S6 CHEMISTRY

Exam 10

PAPER 2

DURATION: 2 HOUR 30 MINUTES

For Marking guide contact and consultations: Dr. Bbosa Science 0778 633 682.

INSTRUCTIONS
-Answer any five questions
- Time 2hr 30minutes

1. (a) A compound X, vapour density 58, contains carbon 62.07%, hydrogen 10.34% and the rest being oxygen. X does not burn with a sooty flame.

    i. Calculate the empirical formula of X (C=12, O=16, H=1) (3 marks)

    Solution

    Percentage of = 100-(62.07 + 10.34) =27.59

Elements	C	H	O
Percentage	62.07	10.34	27.59
RAM	12	1	16
Moles	5.173	10.34	1.724
Mole ratio	3	6	1

Empirical formula C_3H_6O

ii. Determine the molecular formula (2 marks)

Molecular mass = 58 x 2 = 116

$(C_3H_6O)n = 116$

n = 2

molecular formula = $C_6H_{12}O_2$

b. Hydrolysis of X yielded compounds, Y, $C_4H_{10}O$ and Z, $C_2H_4O_2$. Both Y and Z react with metallic sodium. Z reacted with sodium carbonate but Y did not.

(i) Identify Z. (1 mark)

Ethanoic acid, CH_3COOH

(ii) Write names and the structural formulae of all the possible isomers of Y. (4 marks)

$CH_3CH_2CH_2CH_2OH$ butan-1-ol

$CH_3CH_2CHCH_3$ butan-2-ol

|

OH

$(CH_3)_3COH$ 2-methylpropan-2-ol

CH_3CHCH_2OH 2-methylpropan-1-ol

|

CH_3

(iii) Name a reagent that can be used to distinguish between the isomers in (b) (ii) and state what would be observed if the reagent you have named is reacted separately with each of the isomers. (4 marks)

Reagent: anhydrous zinc chloride/conc. HCl

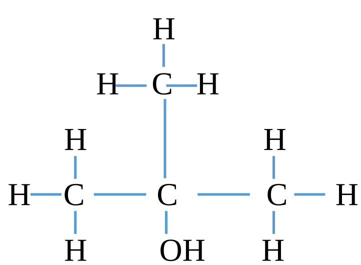
Butan-1-ol and 2-methylpropan-1-ol	- no observable change
Butan-2-ol	- two layers in 5 -10minutes
2-methylpropan-2-ol	- immediate cloudiness

c. When Y was warmed with acidified potassium dichromate solution, there was no observable change.

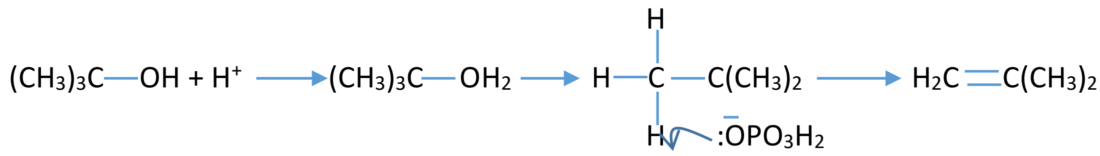
i. Identify Y.

2-methylpropan-2-ol

ii. write the structural formulae of Y



d. (i) write equation and outline a mechanism for the reaction between Y and concentrated phosphoric acid (3½ marks)



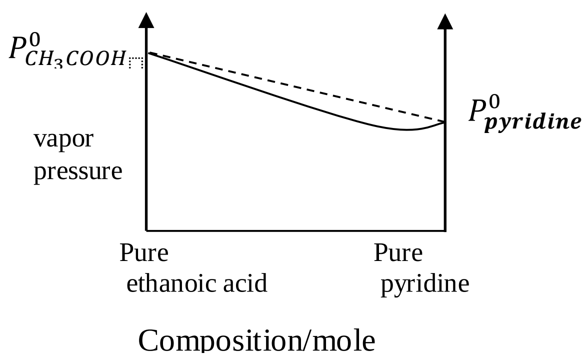
(ii) Write the IUPAC name of the product in d(i). (½ mark)

2-methylpropene

2. (a) state **Raoult's Law.** (3 marks)

(b) A mixture of ethanoic acid (B.P 118^{0}C) and pyridine (b.p. 123^{0}C) show negative deviation from Raoult's law.

(i) Draw the vapour pressure/composition curve for the mixture of ethanoic acid and pyridine and indicate the line of Ideal behavior. (4 marks)



—— mixture
----- ideal

Note that
- ethanoic acid with lower boiling point thus has higher vapor pressure
- The minimum boiling point occurs to the composition containing more pyridine (the less volatile) than ethanoic acid.

(ii) Explain the shape of the curve in relation to Raoult's Law. (6 marks)

- the curve for the mixture lies below the line for ideal behavior
- this is because the attraction between the molecules of ethanoic acid and those of pyridine are greater (stronger) than those between ethanoic acid-ethanoic acid or pyridine – pyridine
- pyridine molecules are held by weak van der Waal forces
- ethanoic acid molecules are associated with hydrogen bonds
- when ethanoic acid and pyridine are mixed , intermolecular hydrogen bonds are formed between ethanoic acid and pyridine molecules which are stronger than the bonds in pure or equal to those in pure ethanoic acid

- consequently, the escaping tendency of individual molecules of each component is reduced, leading to reduced vapor of solution of the mixture

(c) (i) Explain what is meant by '**steam distillation**' (3 marks)

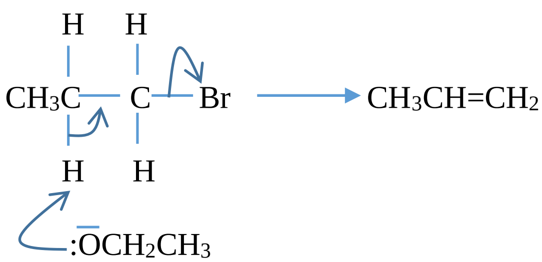
It is a technique of separating a volatile liquid/substance that is immiscible with water from nonvolatile component at temperature below its boiling point by bubbling steam through the mixture

(ii) When a compound Y, was steam distilled at standard atmospheric temperature and pressure, the temperature of distillation was 96^0C. The vapour pressure of water t this temperature was 730mm Hg and the distillate contained 74% of water.

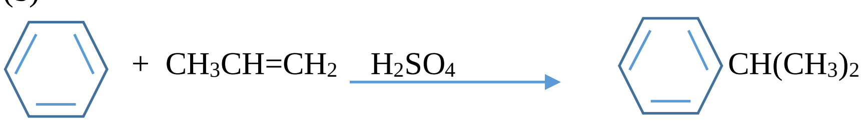
Calculate the relative molar mass of Y (4 marks)

3. Complete the following equations and in each case outline a mechanism of the reaction

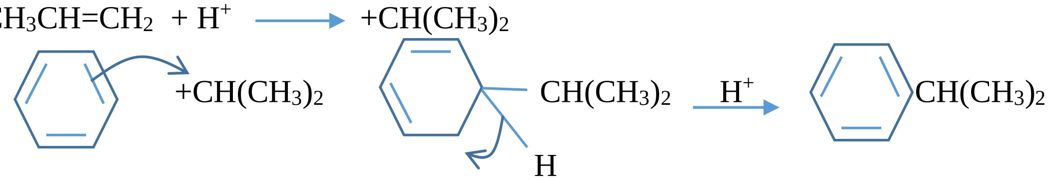
(a) $CH_3CH_2CH_2Br + CH_3CH_2ONa \xrightarrow{CH_3CH_2OH} CH_3CH{=}CH_2$



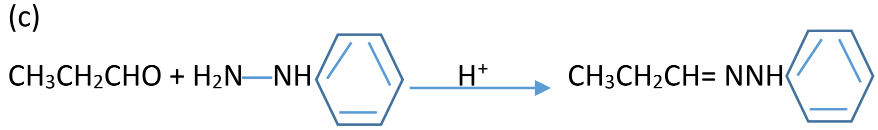
(b)

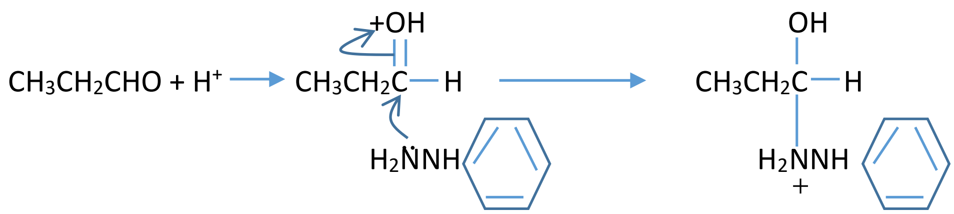


$CH_3CH{=}CH_2 + H^+ \longrightarrow {}^+CH(CH_3)_2$

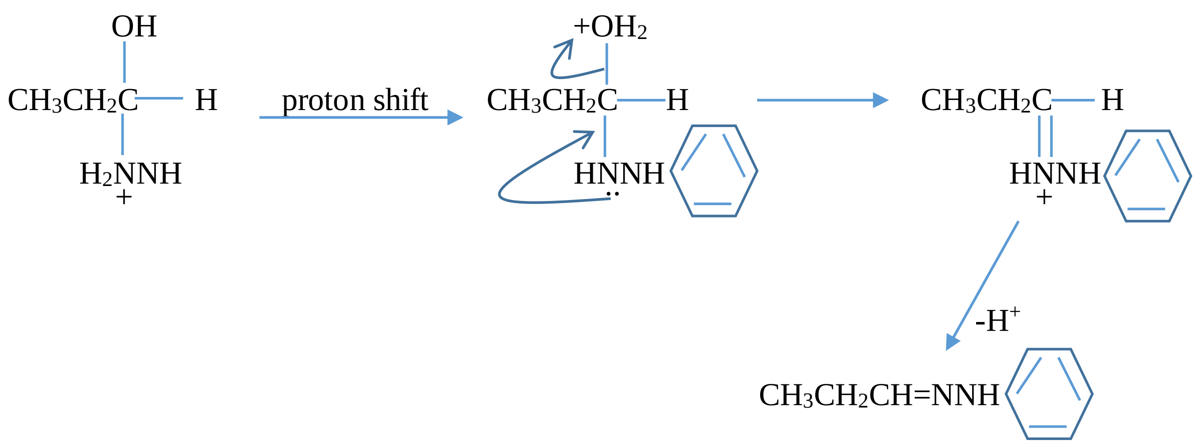


(c)

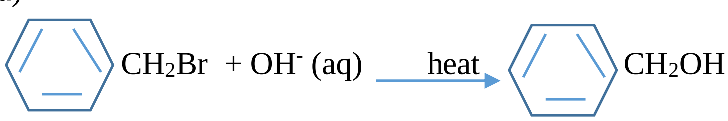




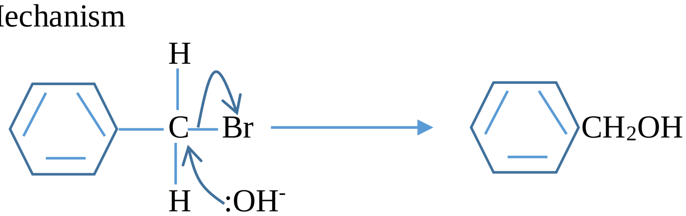
Then



(d)



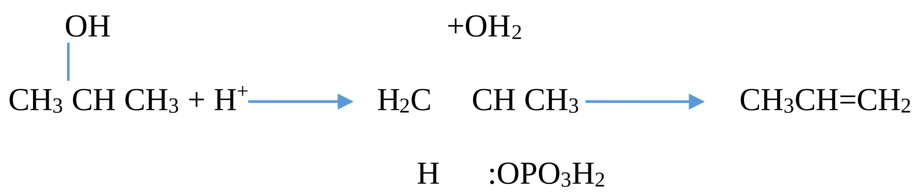
Mechanism



(e)

$CH_3CH(OH)CH_3 + \text{Conc. } H_3PO_4 \xrightarrow{\text{heat}} CH_3CH{=}CH_2$

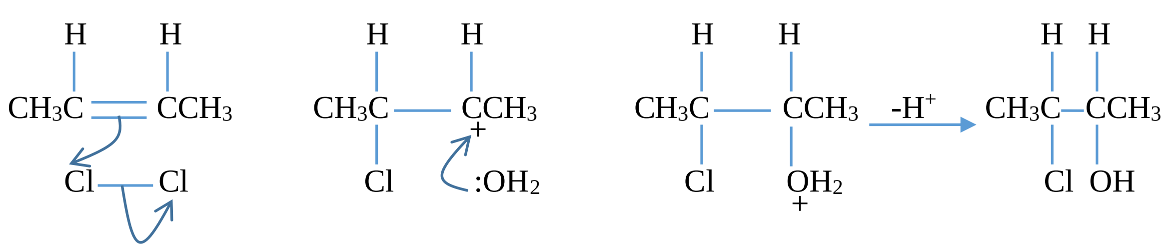
Mechanism



(f)

$CH_3CH{=}CHCH_3 \xrightarrow{Cl_2/H_2O} CH_3CH(Cl)-CH(OH)CH_3$

Mechanism



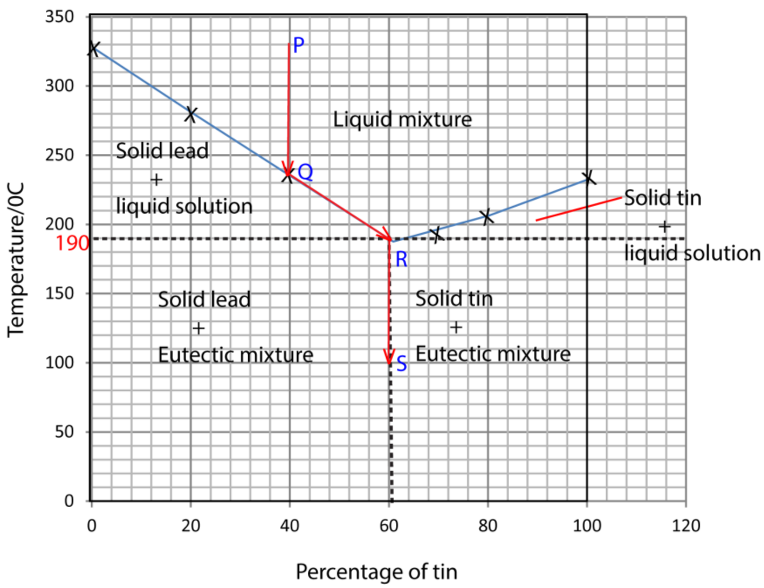
4. (a) Define the term *eutectic mixture*. (3 marks)

These are mixtures which at constant pressure freeze at constant temperature to give a solid of the same composition.

(b) The table below shows the melting points f various mixtures of lead and tin.

% tin	0	20	40	70	80	100
Melting point/^{0}C	327	280	234	193	206	232

(i) Draw a fully labeled diagram for the tin-lead system. (5 marks)



(ii) Determine the eutectic temperature and the composition of the eutectic mixture (3 marks)

Eutectic composition 60% tin,
Eutectic temperature 190^{0}C

(c) Describe the changes that would take place when a liquid mixture of the above system containing 40% tin is cooled from 400^{0}C to 100^{0}C.

The temperature of the liquid falls from 400^{0}C to about 235^{0}C along PQ (shown on the graph); at Q solid lead crystallizes out and the freezing point of the remaining solution drops along QR as more lead solidifies. At R (190^{0}C) the composition of tin will be 60%, temperature remains constant until all the liquid has turned into a solid before the temperature drops further to 100^{0}C along RS.

(d) (i) State one application of the lead-tin eutectic mixture (1 mark)
welding
(ii) Name one other pair of metals which can give a similar phase diagram as in (b) (i). (1 mark)

(ii) Zn and Cd; Cu and Zn; Ca and Mg; Pb +Ag

(iii) State one similarity between a eutectic mixture and pure metal (1 mark)
Have same cooling curve
Have the same composition in solid as in liquid

5. (a) Describe the spectrum of a hydrogen atom.
Use diagrams to illustrate your answer (7 marks)

Hydrogen spectrum is of two types:

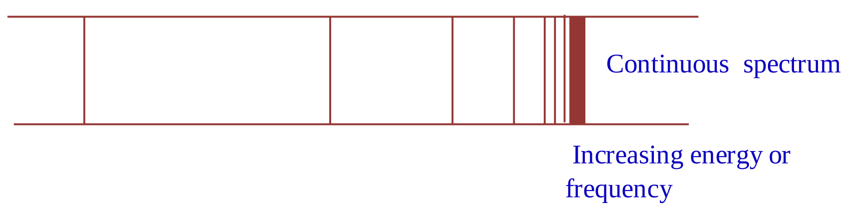
(i) Absorption spectra

It is observed as dark lines on a black background when white light is passed through gaseous hydrogen. This is caused by hydrogen atoms absorbing energy corresponding to certain wavelengths from the light.

(ii) Emission

It is observed as a pink glow when an electric discharge is passed through hydrogen at low pressure. Analyzed through a spectrometer, the emission is seen to be a number of separate sets of lines or series of lines.

In each series, the intervals between the frequencies of the lines become smaller and smaller towards the high frequency end of the spectrum until the lines run together or converge to form a continuum of light or continuum.



(b) Explain how the spectrum of a hydrogen atom
(i) is formed (4 marks)

When a hydrogen atom in ground state is struck by light, its electron absorbs energy of certain wavelength/frequency. The absorbed frequency appears as a dark line in absorption spectrum

After absorbing energy, an electron jumps to a higher energy level. Energy absorbed is equal to the energy difference between two the energy levels. When the excited electron drops to the orbits of a lower energy level, it emits this energy in form of radiation giving, an emission spectrum corresponding to the frequency of radiation emitted.

(ii) Provides evidence for the existence of energy levels in an atom (7 marks)

The fact that the hydrogen spectrum is a line spectrum, suggests that only specific amounts of energy absorptions and emissions are possible suggesting existence of energy levels within an atom and that an electron occupies certain energy levels around the nucleus. The various lines in each series are suggestive that the main energy levels are subdivided into lower energy levels.

(c) The frequency of hydrogen at the point of ionization id 32.8×10^{14}HZ
Calculate the ionization energy of hydrogen. (Planks constant = 6.6×10^{-34}JS (2 marks)

Energy = hf (h is Plank's constant, f = frequency)

$= 6.6 \times 10^{-34} \times 32.8 \times 10^{14}$

$= 2.165 \times 10^{-18}$J or 2.165×10^{-21} kJ

But 1 mole contains 6.023particles, according to Avogadro

$E = 2.165 \times 10^{-21} \times 6.0^{23} \times 10^{23} = 1304$ kJ

6. (a) The first ionization energies of an element B are shown below

Ionization Energy/kJMol^{-1}							
1st	2nd	3rd	4th	5th	6th	7th	8th
786	1580	3230	4360	16000	20000	23600	29100

(I) explain what is meant by the term *Fist ionization energy*?
Is the energy required to remove one mole of electron from 1 mole gaseous atoms to form gaseous ions with single positive charge
(ii) State the factors that determine the value of first ionization energy
(i) Atomic radius
(ii) Nuclear charge
(iii) The screening effect of the inner electrons

(ii) To which group of the periodic table does element B belong
Give reason for your answer

Group 4; the big difference of ionization energy between the 4th and 5th indicates that the 5th electron resides in stable full electron shell and that the outermost shell contains 4 electrons.

(b) Explain the term *electronegativity*.
State the factors that determine the value of electronegativity of an element.

(i) Atomic radius
(ii) Nuclear charge
(iii) The screening effect of the inner electrons

(c) Explain how the following factors affect the value of electronegativity of an element

(i) Atomic radius

The bigger the atomic radius the farther from the nucleus the outer electrons and thus experience less nuclear charge lowering the values of electronegativity

(ii) Nuclear charge

When the nuclear charge is high electronegativity is high because the outer electrons are strongly attracted to the nucleus

(iii) The screening effect of the inner electrons

When screening effect is high; electronegativity is low because the outer electrons are less attracted to the nucleus.

(d) Explain the difference between electronegativity and electron affinity.

Electronegativity is the relative tendency of an atom to attract bonding electrons in a covalent bond while electron affinity is energy change when an electron is added to gaseous atom or an anion

7. (a) (i) Define " Standard Electrode potential" (2marks)

It is the electrode potential value of an electrode measure with respect to a standard hydrogen electrode of 0 volts. When an electrode is immersed or dipped into a solution of 1M concentration of its ions at a standard temperature of 298K and pressure of1atmospheres.

(ii) Why is it not possible to measure standard electrode potential absolutely? (2marks)

It requires a second electrode to be introduced since it's a difference in potential, however, the second electrode also produces its own electrode potential making such a difference relative rather than absolute

(iii) Discuss the factors which affect the value of standard electrode potential (5½marks)

Electrode potential = sublimation energy + ionization + Hydration energy

- Sublimation energy: the higher the sublimation energy the more positive the electrode potential. This is because it becomes difficult to convert a solid into gaseous atoms (i.e. sublimation is endothermic)

- Ionization energy: if ionization energy is high; electrode potential becomes more positive because ionization energy is endothermic.
- Hydration energy: a high hydration energy give a more negative electrode potential since hydration is exothermic reaction.

(b) Describe a standard hydrogen half cell (2marks)

It consists of a molar solution of H^+ ions having platinized titanium or platinum coated with finely divided titanium, around which pure hydrogen gas at 1 atmosphere and 298K (25^0) is bubbled.

(c) How would you measure standard electrode potential of a metal in solution of its ions? (3marks)

The metal is placed in one molar solution of its ions and connected to the standard hydrogen electrode by a salt bridge

A voltmeter connected in parallel will show the emf of the cell

The standard electrode potential of the metal is equal to the emf shown by the voltmeter, measured relative to the electrode potential of hydrogen electrode considered to be zero

(d) $Ca^{2+}(aq) + 2e^- \longrightarrow Ca(s)$ E0 = -2.87V

$Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$ E0 = -2.37V

A cell was set up as below

$Mg(s)/Mg^{2+}(aq) \| Ca^{2+}(aq)/Ca(s)$

(i) Calculate the e.m.f of the cell (2marks)

$$E^0_{cell} = E^0_{Reduction} - E^0_{oxidation}$$
$$= -2.87-(-2.37)$$
$$= -0.5V$$

(ii) What conclusion can you draw from your e.m.f value in (d)(i) above (3marks)

The cell as set up is non spontaneous because emf is negative. It is spontaneous in the opposite direction.

8.(a) Write the name and formula a of one ore from which aluminium can be extracted and describe how aluminium is extracted from the ore (08marks)

Extraction of Aluminium
Ore: Bauxite ($Al_2O_{3.x}H_2O$)

Major impurities are

- ✓ Silica or SiO_2
- ✓ Iron salts

Principles in extraction

Extraction of aluminium involves removal of impurities (purification) and then reduction to metal by electrolysis.

Steps in extraction of Aluminium

(i) The ore is heated
- to remove water and,
- To convert iron salts to iron III oxide

(ii) 2. The powdered ore is heated with concentrated sodium hydroxide to dissolve aluminium oxide and silica such that the insoluble iron oxide is filtered off.

Aluminium oxide form aluminate

$Al_2O_3 (s) + 2NaOH (aq) + 7H_2O (l) \rightarrow 2Na[Al(OH)_4(H_2O)_2] (aq)$

Or the ionic form

$Al_2O_3 (s) + OH^- (aq) \rightarrow 2AlO_2^- (aq) + H_2O(l)$

Silica also dissolves forming sodium silicate.

$SiO_2 (s) + 2NaOH (aq) \rightarrow Na_2SiO_3 (aq) + H_2O (l)$

(iii) 3. To the filtrate a little aluminium hydroxide is added to precipitate Aluminium hydroxide,(seeding).

$NaAlO_2 (aq) + 2H_2O(l) \rightarrow NaOH(aq) + Al(OH)_3 (s)$

Alternatively carbon dioxide bubbled through the filtrate to precipitate aluminium hydroxide as follows

$2NaAl(OH)_4 (aq) + CO_2 (g) \rightarrow 2Al(OH)_3 (s) + Na_2CO_3 (aq) + H_2O(l)$

(iv) 4. The precipitated aluminium hydroxide is filtered off, washed and ignited to give pure aluminium oxide (alumina).

$2Al(OH)_3 (s) \rightarrow \underset{\text{Alumina}}{Al_2O_3 (s)} + 3H_2O (g)$

(v) 5. Aluminum is obtained form aluminium oxide by electrolysis.

Cryolite, Na_3AlF_6, is added to
- lower the melting point of alumina from2050^{0}C to 900^{0}C
- and improve conductivity of aluminium oxide

At the cathode (carbon) aluminium is liberated

$Al^{3+} (aq) + 3e^- \rightarrow Al (s)$

At the anode (carbon) oxygen is liberated

$2O^{2-} - 4e \rightarrow O_2 (g)$

The anode is eaten up by oxygen

$C + O_2 (g) \rightarrow CO_2 (g)$

(b) Write equations and state conditions under which aluminium reacts with

(i) Air

Hot aluminium reacts with air to form aluminium oxide

$4Al(s) + 3O2(g) \rightarrow 2Al_2O_3$

(ii) Sodium hydroxide

Aluminium reacts with hot concentrated sodium hydroxide solution to form sodium aluminate

$2Al(s) + 2OH^-(aq) + 6H_2O\ (l) \rightarrow 2Al(OH)_4^-(aq) + 3H_2(g)$

(iv) hydrochloric acid

Aluminium reacts with dilute hydrochloric acid to liberate hydrogen

$2Al(s) + 6HCl\ (aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$

(c) State what is observed and write equation for the reaction which take place when aqueous ammonia is added drop-wise to a solution containing aluminium ions (2½ marks)

White precipitate insoluble in excess

$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$

(d) Write equation for the reaction that take place when aluminium chloride is dissolved in water (1½ marks)

$AlCl_3(aq) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3HCl\ (aq)$

END