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CHEMISTRY
PHYSICAL CHEMISTRY

Level & Board	CIE (A-LEVEL)
TOPIC:	ATOMS, MOLECULES & STOICHIOMETRY
PAPER TYPE:	QUESTION PAPER - 1
TOTAL QUESTIONS	13
TOTAL MARKS	100

Atom, Molecules & Stoichiometry - 1

Question 1

(a) Sodium chlorate (V) is an important industrial chemical, many thousands of tonnes being used each year to manufacture chlorine dioxide bleach for the paper industry. It is made commercially by the electrolysis of brine in a cell with no diaphragm, so that the solutions at the anode and the cathode mix.

The overall process can be represented by the following equations:

$$Cl^- + 6OH^- - 6e^- \longrightarrow ClO_3^- + 3H_2O$$

$$6H_2O + 6e^- \longrightarrow 3H_2 + 6OH^-$$

(i) Calculate the current needed to produce 1 tonne (1×10^6g) of $NaClO_3$ per day (24 hours).

(ii) Calculate the volume of hydrogen (measured at room temperature and pressure) that is also produced. **[6]**

Question 2

Potassium dichromate (VI) is a useful oxidizing agent, acidified solutions of which can be used to titrate reducing agents.

(i) Assuming a suitable indicator is available (e.g ferroin, which is red in reduced solutions and blue in oxidized solutions), describe in outline the **practical** details you would need to follow in order to use a standard solution of potassium of dichromate (VI) to measure the mass of iron (II) sulphate, $FeSO_4$, in an iron – supplement tablet. You should include an equation for the titration reaction, and name any other chemicals you would use. Do not include any details of the calculation.

(ii) When a 1 cm length of iron wire is dissolved in acid and titrated with 0.025mol dm^{-3} $K_2Cr_2O_2$,

10.50 cm^3 of oxidant solution is required to reach the end point. Calculate the mass of iron in the wire. **[7]**

I am Sorry !!!!

Question 3

Most submarines travel under water using electrical power from batteries. The German engineer Helmut Water designed a diesel engine that could be used to propel a submarine beneath the surface of the sea. Instead of taking air from above the surface of the sea, Walter's engine used hydrogen

peroxide. H_2O_2, to provide oxygen for a conventional diesel engine.

Hydrogen peroxide may be catalytically decomposed to give water and oxygen.

(a) **(i)** What is meant by the term catalyst?

(ii) Construct a balanced equation for the decomposition of H_2O_2, **[3]**

Diesel fuel may be considered to consist of the hydrocarbon $C_{15}H_{32}$ which reacts completely with oxygen according to the following equation.

$$C_{15}H_{32} + 23O_2 \longrightarrow CO_2 + 16H_2O$$

(b) **(i)** To which homologous series does $C_{15}H_{32}$ belong?

(ii) Use the equation above and your answer to (a)(ii) to calculate the amount, in moles, of H_2O_2 that will provide sufficient oxygen for the complete oxidation of one mole of $C_{15}H_{32}$ **(3)**

A submarine equipped with a water engine used 212 tonnes of diesel fuel during an underwater voyage. The submarine also carried concentrated aqueous H_2O_2.. **[1 tonne = 10^6g]**

(c) **(i)** Calculate the amount, in moles, of diesel fuel used during the underwater voyage.

(ii) Use your answers to (b)(ii) and (c)(i) to calculate the mass, in tonnes, of hydrogen peroxide used during the underwater voyage. **[4]**

(d) The exhaust products of the Walter engine were passed into the sea.

What would happen to them? **[1]**

Question 4

(a) Describe and explain qualitatively the trend in the solubilities of the sulfates of the Group II elements. **[3]**

(b) The major ore of barium is barytes, $BaSO_4$. This is very unreactive, and so other barium compounds are usually made from the sulfide, BaS. This is obtained by heating the crushed ore with carbon, and extracting the BaS with water.

$$BaSO_4(s) + 4C(s) \longrightarrow BaS\ (s) + 4CO(g)$$

When 250 g of ore was heated in the absence of air with an excess of carbon, it was found that the

CO produced look up a volume of 140 dm^3 at 450 K and 1 atm.

(i) Calculate the number of moles of CO produced.
(ii) Calculate the number of moles of $BaSO_4$ in the 250g sample of the ore.
(iii) Calculate the percentage by mass of $BaSO_4$ in the ore. **[4]**

(c) (i) Use the following data and data from the *Data Booklet* to construct a Born – Haber cycle and calculate the lattice energy of BaS.

Standard enthalpy change of formation of BaS(s)	-460 kJ mol^{-1}
Standard enthalpy change of atomization of Ba(s)	+180 kJ mol^{-1}
Standard enthalpy change of atomization of S(s)	+279 kJ mol^{-1}
Electro affinity of the sulfur atom.	-200 kJ mol^{-1}
Electron affinity of the S^- ion	+640 kJ mol^{-1}

(ii) Explain whether the magnitude of the lattice energy of BaS is likely to be greater or less than that of BaO. [4]

Question 5

In 1814, Sir Humphrey Davy and Michael Faraday collected samples of a flammable gas, A,from the ground near Florence in Italy.

They analysed **A** which they found to be a hydrocarbon. Further experiments were then carried out to determine the molecular formula of **A**.

(a) What is meant by the term *molecular formula*? [2]

Davy and Faraday deduced the formula of A by exploding it with an excess of oxygen and analyzing the products of combustion.

(b) Complete and balance the following equation for the complete combustion of a hydrocarbon with the formula C_xH_y.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \longrightarrow \text{.....} + \text{.....}$$

[2]

(c) When 10 cm^3 of **A** was mixed at room temperature with 50 cm^3 of oxygen (an excess) and exploded, 40 cm^3 of gas remained after cooling the apparatus to room temperature and pressure.

When this 40 cm^3 of gas was shaken with an excess of aqueous potassium hydroxide, KOH, 30 cm^3

Of gas still remained.

(i) What is the identity of the 30 cm^3 of gas that remained at the end of the experiment?

(ii) The combustion of **A** produced a gas that reacted with the KOH(aq).
What is the identity of this gas?

(iii) What volume of the gas you have identified in (ii) was produced by the combustion of **A**

(iv) What volume of oxygen was used up in the combustion of **A?**

(d) Use your equation in (b) and your results from**(c) (iii)** and **(c)(iv)** to calculate the molecular formula of

Show all of your working. [3]

Question 6

Ethanoic acid can be reacted with alcohols to form easters, an equilibrium mixture being formed.

$$CH_2CO_2H + ROH \rightleftharpoons CH_3CO_2 + H_2O$$

The reaction is usually carried out in the presence of an acid catalyst.

(a) Write an expression for the equilibrium constant, K_c for this reaction, clearly stating the units. **[2]**

In an experiment to determine K_c a student placed together in a conical flask 0.10mol of ehanoic acid, 0.10 mol of an alcohol ROH, and 0,005 mol of hydrogen chloride catalyst.

The flash was sealed and kept at 25^0 C for seven days.

After this time, the student titrated all of the contents of the flask with 2.00 mol dm^{-3}

NaOH using phenolphthalein indicator. At the end – point, 22.5 cm^3 of NaOH had been used.

(b) (i) Calculate the amount, in moles, of NaOH used in the titration.

(ii) What amount, in moles, of this NaOH reacted with the hydrogen chloride?

(iii) Write a balanced equation for the reaction between ethanoic acid and NaOH.

(c) (i) Use your results from (b) to calculate the amount, in moles, of ethanoic acid present at equilibrium. Hence complete the table below.

	CH_3CO_2H	ROH	CH_3CO_2R	
Initial amount/mol	0.10	0.10	0	0
Equilibrium amount/mol				

(ii) Use your results to calculate a value for K_c for this reaction. [3]

(d) Esters are hyrolysed by sodium hydroxide. During the titration, sodium hydroxide reacts with ethanoic acid and the hydrogen chloride, but not with the ester.
Suggest a reason for this. [1]

(e) What would be the effect, if any, on the amount of ester present if all of the water were removed from the flask and the flask kept for a further week at 25^0C?
Explain your answer. [2]

Question 7

Compound **A** is an organic compound which contains carbon, hydrogen and oxygen.

When 0.240 g of the vapour of **A** is slowly passed over a large quantity of heated copper (II) oxide, CuO, the organic compound **A** is completely oxidized to carbon dioxide and water. Copper is the only other product of the reaction.

The products are collected and it is found that 0.352g of CO_2 and 0.144g of H_2O are formed.

(a) In this section, give your answers to three decimal places.

(i) Calculate the mass of carbon present in 0.35 g of CO_2.
Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.240 g of **A**

(ii) Calculate the mass of hydrogen present in 0.144 g of H_2O.
Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.240 g of **A.**

(iii) Use your answers to calculate the mass of oxygen present in 0.240 g of **A.**
Use this value to calculate the amount, in moles, of oxygen atoms present in 0.240 g of **A.** **[6]**

(b) Use your answers to (a) to calculate the empirical formula of **A.** **[1]**

(c) When a 0.148 g sample of A was vapourised at 60 0C, the vapour occupied a volume of 67.7 cm3 at a pressure of 101 kPa.

(i) Use the general gas equation pV = nRT to calculate M_r of **A**

(ii) Hence calculate the molecular formula of **A**. [3]

(d) Compound A is a liquid which does not react with 2, 4 – dinitrophenylhydrazine reagent or with equeous bromine.

Suggest two structural formulae for **A**.

(e) Compound A contains only carbon, hydrogen and oxygen.

Explain how the information on the opposite page about the reaction of A

With CuO confirms this statement.

Question 8

Zinc is an essential trace element which is necessary for the healthy growth of animals and plants. Zinc deficiency in humans can be easily treated by using zinc salts as dietary supplements.

(a) One salt which is used as a dietary supplement is a hydrated zinc sulfate, $ZnSO_4$, xH_2O , which is a colourless crystalline solid.

Crystals of zinc sulfate may e prepared in a school or college laboratory by reacting dilute sulfuric acid with a suitable compound of zinc.

Give the formulae of two simple compound of zinc that could each react with dilute sulfuric acid to produce zinc sulfate.

(b) A simple experiment to determine the value of x in the formula $ZnSO_4$, xH_2O is to heat is carefully to drive off the water.

$$ZnSO_4\,xH_2O(s) \longrightarrow ZnSO_4(s) + xH_2O(g)$$

A student placed a sample of the hydrated zinc sulfate in a weighted boiling tube and reweighed it. He then heated the tube for a short time, cooled it and reweighed it when cool. This process was repeated four times. The final results are shown below.

Mass of empty tube/g	Mass of tube + hydrated salt/g	Mass of tube + salt after fourth heating /g
74.25	77.97	76.34

(i) Why was the boiling tube heated, cooled and reweighed four times?

(ii) Calculate the amount, in moles, of the anhydrous salt produced.

(iii) Calculate the amount, in moles, of water driven off by heating.

(iv) Use your results to (ii) and (iii) to calculate the value of x in $ZnSO_4$. xH_2O.

[7]

(c) For many people, an intake of approximately 1.5 mg per day of zinc will be sufficient by prevent deficiencies.

Zinc ethanoate crystals, $(CH_3CO_2)_2$ Zn_2H_2O, may be used in this way.

(i) What mass of pure crystalline zinc ethanoate (M_r = 219.4) will need to be taken to obtain a close of 15 mg of zinc?

(ii) If this dose is taken in solution as 5 cm^3 of aqueous zinc ethanoate, what would be the concentration of the solution used?
Give your answer in mol dm^{-3} [3]

Question 9

(c) Iron (III) chloride, $FeCl_3$,is used to dissolve unwanted copper from printed circuit boards (PCBs) by the following reaction.

$$2FeCl_3(aq) + Cu(s) \longrightarrow 2FeCl_2(aq) + CuCl_2(aq)$$

A solution in which [Fe^{3+}(aq)] was originally equal to 1.50 mol dm^{-3} was re – used several times to dissolve copper from the PCBs, and was then titrated as follows.

A 2.50cm^3 sample of the partially – used – up solution was acidified and titrated with 0.0200 mol dm^{-3} $KMnO_4$.

This oxidized any $FeCl_2$ in the solution back to $FeCl_3$.

It was found that 15.0 cm^3 of $KMnO_4$(aq) was required to reach the end point.

(i) Construct an ionic equation for the reaction between Fe^{2+} and MnO_4^- in acid solution.

(ii) State here the Fe^{2+} : MnO_4^- ratio from your equation in (i).

(iii) Calculate the number of moles of MnO_4^- used in the titration.

(iv) Calculate the number of moles of Fe^{2+} in 2.50 cm^3 of the partially used – up solution.

(v) Calculate the [Fe^{2+}] in the partially – used – up solution.

(vi) Calculate the mass of copper that could still be dissolved by 100 cm3 of the partially – used – up solution. [6]

Question 10

Chile saltpeter is a mineral found in Chile and Peru and which mainly consists of sodium nitrate, $NaNO_3$. The mineral is purified to concentrate the $NaNO_3$ which is used as a fertilizer and in some fireworks.

In order to find the purity of a sample of sodium nitrate, the compound is heated in NaOH(aq) with Devarda's alloy which contains aluminium. This reduces the sodium nitrate to ammonia which is boiled off and then dissolved in acid.

$3NaNO_3(aq) + 8al(s) + 5NaOH(aq) + 18H_2O\ (l) \longrightarrow 3NH_3(g) + 8NaAl(OH)_4(aq)$

The ammonia gas produced is dissolved in an excess of H_2SO_4 of known concentration.

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

The amount of unreacted H_2SO_4 is then determined by back – titration with NaOH of known concentration.

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$$

(a) A 1.64 g sample of impure $NaNO_3$ was reacted with an excess of Devarda's alloy.
The NH_3 produced was dissolved in 25.0cm^3 of 1.00 mol dm^{-3} H_2SO_4 When all of the NH_3 had dissolved, the resulting solution was titrated with NaOH(aq).
For neutralization, 16.2 cm^3 of 2.00 mol dm-3 NaOH were required.

(i) Calculate the amount, in moles, of H_2SO_4 present in the 25.0 cm^3 of 1.00 mol dm^{-3} H_2SO_4.

(ii) Calculate the amount, in moles, of NaOH present in 16.2 cm^3 of 2.00 mol dm^{-3} H_2SO_4

(iii) Use your answer to (ii) to calculate the amount, in moles, of H_2SO_4 that reacted with 16.2 cm^3 of 2.00 mol dm^{-3} NaOH.

(iv) Use your answers to (i) and (iii) to calculate the amount, in moles, of H_2SO_4 that reacted with the NH_3.

(v) Use your answer to (iv) to calculate the amount, in moles, of NH_3 that reacted with the H_2SO_4.

(vi) Use your answers to (v) to calculate the amount, in moles, of $NaNO_3$ that reacted with the Devarda's alloy.

(vii) Hence calculate the mass of $NaNO_3$ that reacted.

(viii) Use your answer to (vii) to calculate the percentage by mass of $NaNO_3$ present in the impure sample.

Write your answer to a suitable number of significant figures. [g]

(b) The above reaction is an example of a redox reaction.

What are the oxidation numbers of nitrogen in $NaNO_3$ and in NH_3?

$NaNO_3$ …….. NH_3 ……. [1]

Question 11

(a) Explain what is meant by the term nucleon number. [1]

(b) Bromine exists naturally as a mixture of two stable isotopes, ^{79}Br and ^{81}Br. With relative isotopic masses of 78.92 respectively.

(i) Define the term relative isotopic mass. [2]

(ii) Using the relative atomic mass of bromine, 79.90, calculate the relative isotopic abundances of ^{79}Br and ^{81}Br. [3]

(c) Bromine reacts with the element A to form a compound with empirical formula ABr3. The percentage composition by mass of ABr3 is A 4.31; Br, 95.69.

Calculate the relative atomic mass, A, of A.

Give your answer to three significant figures. [3]

Question 12

A 6.30 g sample of hydrated ethanedioic acid, $H_2C_2O_4.xH_2O$, was dissolved in water and the solution made up to 250 cm^3.

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.100 mol dm^{-3} potassium manganite (VII) solution. 20.0 cm^3 of this potassium manganite (VII) solution was required to react fully with the ethanedioate ions, $C_2O_4^{2+}$, present in the sample.

(a) The MnO_4^- ions in the potassium manganite (VII) oxidise the ethanedioate ions.

(i) Explain, in terms of electron transfer, the meaning of the term oxidise in the sentence above. [1]

(ii) Complete and balance the ionic equation for the reaction between the manganite (VII) ions and the ethanedioate ions.

$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + ……. H^+(aq) \longrightarrow ……. (aq) + 10CO_2(aq) + …….H_2O(l)$

[3]

(b) (i) Calculate the number of moles of manganite (VII) used in the titration.

[1]

(ii) Use the equation in (a)(ii) and your answer to (b)(i) to calculate the number of moles of $C_2O_4^{2+}$ present in the 25.0cm3 sample of solution used. [1]

(iii) Calculate the number of moles of $H_2C_2O_4.xH_2O$ in 6.30 g of the compound. [1]

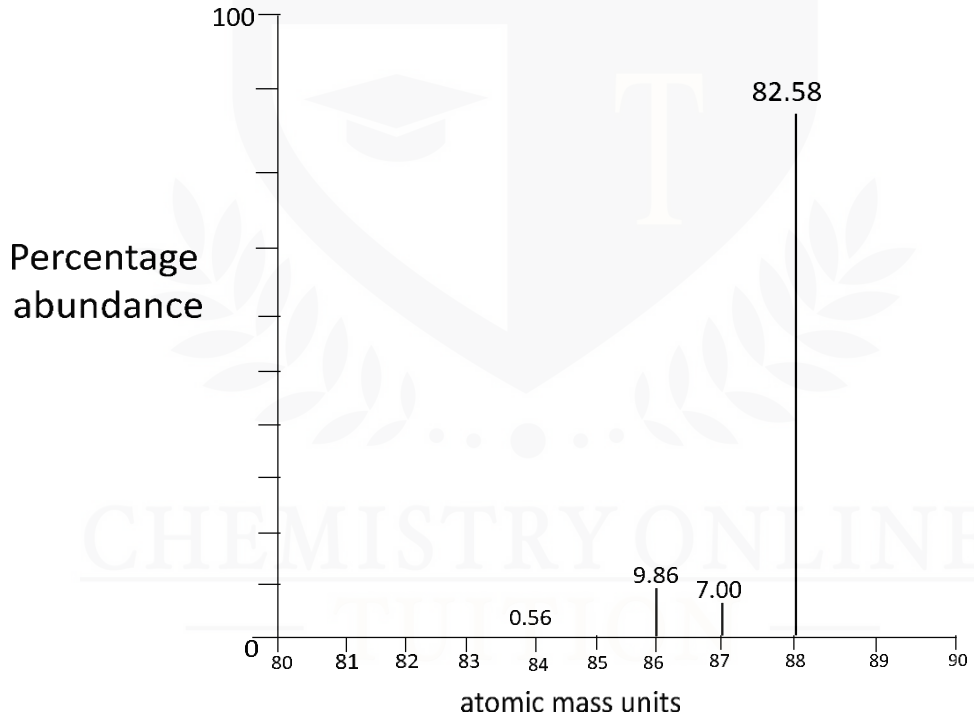
(iv) Calculate the relative formula mass of $H_2C_2O_4.xH_2O$. [1]

(v) The relative formula mass of anhydrous ethanedioic acid, $H_2C_2O_4$, is 90.

Calculate the value of x in $H_2C_2O_4.xH_2O$. [1]

Question 13

(c) A sample of strontium, atomic number 38, gave the mass spectrum shown. The percentage abundacnes are given above each peak.



(i) Complete the full electronic configuration of strontium.

$1s^2\ 2s^2\ 2p^6$ [1]

(ii) Explain why there are four different peaks in the mass spectrum of strontium. [1]

(iii) Calculate the atomic mass, A_r, of this sample strontium.

Give your answer to **three** significant figures. [2]

(d) A compound of barium, **A**, is used in fireworks as an oxidizing agent and to produce a green colour.

(i) Explain, in terms of electron transfer, what is meant by the term *oxidizing agent.* [1]

(ii) **A** has the following percentage composition by mass:

Ba, 45.1: Cl, 23.4; O, 31.5. Calculate the empirical formula of **A**. [3]

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