Atoms, Molecules & Stoichiometry

Question Paper 3

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Atoms, Molecules & Stoichiometry
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 3

Time Allowed: **77 minutes**

Score: **/64**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 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 oxidised to carbon dioxide and water. Copper is the only other product of the reaction.

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

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

(i) Calculate the mass of carbon present in 0.352 g of CO_2.

Use this value to calculate the amount, in moles, of carbon 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°C, the vapour occupied a volume of 67.7 cm^3 at a pressure of 101 kPa.

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

M_r =.....

(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 aqueous bromine.

Suggest **two** structural formulae for **A**.

[2]

(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.

.....

..... [1]

[Total: 13]

2 **(a)** Complete the electronic configurations of the following ions.

Cr^{3+}: $1s^2 2s^2 2p^6$.....

Mn^{2+}: $1s^2 2s^2 2p^6$.....

[2]

(b) Both $KMnO_4$ and $K_2Cr_2O_7$ are used as oxidising agents, usually in acidic solution.

(i) Use information from the *Data Booklet* to explain why their oxidising power increases as the $[H^+(aq)]$ in the solution increases.

.....

.....

.....

(ii) What colour changes would you observe when each of these oxidising agents is completely reduced?

- $KMnO_4$
  from ..... to .....
- $K_2Cr_2O_7$
  from..... to .....

[4]

(c) Manganese(IV) oxide, MnO_2, is a dark brown solid, insoluble in water and dilute acids. Passing a stream of $SO_2(g)$ through a suspension of MnO_2 in water does, however, cause it to dissolve, to give a colourless solution.

(i) Use the *Data Booklet* to suggest an equation for this reaction, and explain what happens to the oxidation states of manganese and of sulfur during the reaction.

.....

.....

.....

(ii) The pH of the suspension of MnO_2 is reduced.
Explain what effect, if any, this would have on the extent of this reaction.

.....

.....

[4]

(d) The main ore of manganese, pyrolusite, is mainly MnO_2. A solution of $SnCl_2$ can be used to estimate the percentage of MnO_2 in a sample of pyrolusite, using the following method.

- A known mass of pyrolusite is warmed with an acidified solution containing a known amount of $SnCl_2$.
- The excess $Sn^{2+}(aq)$ ions are titrated with a standard solution of $KMnO_4$.

In one such experiment, 0.100 g of pyrolusite was warmed with an acidified solution containing 2.00×10^{-3} mol Sn^{2+}. After the reaction was complete, the mixture was titrated with 0.0200 mol dm^{-3} $KMnO_4$, and required 18.1 cm^3 of this solution to reach the end point.

The equation for the reaction between $Sn^{2+}(aq)$ and $MnO_4^-(aq)$ is as follows.

$$2MnO_4^- + 5Sn^{2+} + 16H^+ \rightarrow 2Mn^{2+} + 5Sn^{4+} + 8H_2O$$

(i) Use the *Data Booklet* to construct an equation for the reaction between MnO_2 and Sn^{2+} ions in acidic solution.

.....

(ii) Calculate the percentage of MnO_2 in this sample of pyrolusite by the following steps.

- number of moles of MnO_4^- used in the titration

- number of moles of Sn^{2+} this MnO_4^- reacted with

- number of moles of Sn^{2+} that reacted with the 0.100 g sample of pyrolusite

- number of moles of MnO_2 in 0.100 g pyrolusite. Use your equation in **(i)**.

- mass of MnO_2 in 0.100 g pyrolusite

- percentage of MnO_2 in pyrolusite

percentage = ...%

[6]

[Total: 16]

3 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 analysing the products of combustion.

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

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

[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**?

..... cm^3

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

..... cm^3 [4]

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

[3]

[Total: 11]

4 Copper and titanium are each used with aluminium to make alloys which are light, strong and resistant to corrosion.

Aluminium, A*l*, is in the third period of the Periodic Table; copper and titanium are both transition elements.

(a) Complete the electronic configuration of aluminium and of titanium, proton number 22.

A*l*	$1s^2$
Ti	$1s^2$

[1]

Aluminium reacts with chlorine.

(b) **(i)** Outline how, starting from aluminium powder, this reaction could be carried out in a school or college laboratory to give a small sample of aluminium chloride. A diagram is not necessary.

.....

.....

.....

(ii) Describe what you would see during this reaction.

.....

.....

(iii) At low temperatures, aluminium chloride vapour has the formula Al_2Cl_6.
Draw a 'dot-and-cross' diagram to show the bonding in Al_2Cl_6.
Show outer electrons only.
Represent the aluminium electrons by ●.
Represent the chlorine electrons by ***x***.

[6]

Copper forms two chlorides, $CuCl$ and $CuCl_2$.

(c) When copper is reacted directly with chlorine, only $CuCl_2$ is formed.
Suggest an explanation for this observation.

.....

..... [1]

Titanium also reacts with chlorine.

(d) When an excess of chlorine was reacted with 0.72 g of titanium, 2.85 g of a chloride **A** was formed.

(i) Calculate the amount, in moles, of titanium used.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Hence, determine the empirical formula of **A**.

(iv) Construct a balanced equation for the reaction between titanium and chlorine.

.....
[4]

(e) At room temperature, the chloride of titanium, **A**, is a liquid which does not conduct electricity.

What does this information suggest about the bonding and structure in **A**?

.....

.....

..... [2]

[Total: 14]

5 Iron and cobalt are adjacent elements in the Periodic Table. Iron has three main occurring isotopes, cobalt has one.

naturally

(a) Explain the meaning of the term *isotope*.

.....

.....

..... [2]

(b) The most common isotope of iron is ^{56}Fe; the only naturally occurring isotope of cobalt is ^{59}Co.

Use the *Data Booklet* to complete the table below to show the atomic structure of ^{56}Fe and of ^{59}Co.

	number of		
isotope	protons	neutrons	electrons
^{56}Fe			
^{59}Co			

[3]

(c) A sample of iron has the following isotopic composition by mass.

isotope mass	54	56	57
% by mass	5.84	91.68	2.17

(i) Define the term *relative atomic mass*.

.....

.....

.....

.....

(ii) By using the data above, calculate the relative atomic mass of iron to **three** significant figures.

[5]

[Total: 10]