \times I_2 = \frac{2}{1} \times 0.004425 = 0.00885$ (1 mark)

$^{n}Sb = {}^{n}H_3SbO_4 = 0.00885$ (1 mark)

$^{mass}Sb = 0.00885 \times 121.8 = 1.078$ g (1 mark)

$\%Sb = \frac{1.078}{206.9} \times 100 = 0.52\%$ (1 mark)

3. $CH_4 + H_2O \rightarrow CO + 3H_2$

$V = 5.00 \times 10^5$ L

P = 110 kPa

T = 105 = 378

PV = nRT

$(110)(5 \times 10^5) = n(8.315)(378)$

$\Rightarrow n = 17\,498$ mol

$vH_2 = \frac{3}{1} \times vCH_4$

$= 3 \times 5.00 \times 10^5$

1.5×10^6 L (1 mark)

if only 73% efficient

$vH_2 = \frac{73}{100} \times 1.5 \times 10^6$

$= 1.095 \times 10^6$ L (1 mark)

PV =nRT

$(110)(1.095 \times 10^6) = n(8.315)(378)$

$nH_2 = 38\,322.4$mol (1 mark)

$N_2 + 3H_2 \rightarrow 2NH_3$

$^{n}NH_3 = \frac{2}{3} \times {}^{n}H_2 = \frac{2}{3} \times 38\,322.4 = 25\,548.3$ mol (1 mark)

if 40% efficient $^{n}NH_3 = \frac{40}{100} \times 25\,548.3 = 10\,219.3$ mol (1 mark)

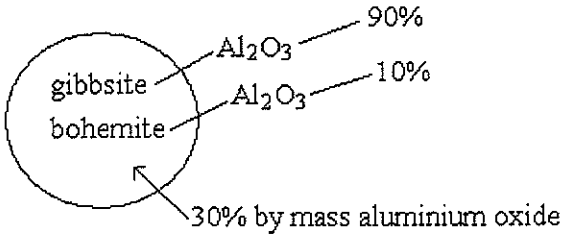
PV = nRT

(25 000) V = (10219.3)(8.315)(823)

$\Rightarrow V_{NH_3} = 2797$ L

$= 2.80 \times 10^3$ L (3 sig fig) (1 mark)

4.



a) 1000 000 g aluminium
$I = 5 \times 10^4$
$t = ?$

$^{n}Al = \frac{1000\ 000}{26.98} = 37\ 064$ mol (1 mark)

$Al^{3+} + 3e^- \rightarrow Al$

$n(e) = \frac{3}{1} \times {}^{n}Al = \frac{3}{1} \times 37\ 064 = 111\ 193$ mol (1 mark)

$n(e) = \frac{Q}{9.649 \times 10^4}$

$111\ 193 = \frac{Q}{9.649 \times 10^4}$

$Q = 1.0729 \times 10^{10}$ (1 mark)

$Q = It$

$1.0729 \times 10^{10} = 5 \times 10^4\, t$

$\Rightarrow t = 214\ 581$ sec (1 mark)

b) $Al_2O_3 \rightarrow 2Al$

$^{n}Al_2O_3 = ½ \times {}^{n}Al = ½ \times 37\ 064 = 18\ 532$ mol (1 mark)

$^{mass}Al_2O_3 = 18\ 532 \times (2 \times 26.98 + 3 \times 16) = 1889\ 523$ g (1 mark)

c) gibbsite is 90% 30% by mass aluminium oxide

27% of one is gibbsite (1 mark)

Mass one $= 1889\ 523 \times \frac{100}{27}$

$= 7.00 \times 10^6$ g (1 mark)

5. 250 mL water sample → 10.40 mg Ca^{2+} ; 4.230 mg Mg^{2+}

a) $c\ Ca^{2+} = \frac{0.0104}{40.08} = 0.000259$ mol (1 mark)

$n = cv = (0.000259)(250) = 0.06475$mol

$c\ Mg^{2+} = \frac{0.00423}{24.31} = 0.000174$ mol (1 mark)

$n = cv = (0.000174)(250) = 0.0435$mol

${}^{n}CO_3^{2-}$ needed = 0.06475 + 0.0435 = 0.10825 mol (1 mark)

${}^{n}Na_2CO_3.10H_2O = \frac{20}{(2 \times 22.99 + 12.01 + 3 \times 16) + 10 \times 18.016} = \frac{20}{286.15} = 0.0699$ mol(2 marks)

${}^{n}Na_2CO_3.10H_2O = {}^{n}CO_3^{2-}$ (1 mark)

not enough added (1 mark)

b) mol $NaCO_3.10H_2O$ needed = 0.10825 – 0.0699

= 0.03835 mol (1 mark)

${}^{mass}Na_2CO_3.10H_2O = 0.03825 \times 286.15$

= 10.97 g needed (1 mark)

6. $CHSNO + O_2 \rightarrow CO_2 + H_2O$

5 g 5.359 g 3.291 g

mass C = $\frac{12.01}{44.01} \times 5.359$

= 1.462 g (1 mark)

mass H = $\frac{2.016}{18.016} \times 3.291$

= 0.368 g (1 mark)

${}^{n}N_2 = \frac{V}{22.4} = \frac{0.9096}{22.4} = 0.040607$ mol (1 mark)

${}^{mass}N_2 = (0.040607 \times 28.02) = 1.1378$ g for 10 g sample

= 0.5689 g for 5 g sample (1 mark)

${}^{mass}BaSO_4 = 18.950$ g

${}^{n}BaSO_4 = \frac{18.950}{137.3 + 32.06 + 4 \times 16} = \frac{18.950}{233.36} = 0.0812$ mol (1 mark)

${}^{n}S = {}^{n}BaSO_4 = 0.0812$ mol (1 mark)

${}^{mass}S = 0.0812 \times 32.06 = 2.60$ g from 10 g sample

= 1.302 g from 5 g sample (1 mark)

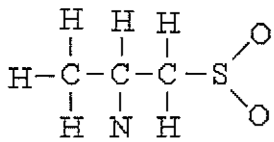
	C	H	S	N	O
Mass	1.462	0.368	1.302	0.5689	S – (1.462 + 0.368 + 1.302 + 0.5689) S – 3.7009 1.2991 g (1 mark)
Moles	$\frac{1.462}{12.01}$ 0.1217	$\frac{0.368}{1.008}$ 0.365	$\frac{1.302}{32.06}$ 0.0406	$\frac{0.5689}{14.01}$ 0.03997	$\frac{1.2991}{16}$ 0.08119 (1 mark)
Ratio	$\frac{0.1217}{0.03997}$ 3	$\frac{0.365}{0.03997}$ 9	$\frac{0.0406}{0.03997}$ 1	$\frac{0.03997}{0.03997}$ 1	$\frac{0.08119}{0.03997}$ 2 (1 mark)

EF is $C_3H_9SNO_2$

EF mass is (3 x 12.01 + 9 x 1.008 + 32.06 + 14.01 + 2 x 16)
= 123.172 (1 mark)

MF is same as EF

MF is $C_3H_9SNO_2$



(1 mark)

Part 4

This answer does not claim to be ideal. It is a response to the question, written in twenty minutes, of about the right length and satisfies the marking expectations set by the examiner.

Where applicable use equations, diagrams and illustrative examples of the chemistry you are describing.
Marks are awarded principally for the relevant chemical content of your answer, and also for coherence and clarity of expression. Your answer should be presented in about $1^{1/2}$ to 2 pages on the lined paper after the questions.

The methods used for the extraction of metals from their ores are largely determined by the reactivity of the metals and the degree of difficulty of reducing the metal ions.
Iron and nickel are both quite reactive metals with standard reduction potentials of -0.44 and -0.26 respectively. This suggests that the extraction methods for these metals may be similar to each other. In fact, they are not.
The most significant difference in the conditions of the reduction of iron and nickel from their ores is the operating temperature. The blast furnace operates with a temperature gradient from 250°C at the top to 1800°C at the bottom. This suggests that whilst the reduction potentials of nickel and iron ions may be similar, the activation energies of the two processes are vastly different.
The reducing agents used to produce iron and nickel are different too. Nickel oxide is reduced by heating in a stream of hydrogen (as a component of water gas), whilst iron oxide is reduced by heating with carbon. In the blast furnace, the carbon forms carbon monoxide by reaction with air via the formation of carbon dioxide.

$$C + O_2 \rightarrow CO_2$$
$$CO_2 + C \rightarrow 2CO$$

This carbon monoxide is the principal reducing agent.

$$Fe_2O_3 + 3CO \Leftrightarrow 2Fe + 3CO_2$$

Although this reaction does not actually happen as a single step.
At the cooler part of the furnace Fe_2O_3 forms Fe_3O_4 and in the warmer parts Fe_3O_4 forms FeO. In the hottest region of the furnace the FeO is reduced to Fe.

This is different from the single step reduction of NiO to Ni at 200°C.

The iron oxide to iron reactions are reversible and the forward reaction:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

is favoured by high concentration of CO and low concentration of CO_2. The flow of gases through the blast furnace removes CO_2 and thermal decomposition of limestone in the furnace helps to keep the Co concentration high. There is no indication that the hydrogen reduction of NiO is reversible.

Another significant difference between these processes involves the role of the waste material. In the Mond process the nickel is complexed with CO to allow the removal of impurities whilst in the blast furnace the impurities themselves are reacted to allow the removal of the iron.

The main impurities in nickel ore are iron and cobalt whilst in iron ore they are siliceous materials which react with decomposed limestone (essentially CaO) to form slag.

$$CaO + SiO_2 \rightarrow CaSiO_3$$

The Mond process is limited to the extraction of nickel from its ores as it is the only metal which forms a carbonyl compound under these mild conditions. The blast furnace is more versatile as a number of other metals with reactivities similar to iron, such as zinc, chromium and cadmium may be removed from their oxide ores in the same way.

633 words (about 3 handwritten pages)