Jan 2009

SECTION A

Answer **all** *the questions in the spaces provided.*

1. An isotope of magnesium, ^{27}Mg, is used to detect leaks in water pipes.

(a) It decays by β–emission with a half life of 9·5 minutes.

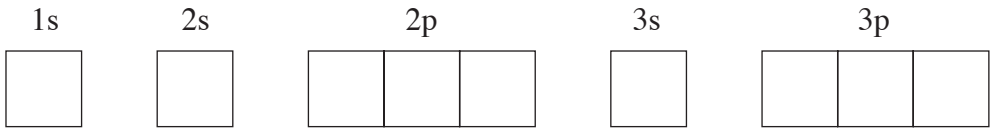
(i) Give the symbol and mass number of the atom formed by the loss of one β particle from an atom of ^{27}Mg. [1]

.....

(ii) Calculate how long it will take for the activity of the isotope to decay to $\frac{1}{16}^{th}$ of its original activity. [1]

..... minutes

(b) Complete the boxes below, by inserting arrows to represent electrons, to show the electronic configuration of an atom of magnesium. [1]



2. Calcium oxide is made by heating calcium carbonate in air.

$$\underset{1 \text{ mole}}{CaCO_3} \longrightarrow \underset{1 \text{ mole}}{CaO} + CO_2$$

Calculate the maximum mass of calcium oxide formed when 0·500 mole of pure calcium carbonate is heated. [2]

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.....

(c) One method of removing sulfur dioxide from power station emissions is to react the flue gases with moist calcium carbonate (limestone), giving hydrated calcium sulfate (gypsum) and carbon dioxide.

$$2SO_2 + 2CaCO_3 + 4H_2O + O_2 \longrightarrow 2CaSO_4.2H_2O + 2CO_2$$

One **advantage** of this process is that the gypsum can be used for the production of plaster.
State two **disadvantages** of this method of sulfur dioxide removal, apart from cost. [2]

Disadvantage 1 .....

.....

Disadvantage 2 .....

.....

(d) Some students measured the concentration of sulfur dioxide in the air.
They pumped air at a rate of 20 dm^3 per hour for 5 days through a suitable solution that absorbed the sulfur dioxide present.
The resulting solution was then treated to give 0·0047 g of barium sulfate, $BaSO_4$.
You should assume that 1 mole of sulfur dioxide gives 1 mole of barium sulfate.

(i) Calculate the total volume of air passed through the solution in 5 days. [1]

.....

..... dm^3

(ii) Calculate the relative molecular mass of barium sulfate. [1]

.....

.....

(iii) Use your answer to (ii) to calculate the number of moles of barium sulfate present. [1]

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(iv) State the number of moles of sulfur dioxide present in the sampled air. [1]

.....

(v) Calculate the volume of sulfur dioxide present in the sampled air. [1]
[One mole of sulfur dioxide has a volume of 24·0 dm^3 under these conditions.]

.....

..... dm^3

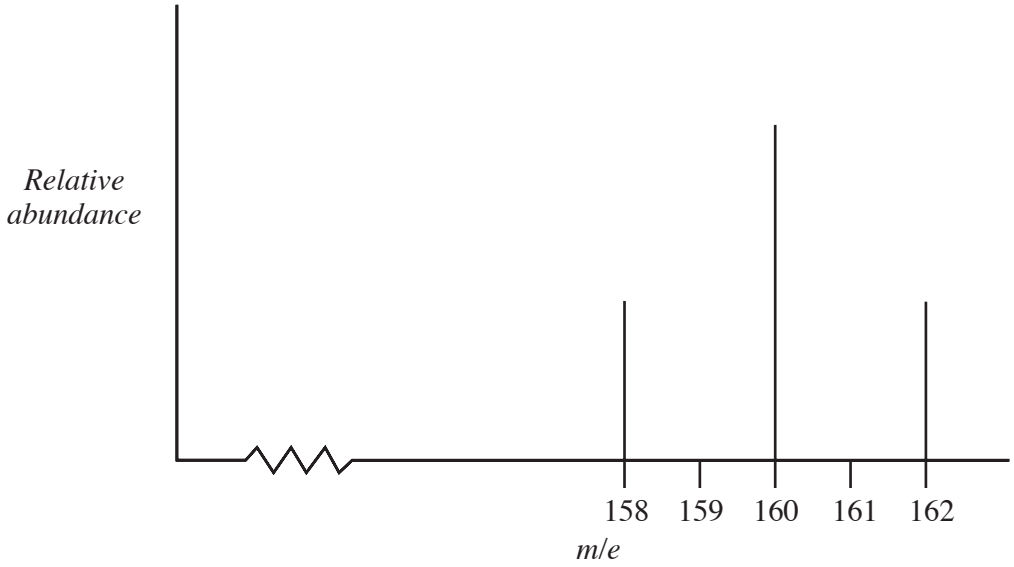
(vi) Calculate the percentage by volume of sulfur dioxide in the sampled air. [1]

.....

.....

Total [14]

(iii) The products of the reaction were examined using a mass spectrometer. The molecular ion peaks for Br_2^+ are shown in the diagram.



Use this information to

I. state the relative isotopic masses of the two bromine atoms, ^{x}Br, [1]

.....

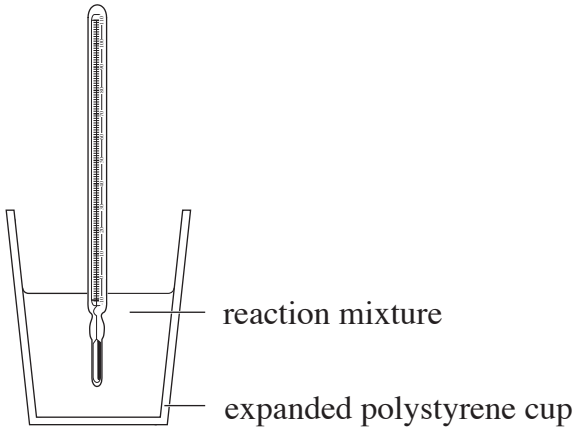
II. find the relative abundance of the two bromine isotopes, giving a reason for your answer. [2]

.....

.....

(c) Elfed carried out an experiment, using the simple apparatus shown below, to find the enthalpy change for the reaction between hydrobromic acid, HBr(aq), and aqueous sodium hydroxide.

$$HBr(aq) + NaOH(aq) \longrightarrow NaBr(aq) + H_2O(l)$$



Examiner only

(b) Neon, discovered in 1898, has three naturally occurring isotopes, of which ^{20}Ne is the most abundant. It is unreactive and forms no compounds.
Use this information to help you answer the questions below.

(i) One reason that neon does not react with other elements is because its first standard molar ionisation energy is very high, having a value of 2081 kJ mol^{-1}. Write an equation that represents the first standard molar ionisation energy of neon. [2]

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(ii) Explain the meaning of the term ***relative isotopic mass***. [2]

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(iii) Explain, how the ***relative atomic mass*** differs from the ***relative isotopic mass***. [1]

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(iv) At a certain temperature and pressure, 0·890 g of ^{20}Ne occupies a volume of 1 dm^3. Use this value to find the volume occupied by 1 mole of neon at this temperature and pressure. [2]

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..... dm^3

Total [14]

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(ii) 20·0 cm^3 of the diluted sodium hydroxide solution reacted with 0·00500 mole of hydrochloric acid.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

I. State the number of moles of sodium hydroxide present in the 20·0 cm^3 sample. [1]

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II. Calculate the concentration of the **diluted** sodium hydroxide solution. [2]

.....

.....

..... mol dm^{-3}

III. State the concentration of the **original** sodium hydroxide solution. [1]

.....

.....

..... mol dm^{-3}

IV. State how you would identify the end-point of this titration. [1]

.....

Total [14]

Section B Total [70]

2. *(a)* Cobalt reacts with hydrochloric acid to give cobalt chloride and hydrogen.

$$Co(s) + 2HCl(aq) \longrightarrow CoCl_2(aq) + H_2(g)$$

(i) Suggest a method for measuring the rate of this reaction. [1]

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(ii) State what could be done to the cobalt to increase the rate of this reaction. [1]

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(b) A radioactive isotope of cobalt has a half-life of 71 days. Starting with 16 g, calculate the mass of this isotope remaining after 213 days. [1]

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3. State the mass of carbon that contains the same number of atoms as there are molecules in 16 g sulfur dioxide, SO_2. [1]

A 3 g

B 6 g

C 12 g

D 64 g .....

(b) The use of lead compounds in paints and pigments has been common for many centuries, although, due to its toxicity, this is now rare.

(i) 'White lead', which is based on lead carbonate, was used as a skin whitening cosmetic by Queen Elizabeth I in the 16th century.

Analysis of lead carbonate shows that it has the following percentage composition by mass: Pb 77.5%; C 4.50%; O 18.0%.

Calculate the empirical formula of lead carbonate.
Show your working. [2]

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(ii) 'Red lead', which is based on lead oxide, Pb_3O_4, is used in anti-corrosive paint. It is formed by oxidising lead(II) oxide with oxygen.

$$6PbO + O_2 \longrightarrow 2Pb_3O_4$$

I. Calculate the molar mass of Pb_3O_4. [1]

.....

II. Calculate the mass of Pb_3O_4 that could be formed from 134 g of PbO. [3]

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Total [14]

(iii) On the diagram, draw and label the transition corresponding to the ionisation of the atom. [1]

(b) Hydrogen exists as two naturally occurring isotopes, ^{1}H and ^{2}H.

(i) A mass spectrum of a sample of hydrogen showed that it contained ^{1}H 99.20% and ^{2}H 0.8000%.

Calculate the relative atomic mass of the hydrogen sample, giving your answer to **four significant figures**. [2]

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(ii) In the mass spectrum, explain why peaks due to hydrogen atoms are present, although hydrogen gas contains only H_2 molecules. [1]

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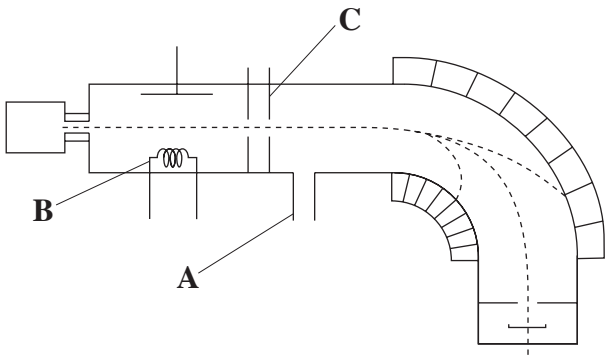
(c) Below is a diagram of a mass spectrometer.



(i) Name part **B**. [1]

.....

(ii) Name part **C**. [1]

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(iii) State the function of part **A**. [1]

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9. Elinor is given a mixture containing sodium carbonate and she carries out a two-part experiment to determine the percentage of sodium carbonate in the mixture.

In part 1, she accurately weighs 2.05 g of the mixture, transfers all of it to an appropriate container, adds 100 cm^3 of distilled water to ensure that it all dissolves and accurately makes up the solution to 250 cm^3 with distilled water.

In part 2, she pipettes 25.0 cm^3 of the solution into a container, adds 3 drops of an appropriate indicator and titrates this solution with hydrochloric acid of concentration 0.100 mol dm^{-3}. She repeats this procedure three times and obtains the following results.

Titration	1	2	3	4
Final reading (cm^3)	23.50	24.10	24.10	23.40
Initial reading (cm^3)	0.40	0.15	0.90	0.25
Titre (cm^3)				

(a) Name a suitable container to make up the solution that could be used in part 1. [1]

.....

(b) Complete the table to show the values of the titres. [1]

(c) Identify clearly any anomalous results and calculate a mean value. [1]

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.....

(d) The equation for the reaction between sodium carbonate and hydrochloric acid is given below.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

(i) Use your answer to part *(c)* to calculate the number of moles of HCl used in the titration. [1]

.....

.....

(ii) Deduce the number of moles of Na_2CO_3 in 25.0 cm^3 of the solution. [1]

.....

(iii) Calculate the total number of moles of Na_2CO_3 in the original 250 cm^3 solution. [1]

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.....

(iv) Calculate the mass of Na_2CO_3 in the original solution. [1]

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(v) Calculate the percentage of Na_2CO_3 in the mixture. [1]

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.....

(e) Elinor's percentage for sodium carbonate was slightly lower than the actual value. When asked why, she stated 'I did not add the acid drop by drop at the end and so overshot the end-point'.

State **two** other common sources of error in such experiments and explain why Elinor's statement cannot be correct.
(Assume that all the equipment is clean and all chemicals are pure.) [4]

QWC [2]

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.....

Total [14]

Section B Total [70]

Examiner only

(iii) Determine the total time required for the 10 g mass of ^{192}Ir to decay to 1.25 g. [2]

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(iv) Calculate, from the graph, the rate of decay of ^{192}Ir (g day^{-1}) during the first 20 days. [2]

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(d) Compound **P**, one of the most important compounds of iridium, is a black solid containing 10.2 % sodium, Na, 42.6 % iridium, Ir, and 47.2 % chlorine, Cl, by mass.

(i) Calculate the empirical formula (which is also the molecular formula) of compound **P**.

A_r(Na) = 23.0; A_r(Cl) = 35.5; A_r(Ir) = 192. [2]

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.....

.....

(ii) Compound **P** is made by reacting a mixture of sodium chloride, NaCl, and an iridium chloride, $IrCl_x$. There is only one product of the reaction. By constructing a balanced equation, or otherwise, determine the value of **x** in the iridium chloride formula, $IrCl_x$. [1]

.....

.....

Total [17]

Examiner only

(c) Another area of investigation is the use of a new type of plastic membrane, structured by means of nanotechnology, to catch carbon dioxide gas whilst allowing other waste gases to pass freely through.

If 1000 dm^3 of waste gas at 25 °C yielded 275 g of carbon dioxide, separated by a plastic membrane, calculate:

(i) the number of moles of carbon dioxide in the 275 g separated by the membrane; [2]

.....

.....

(ii) the volume of carbon dioxide separated at 25 °C; [1]

.....

.....

[One mole of gas has a volume of 24.0 dm^3 at 25 °C and 1 atm pressure]

(iii) the percentage by volume of carbon dioxide in the waste gas. [1]

.....

.....

(d) Carbon dioxide, CO_2 is an *acid gas*.

(i) Define the term *acid*. [1]

.....

(ii) By considering its interaction with water, explain how carbon dioxide can behave as an acid. [1]

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.....

(iii) Though the pH of pure water is 7, explain why naturally-occurring water in contact with air has a pH of less than 7. [1]

.....

.....

Total [17]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. A gaseous isotope of hydrogen, tritium, $^{3}_{1}H$, is produced in the upper atmosphere.

(i) State which of the following correctly describes an atom of tritium. [1]

	Number of protons	Number of neutrons	Number of electrons
A	1	1	1
B	1	1	2
C	1	2	1
D	1	2	0

.....

(ii) Tritium is a radioactive gas with a half-life of 12.5 years. A sample of tritium has a mass of 0.960 g.
Calculate the mass of tritium remaining after 37.5 years. [1]

.....

.....

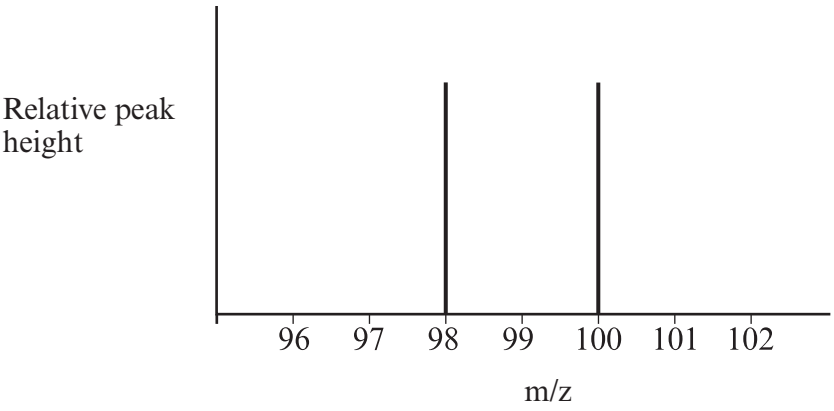
2. Cyanogen is a compound containing only carbon and nitrogen.
It has a relative molecular mass of 52.

(i) State the molecular formula of cyanogen. ..... [1]

(ii) State the empirical formula of cyanogen. ..... [1]

Examiner only

3. The mass spectrum of the colourless gas bromine fluoride, $Br^{19}F$, shows two molecular ions.



(i) State the mass numbers of the two bromine isotopes present in bromine fluoride. [1]

..... and .....

(ii) Bromine fluoride is unstable and readily gives $Br^{19}F_3$.
State the mass/charge (m/z) value for the molecular ion $Br^{19}F_3^+$, when all the bromine is present as the isotope ^{85}Br. [1]

.....

4. The first two standard molar ionisation energies for magnesium are shown in the table.

Electron removed	Standard molar ionisation energy / kJ mol^{-1}
first	736
second	1450

State which of the following is the value for the third molar standard ionisation energy, in kJ mol^{-1}, of magnesium. [1]

A 457

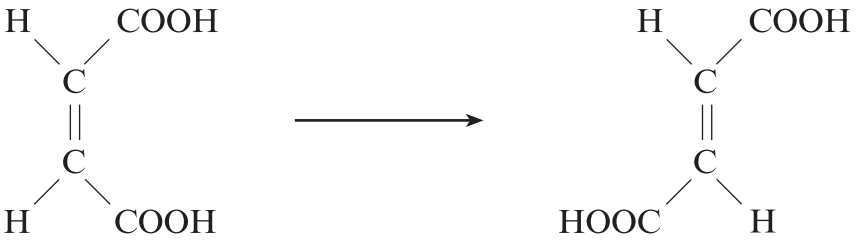
B 923

C 2170

D 7740 .....

Examiner only

5. One industrial method of preparing fumaric acid is to heat maleic acid in the presence of a catalyst.



maleic acid fumaric acid

(i) Deduce the atom economy of this reaction. [1]

..... %

(ii) Data from a manufacturer states that the percentage yield of fumaric acid is 95 % using a 150 kg batch of maleic acid.

Calculate the mass of fumaric acid formed. [1]

..... kg

6. Choose the mass of methane, CH_4, that contains the same number of molecules as there are molecules in 96 g of silane, SiH_4. [1]

A 36 g

B 48 g

C 96 g

D 144 g

.....

Total Section A [10]

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

7. Ammonia, NH_3, is produced from nitrogen and hydrogen.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(a) Typically, this process is carried out at a temperature of 450 °C, at a pressure of 250 atmospheres and in the presence of an iron catalyst. The yield is around 15%.

(i) If this reaction were carried out using a reduced pressure of 50 atmospheres, the process would be safer because of the lower pressure used.

State **one** disadvantage of using this lower pressure. [1]

.....

(ii) In the actual process some of the ammonia is removed as the reaction proceeds.

State and explain what effect this removal has on the position of equilibrium. [2]

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.....

(iii) How would the equilibrium yield be affected if the reaction were run without using the catalyst? [1]

.....

(b) Some of the ammonia is reacted with sulfuric acid to produce the fertiliser ammonium sulfate.

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

(i) State the molar masses of

ammonia ..... g ammonium sulfate ..... g [1]

(ii) Calculate the maximum mass of ammonium sulfate, in tonnes, that can be made from 17.03 tonnes of ammonia. [3]

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Examiner only

(c) A member of the public read in an article that the pH of an ammonium sulfate solution was 6. He asked you to explain what was meant by the pH scale.
What would be your reply? [2]

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.....

(d) Ammonium nitrate, NH_4NO_3, is also used as a fertiliser. However, in the presence of certain impurities, it can explode very violently. This explosive reaction gives nitrogen, oxygen and steam.

$$NH_4NO_3(s) \longrightarrow N_2(g) + 2H_2O(g) + \tfrac{1}{2}O_2(g) \quad \Delta H = -296 \text{ kJ mol}^{-1}$$

M_r 80

Some years ago 400 tonnes (4×10^8 g) of ammonium nitrate, stored in a ship in a harbour, exploded, causing extensive damage.

Calculate the energy produced in this explosion, in kJ. [2]

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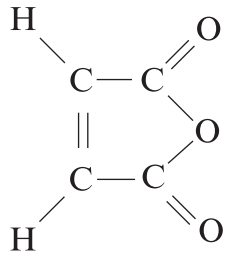
Examiner only

9. *(a)* The compound maleic anhydride (Z-butenedioic anhydride) is an important compound that is used in the production of polyester resins.



maleic anhydride

(i) Three compounds, **L**, **M** and **N**, can be used to produce maleic anhydride in the presence of oxygen. The same conditions are used in each method.

Compound	% Yield of maleic anhydride	Other product(s)
L	75	H_2O and CO_2
M	65	H_2O
N	75	H_2O

I Using the **information in the table only** suggest which compound, **L**, **M** or **N**, should be used to produce maleic anhydride. Explain your reasoning. [2]

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.....

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II Chemical manufacturers are interested in methods of production that have a minimum effect on the environment – 'Green Chemistry'.
Suggest **two** factors (not from information given in the table) that manufacturers should take into account when considering the production of maleic anhydride. [2]

1. .....

.....

2. .....

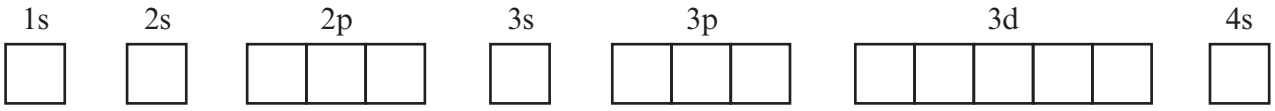
.....

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. By inserting arrows to represent electrons, complete the boxes below to show the electronic configuration of a calcium atom. [1]



2. *(a)* Calculate the molar mass, in $g\,mol^{-1}$, of calcium sulfate dihydrate, $CaSO_4.2H_2O$. [1]

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(b) Calculate the percentage of water, by mass, in calcium sulfate dihydrate. [1]

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.....

3. Ions of two isotopes of the metal lithium are shown below.

$^{6}_{3}Li^{+}$ $^{7}_{3}Li^{+}$

State which **one** of the following statements is **correct**. [1]

A The electron arrangement of both these Li^+ ions is $1s^2 2s^1$.

B The $^{7}Li^{+}$ ion will have more protons in its nucleus than the $^{6}Li^{+}$ ion.

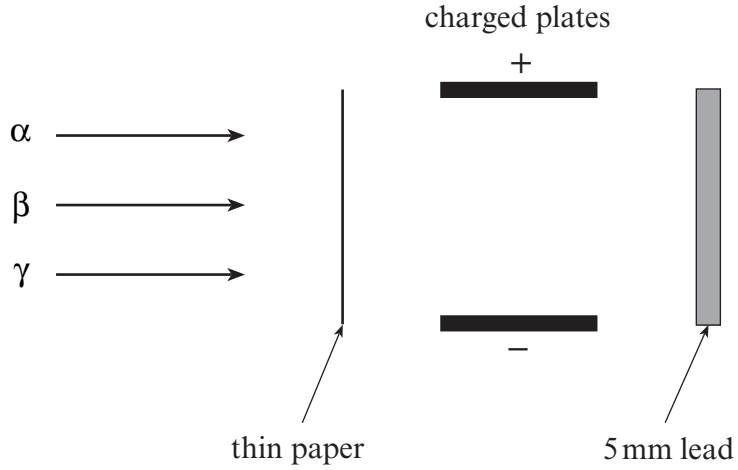
C The $^{7}Li^{+}$ ion will be deflected more than the $^{6}Li^{+}$ ion in a mass spectrometer.

D Both of these Li^+ ions have the same number of electrons.

.....

Examiner only

4. Complete the diagram below to show how radiation is affected by an electric field and by materials of different thickness. [3]



5. A compound of carbon, hydrogen and oxygen has a relative molecular mass of 180. The percentage composition by mass is C 40.0%; H 6.70%; O 53.3%.

1091 010003

(a) Calculate the empirical formula of this compound. [2]

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(b) Determine the molecular formula of this compound. [1]

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Section A Total [10]

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

6. Potassium metal was discovered in 1807 by the British chemist Sir Humphrey Davy. Its name derives from the word 'potash' since potassium was isolated by the electrolysis of molten caustic potash, KOH.

(a) The mass spectrum of a naturally occurring sample of potassium gave the following results.

Isotope	% abundance
^{39}K	93.26
^{40}K	0.012
^{41}K	6.730

These results can be used to determine the relative atomic mass of the potassium sample.

(i) Explain the term *relative atomic mass*. [2]

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.....

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(ii) Calculate the relative atomic mass of the potassium sample, giving your answer to **four** significant figures. [2]

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.....

(b) The mass spectrum which provided these results was produced by potassium ions in a mass spectrometer.

(i) State how potassium ions are formed in a mass spectrometer. [1]

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.....

(ii) State how potassium ions are separated in a mass spectrometer. [1]

.....

.....

Examiner only

(c) Potassium-40, $^{40}_{19}K$, is a radioactive isotope that decays by β-emission and has a half-life of 1.25×10^9 years.

(i) Write an equation for the process by which a potassium-40 isotope emits a β-particle. [2]

.....

(ii) Calculate how long it will take for the activity of the isotope to decay to $\frac{1}{8}$ th of its original activity. [1]

.....

.....

(d) The first and second ionisation energies of potassium and sodium are shown in the table below.

	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}
potassium	419	3051
sodium	496	4562

(i) Explain the term *molar first ionisation energy*. [2]

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(ii) Explain why

I potassium has a lower first ionisation energy than sodium, [2]

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II there is a large difference between the first and second ionisation energies of potassium. [2]

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Total [15]

Examiner only

7. Eurig is asked to measure the rate of reaction of calcium carbonate with dilute hydrochloric acid. He is given 1.50 g of the carbonate and 10.0 cm^3 of acid of concentration 2.00 mol dm^{-3}.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) Give an observation that Eurig makes during this reaction. [1]

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.....

(b) Name a piece of apparatus that he could use to collect and measure the volume of carbon dioxide produced. [1]

.....

(c) Suggest a method, other than measuring the amount of carbon dioxide produced at set time intervals, that Eurig could have used to follow the rate of this reaction. [1]

.....

.....

(d) (i) Calculate the number of moles of hydrochloric acid used in this reaction. [1]

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(ii) Calculate the **minimum** mass of calcium carbonate needed to react **completely** with this amount of acid. [2]

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(iii) Calculate the volume of carbon dioxide gas that would be produced at 25 °C. [2]
(1 mole of carbon dioxide occupies 24 dm^3 at 25 °C.)

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Examiner only

(b) Recently hydrogen has been receiving interest as a 'source of energy'.
It can be prepared by the steam reforming of methane.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = 206\,kJ\,mol^{-1}$$

(i) State Le Chatelier's Principle. [1]

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(ii) Giving your reasons, state how the equilibrium yield of hydrogen is affected, if at all, by

I increasing the temperature at constant pressure, [2]

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II increasing the pressure at constant temperature. [2]

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(iii) Calculate the atom economy of hydrogen production in the above reaction. [2]

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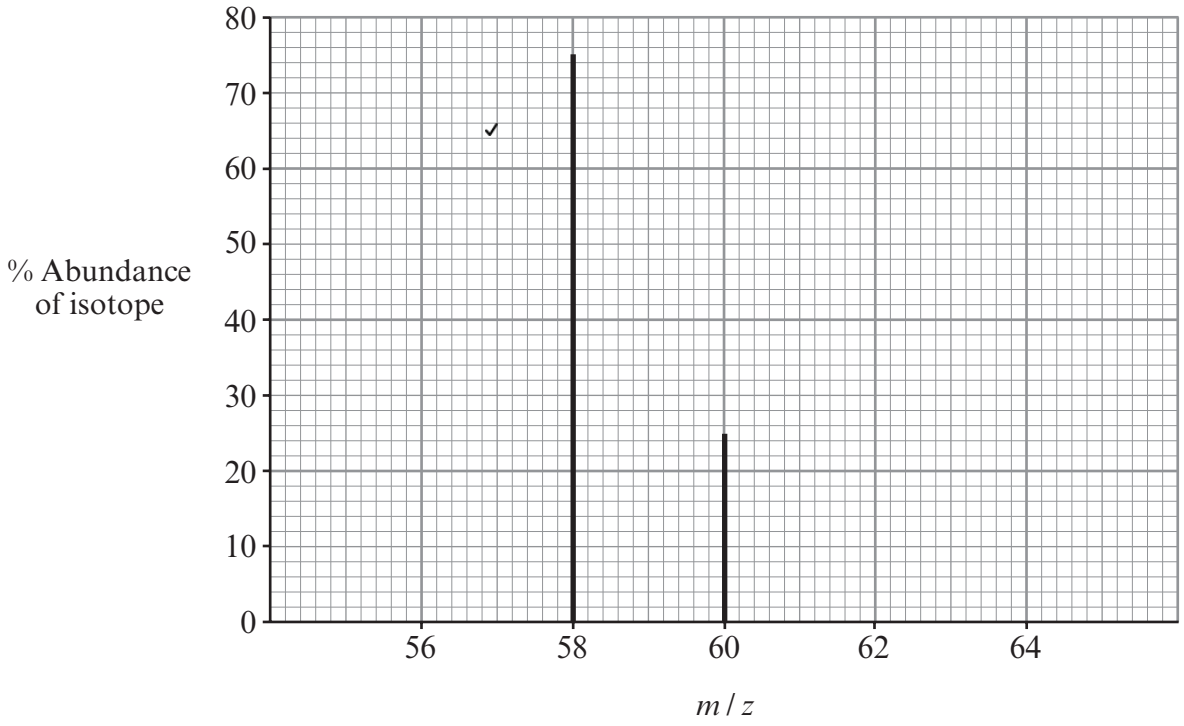
Examiner only

3. The mass spectrum of a sample of nickel is shown below.



Use the data to calculate the relative atomic mass of this sample to **three** significant figures. **You must show your working.** [1]

.....

.....

4. State which of the following letters corresponds to the number of moles of each element in 53 g of sodium carbonate, Na_2CO_3, which has an M_r of 106.

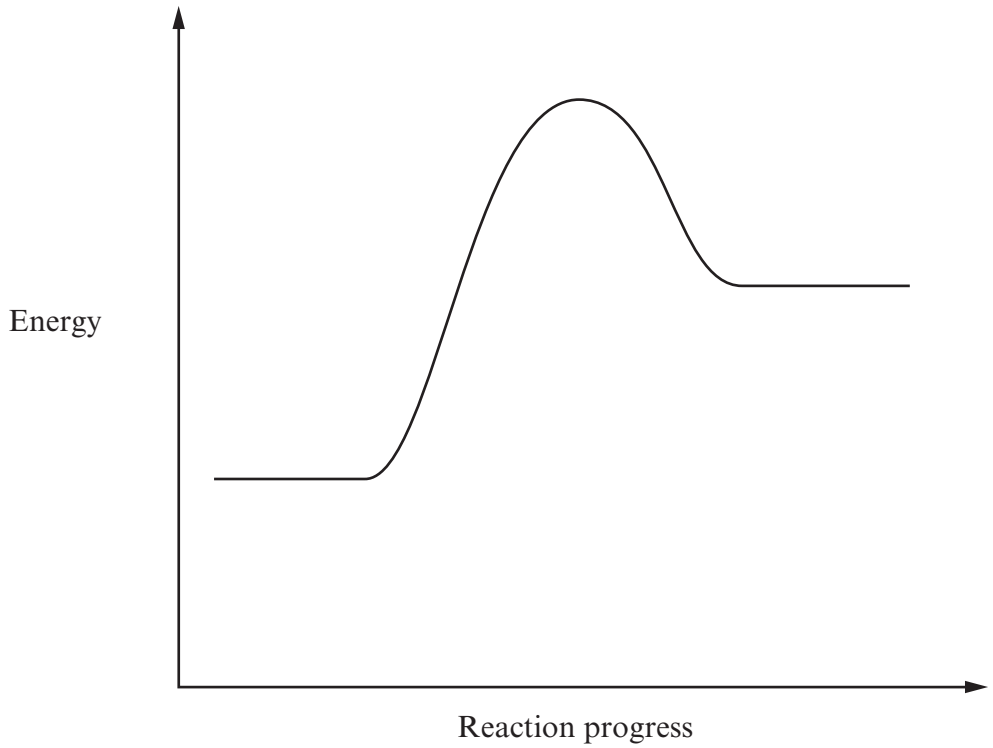
	Na	C	O
A	0.5	0.5	0.5
B	1	0.5	3
C	1	0.5	1.5
D	2	1	3

[1]

Letter .....

Examiner only

5. Label clearly on the energy profile diagram below the forward (E_f) and reverse (E_b) activation energies and the enthalpy change (ΔH) for the reaction. [2]



6. An oxide of nitrogen has a relative molecular mass of 92 and contains 30.4 % of nitrogen and 69.6 % of oxygen, by mass.

Calculate

(a) the empirical formula, [1]

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.....

(b) the molecular formula of this oxide. [1]

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Section A Total [10]

Examiner only

8. *(a)* Chloroethane, C_2H_5Cl, can be made from ethene by the addition of hydrogen chloride, HCl.

$$C_2H_4 + HCl \longrightarrow C_2H_5Cl \qquad \text{Reaction } \mathbf{A}$$

M_r values	28.0	36.5	64.5

(i) Calculate the maximum possible (theoretical) mass of chloroethane obtainable from 42.0 g of ethene. [2]

.....

.....

.....

(ii) The actual mass of chloroethane obtained from 42.0 g of ethene in an experiment was 79.0 g. Calculate the percentage yield in this experiment. [2]

.....

.....

.....

(b) Chloroethane can be formed by another reaction as in the following equation.

$$C_2H_5OH + NaCl + H_2SO_4 \longrightarrow C_2H_5Cl + NaHSO_4 + H_2O \qquad \text{Reaction } \mathbf{B}$$

M_r values	46.0	58.5	98.0	64.5	120	18.0

(i) Describe what is meant by *atom economy*. [1]

.....

.....

(ii) Calculate the % atom economy for reactions **A** and **B**. [2]

.....

.....

.....

(iii) State which of reactions **A** and **B** is preferred, giving your reason. [1]

.....

.....

Examiner only

4. In an experiment, Aled titrated 25.00 cm^3 of potassium hydroxide solution with hydrochloric acid, and obtained the following results.

	1	2	3	4
Initial burette reading / cm^3	0.10	0.25	1.20	21.30
Final burette reading / cm^3	20.85	20.45	21.30	41.60
Volume used / cm^3				

(a) Complete the table to show the volume used in each titration. [1]

(b) Calculate the mean volume that Aled should use for his further calculations. [1]

.....

.....

..... cm^3

1091 010003

Examiner only

6. *(a)* Mesitylene is a hydrocarbon composed of 89.9% carbon and 10.1% hydrogen by mass. Calculate the **empirical** formula of this compound. [2]

.....

.....

.....

(b) The relative molecular mass of mesitylene is 120.1. Give the **molecular** formula of this compound. [1]

.....

.....

Total Section A [10]

Examiner only

9. The metal lead was one of the first in common use and even as far back as two thousand years ago, tens of thousands of tonnes of the metal were being produced every year in the Roman Empire. It is still in common use today, although many of its former uses have declined due to the toxic nature of the element.

(a) Lead is commonly extracted from lead(II) sulfide, PbS. Initially this ore is heated in a limited supply of air to produce lead(II) oxide, PbO, giving off sulfur dioxide gas, SO_2.

$$2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$$

If 20 kg of lead(II) sulfide were heated in air, calculate the mass of lead(II) oxide formed. [3]

.....

.....

.....

.....

Mass of lead(II) oxide formed = ... kg

(b) Metallic lead can then be obtained from lead(II) oxide by one of two methods:

Method 1: Reduction with a fresh supply of lead(II) sulfide in the absence of air

$$2PbO + PbS \longrightarrow 3Pb + SO_2$$

Method 2: Reduction by carbon monoxide in a blast furnace

$$PbO + CO \longrightarrow Pb + CO_2$$

(i) Both methods for producing lead release waste gases. Give an environmental problem associated with each of these gases. [2]

Sulfur dioxide, SO_2 .....

.....

Carbon dioxide, CO_2 .....

.....

(ii) The atom economy for producing lead by method 1 is 90.7%.

I. Calculate the atom economy for producing lead by method 2. [2]

.....

.....

.....

Examiner only

(iii) It is not possible to identify whether γ-radiation is also produced during any of the radioactive decay processes from the information given in the scheme.

State what is meant by γ-radiation and why it cannot be identified from the information given in the scheme. [2]

.....

.....

.....

(iv) A sample of 24 mg of ^{212}Pb was allowed to stand for 31.8 hours. Calculate the mass of ^{212}Pb that would remain after this time. [2]

.....

.....

..... mg

(d) Naturally-occurring lead consists of a mixture of stable isotopes which include ^{206}Pb, ^{207}Pb and ^{208}Pb. The relative amounts of these isotopes can vary between different sources. The abundance of each isotope in a sample is given below.

Isotope	Relative isotopic mass	Percentage abundance
^{206}Pb	206.0	25.48%
^{207}Pb	207.0	22.12%
^{208}Pb	208.0	52.40%

Calculate the relative atomic mass (A_r) for this sample of lead. Give your answer to **four significant figures**. [3]

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.....

.....

.....

Total [19]

Examiner only

10. Callum and Carys wish to measure the enthalpy change of the reaction of aqueous copper(II) sulfate with zinc powder. The reaction that occurs is:

$$CuSO_4(aq) + Zn(s) \longrightarrow ZnSO_4(aq) + Cu(s)$$

(a) Callum prepares copper(II) sulfate solution from hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

(i) Calculate the relative molecular mass of hydrated copper(II) sulfate, $CuSO_4.5H_2O$. [1]

.....

.....

(ii) Callum measures a mass of hydrated copper(II) sulfate and uses this to make exactly 250.0 cm^3 of copper(II) sulfate solution of concentration 0.250 mol dm^{-3}.

I. Calculate the mass of hydrated copper(II) sulfate required to prepare this solution. [2]

.....

.....

.....

Mass of hydrated copper(II) sulfate = ... g

II. Describe, giving full practical details, how Callum should prepare the 250.0 cm^3 of copper(II) sulfate solution. [5]

QWC [1]

.....

.....

.....

.....

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.....

.....

Examiner only

(i) Explain why zinc powder is used in this experiment rather than pieces of zinc metal. [2]

.....

.....

(ii) Draw lines to complete the graph, and use these to find the maximum temperature change.

Maximum temperature change ..... °C [2]

(iii) In this experiment, Carys used 50.00 cm^3 of the copper(II) sulfate solution prepared by Callum and added 0.400 g of zinc powder.

I. Calculate the number of moles of copper(II) sulfate present in this solution. [1]

.....

.....

II. The sample of zinc metal used contained 6.12×10^{-3} moles. State why this value, rather than the number of moles of copper(II) sulfate, is used to calculate the enthalpy change of the reaction. [1]

.....

.....

III. The enthalpy change can be calculated using the expression below.

$$\Delta H = - \frac{mc\Delta T}{n}$$

Where: m is the mass of the copper(II) sulfate solution (50 g)
ΔT is the change in temperature in °C
n is the number of moles of zinc
c is the specific heat capacity of the solution which equals 4.18 $J\,g^{-1}\,°C^{-1}$

Calculate the enthalpy change for the reaction in $kJ\,mol^{-1}$. [2]

.....

.....

.....

.....

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. Sketch a diagram to show the shape of a *p* orbital. [1]

2. Complete the following definition of *relative atomic mass*: [1]

The relative atomic mass of an element is the average mass of one atom of the element relative to

.....

.....

3. State which **one** of the following contains the greatest number of molecules. [1]

A 3 g of hydrogen

B 32 g of oxygen

C 36 g of water

D 66 g of carbon dioxide .....

4. Phosgene is a compound of carbon, oxygen and chlorine. It is used to make polyurethanes and polycarbonates. Its percentage composition, by mass, is as follows.

C 12.1% O 16.2% Cl 71.7%

(a) Calculate the **empirical** formula of this compound. [2]

.....

.....

.....

.....

(b) What other information would you need to know to be able to deduce the **molecular** formula of this compound? [1]

.....

Examiner only

7. Judith carried out three experiments to study the reaction between powdered magnesium and hydrochloric acid.
She used a gas syringe to measure the volume of hydrogen evolved, at room temperature and pressure, at set intervals. In each case, the amount of acid used was sufficient to react with all the magnesium.

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

The details of each experiment are shown in Table 1 below.

Experiment	Mass of magnesium / g	Volume of HCl / cm^3	Concentration of HCl / mol dm^{-3}
A	0.061	40.0	0.50
B	0.101	40.0	1.00
C	0.101	20.0	2.00

Table 1

The results obtained in experiment **C** are shown in Table 2 below.

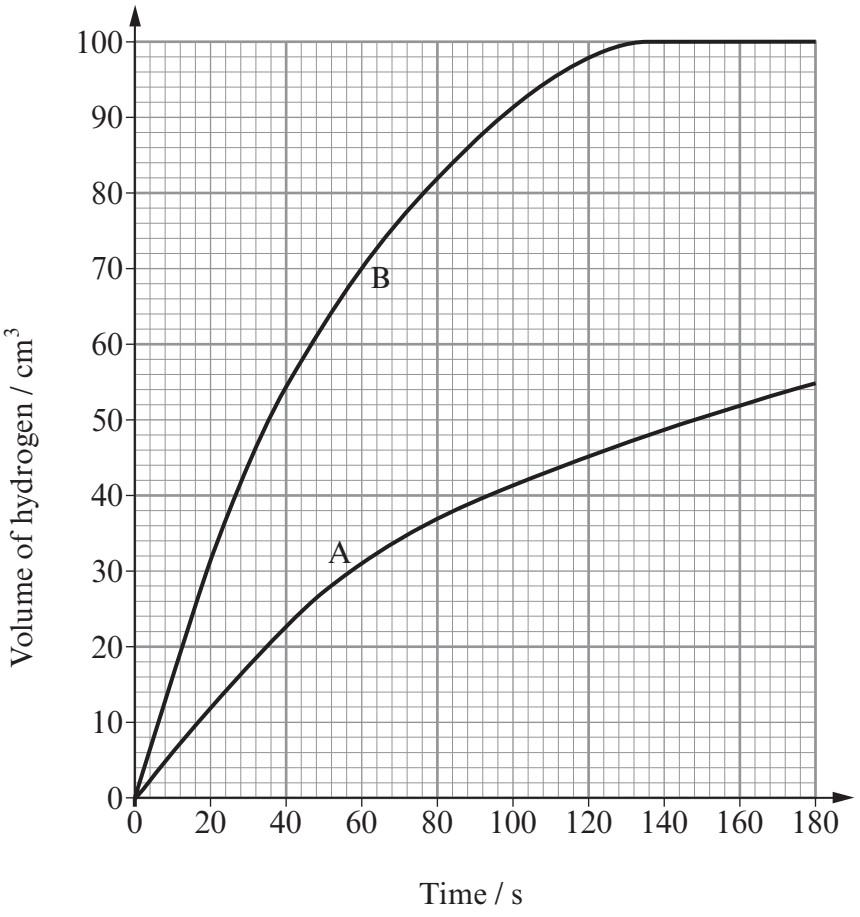
Time / s	Volume of hydrogen / cm^3
0	0
20	50
40	75
60	88
80	92
100	100
120	100

Table 2

Examiner only

(a) The results for experiments **A** and **B** have already been plotted on the grid below.

On the same grid, plot the results for experiment **C** and draw a line of best fit. [3]



(b) (i) State in which experiment the reaction begins most rapidly and **use the graph** to explain your choice. [2]

.....

.....

(ii) By referring to Table 1 give an explanation of your answer in part (i). [1]

.....

.....

(c) State the volume of hydrogen evolved after 30 seconds in experiment **B**. [1]

.....

Examiner only

(d) Using **only** the values in Table 1, show that the acid is in excess in experiment **C**. [2]

.....

.....

.....

(e) (i) In experiment **A**, 0.061 g of magnesium produces 60 cm^3 of hydrogen. If 0.122 g of magnesium were used, under the same conditions, then 120 cm^3 would be produced. Explain why using 0.610 g would not produce 600 cm^3 of hydrogen. [1]

.....

.....

(ii) Calculate the volume of hydrogen produced using 0.610 g of magnesium. [2]

(1 mole of gas molecules occupies 24 dm^3 at 25 °C)

.....

.....

.....

(f) State one method of slowing down the reaction in experiment **C** and use collision theory to explain your choice. Assume that the quantities of magnesium and hydrochloric acid are the same as those in Table 1. [3]
QWC [1]

.....

.....

.....

.....

Total [16]

Examiner only

10. Berian was asked to find the identity of a Group 1 metal hydroxide by titration.

He was told to use the following method.

- Fill a burette with hydrochloric acid solution.
- Accurately weigh about 1.14 g of the metal hydroxide.
- Dissolve all the metal hydroxide in water, transfer the solution to a volumetric flask then add more water to make exactly 250 cm^3 of solution.
- Accurately transfer 25.0 cm^3 of this solution into a conical flask.
- Add 2-3 drops of a suitable indicator to this solution.
- Carry out a rough titration of this solution with the hydrochloric acid.
- Accurately repeat the titration several times and calculate a mean titre.

Berian's results are shown below:

Mass of metal hydroxide = 1.14 g

Concentration of acid solution = 0.730 g HCl in 100 cm^3 of water

Mean titre = 23.80 cm^3

(a) Give a reason why Berian does not simply add 1.14 g of metal hydroxide to 250 cm^3 of water. [1]

.....

.....

(b) Name a suitable piece of apparatus for transferring 25.0 cm^3 of the metal hydroxide solution to a conical flask. [1]

.....

(c) State why he adds an indicator to this solution. [1]

.....

(d) Suggest why Berian was told to carry out a rough titration first. [1]

.....

.....

Examiner only

(e) Explain why he carried out several titrations and calculated a mean value. [1]

.....

.....

(f) The equation for the reaction between the metal hydroxide and hydrochloric acid is given below. M represents the symbol of the Group 1 metal.

$$MOH + HCl \longrightarrow MCl + H_2O$$

(i) Calculate the concentration, in mol dm^{-3}, of the HCl in the burette. [2]

.....

.....

(ii) Calculate the number of moles of HCl used in the titration. [1]

.....

.....

(iii) Deduce the number of moles of MOH in 25.0 cm^3 of the solution. [1]

.....

(iv) Calculate the total number of moles of MOH in the original solution. [1]

.....

.....

(v) Calculate the relative molecular mass of MOH. [1]

.....

.....

(vi) Deduce the Group 1 metal in the hydroxide. [1]

.....

Total [12]

Section B Total [70]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. The mass number of an isotope of gallium is 70.

State the number of neutrons in an atom of this isotope. ..... [1]

2. Write the letter which represents the correct equation for the **second** ionisation energy of gallium in the box below. [1]

A $Ga(g) + 2e^- \longrightarrow Ga^{2-}(g)$

B $Ga(g) \longrightarrow Ga^{2-}(g) + 2e^-$

C $Ga^+(g) \longrightarrow Ga^{2+}(g) + e^-$

D $Ga^{2+}(g) + 2e^- \longrightarrow Ga(g)$

3. An enriched isotopic mixture of lithium contains ^6Li 12.0% and ^7Li 88.0% by mass. Showing your working, calculate the relative atomic mass of this sample of lithium. Give your answer to **three** significant figures. [2]

Relative atomic mass = ...

Examiner only

6. An oxide of titanium contains 60% of titanium by mass. Calculate the empirical formula of this oxide of titanium. [2]

[A_r (Ti) = 48]

Empirical formula .....

Section A Total [10]

Examiner only

(c) Trona is a naturally-occurring 'sodium carbonate' mineral. It has the formula $Na_2CO_3.NaHCO_3.2H_2O$.

(i) Show that the relative molecular mass of trona is 226. [1]

(ii) On heating, trona loses water and carbon dioxide giving sodium carbonate.

$$2[Na_2CO_3.NaHCO_3.2H_2O](s) \longrightarrow 3Na_2CO_3(s) + CO_2(g) + 5H_2O(l)$$

Calculate the atom economy of this reaction, assuming that sodium carbonate is the only required product. [2]

Atom economy = ... %

(iii) The above reaction is used commercially to obtain sodium carbonate.

Suggest **one** environmental disadvantage of this reaction as indicated by the equation, and state what could be done to overcome this problem. [2]

.....

.....

.....

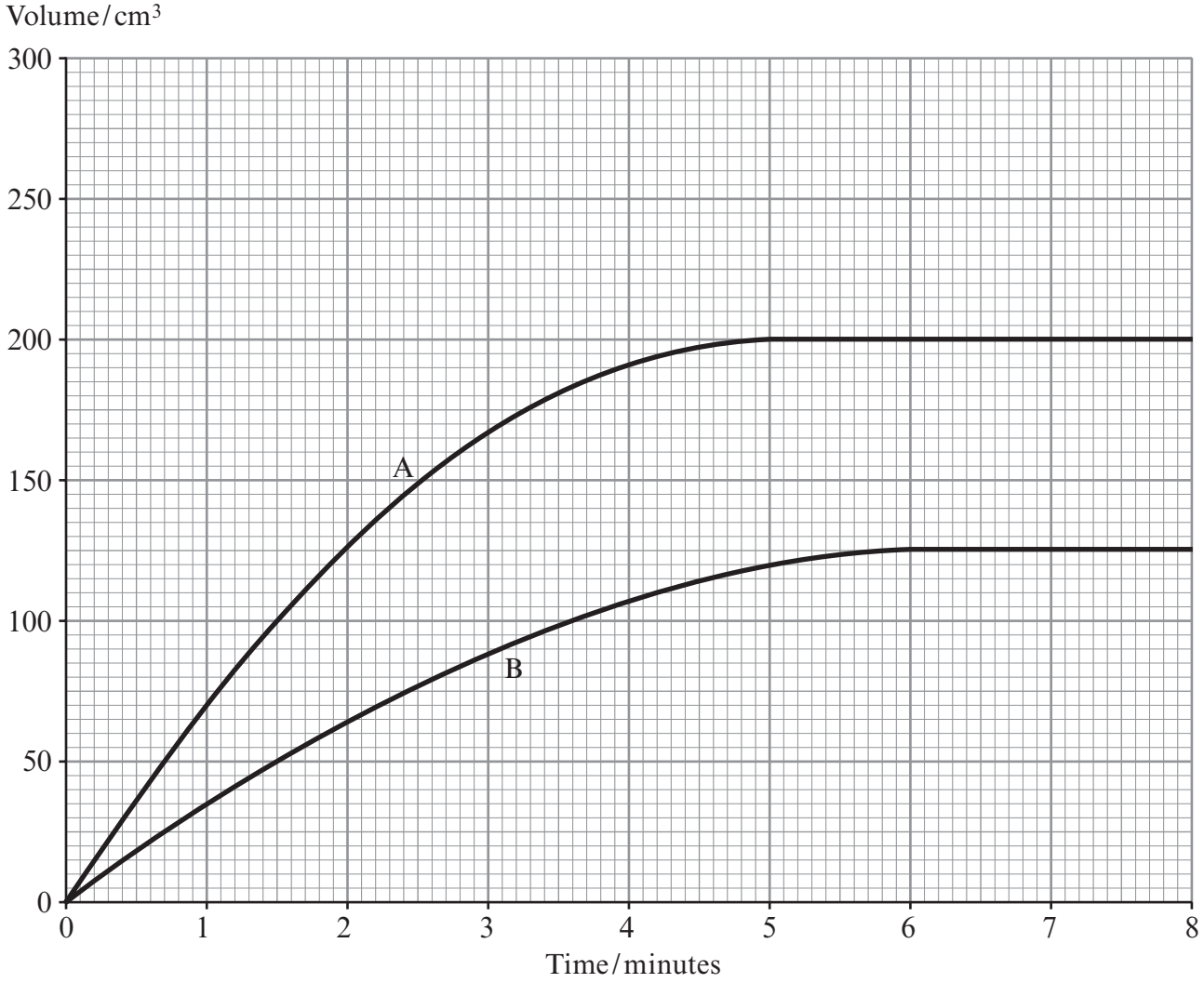
.....

Examiner only

8. Dolomite, $MgCO_3.CaCO_3$, is a mineral containing magnesium carbonate and calcium carbonate.

(a) Some students were asked to react samples of dolomite, each of mass 0.50 g, with an excess of dilute hydrochloric acid and to follow the rate of the reaction by measuring the volume of carbon dioxide evolved at suitable time intervals.

(i) Line **A** on the graph shows Natalie's results. Her teacher said that this was correct. David's line is labelled **B**. Although his line represents his results, the teacher said that he must have done something wrong during the experiment to obtain these results.



Suggest and explain **two** things that he might have done wrongly to obtain these results. [2]

1. .....

.....

2. .....

.....

Examiner only

(ii) Explain why, in Natalie's experiment, 0.25 g of the dolomite has reacted in 1.5 minutes but the remaining 0.25 g has taken a further 3.5 minutes to react. [2]

.....

.....

.....

(iii) Emma asked what the volume of carbon dioxide collected from the samples would be if the temperature rose from 298 K to 323 K.
The teacher explained that, if the pressure remained the same, volume V (in cm^3) and temperature T (in Kelvin) were linked by the equation

$$V = k \times T \qquad \text{where k is constant.}$$

The volume of carbon dioxide evolved at 298 K is 130 cm^3. By finding the value of k, or by other means, calculate the volume of this carbon dioxide when its temperature is raised to 323 K. [2]

Volume of carbon dioxide = ... cm^3

600010
1601

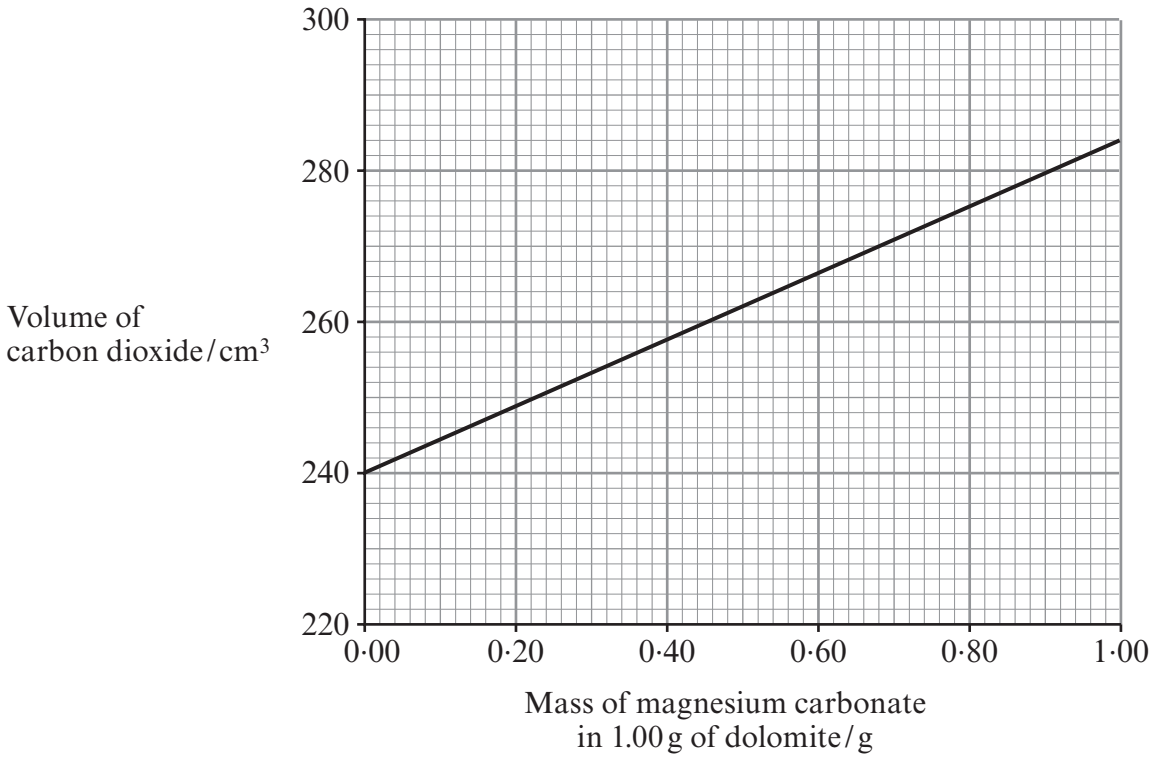
Examiner only

(b) In another experiment 0.623 g of dolomite reacted with an excess of dilute hydrochloric acid. The total volume of carbon dioxide evolved was 162 cm^3.

(i) Calculate the total volume of carbon dioxide that would be evolved if a sample of dolomite of mass 1.00 g was used under the same conditions. [1]

Volume of carbon dioxide = ... cm^3

(ii) Use the graph below to find the mass of magnesium carbonate present in this 1.00 g sample of dolomite. [1]



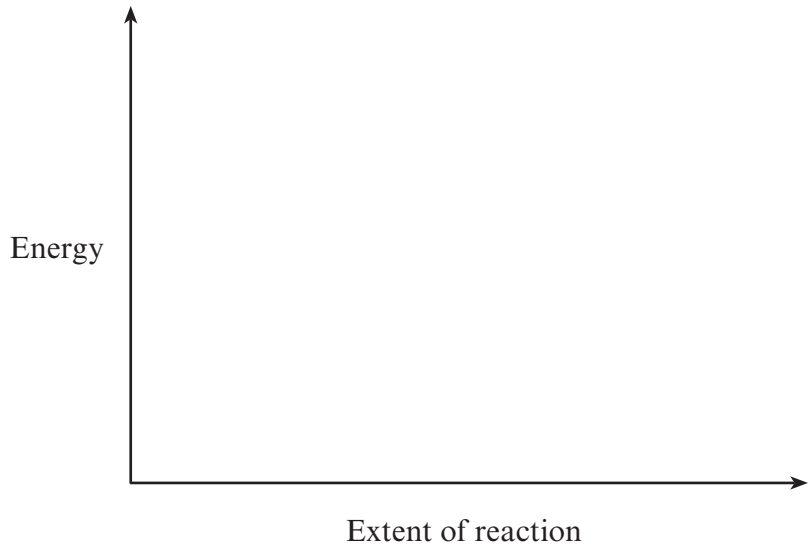
Mass of magnesium carbonate = ... g

Examiner only

(b) A new method for producing phenol, C_6H_5OH, is by reacting benzene, C_6H_6, with nitrogen(I) oxide at 400 °C in the presence of a suitable catalyst.

$$C_6H_6 + N_2O \longrightarrow C_6H_5OH + N_2 \qquad \Delta H = -286\,kJ\,mol^{-1}$$

(i) Sketch the energy profiles for the catalysed and uncatalysed reactions using the axes shown below.
Label your profiles as *catalysed* and *uncatalysed*. [2]



(ii) A pilot-scale plant used 156 kg of benzene ($M_r = 78$) to produce phenol ($M_r = 94$).

I Calculate the number of moles of benzene used. [1]

Moles of benzene = ... mol

II The yield of phenol was 95%. Using your answer to I and the equation below (or another suitable method), calculate the mass of phenol obtained. Show your working. [3]

$$C_6H_6 + N_2O \longrightarrow C_6H_5OH + N_2$$

Mass of phenol = ... kg

Examiner only

(c) Solid potassium hydroxide can be used in analysis to find the percentage of carbon dioxide present in a mixture of gases. The equation for the reaction that occurs is given below.

$$2KOH + CO_2 \longrightarrow K_2CO_3 + H_2O$$

2.0 m^3 of a gas mixture was passed through potassium hydroxide. Analysis showed that 0.050 mol of potassium carbonate had been formed.

(i) State the number of moles of carbon dioxide necessary to produce 0.050 mol of potassium carbonate. [1]

.....

(ii) Calculate the volume of carbon dioxide that produced 0.050 mol of potassium carbonate. [1]

[1 mol of carbon dioxide has a volume of 24.0 dm^3 under these conditions]

Volume of carbon dioxide = ... dm^3

(iii) Calculate the percentage of carbon dioxide in the gas mixture, in terms of volume. [2]

[1 dm^3 = 0.001 m^3]

Percentage of carbon dioxide = ... %

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

7. Jewels such as diamonds, rubies and emeralds are highly valued but are all closely related to much less precious materials.

(a) Emeralds are a form of the mineral beryl, with their green colour due to the impurities present.

A sample of beryl contains 10.04% aluminium, 53.58% oxygen and 31.35% silicon by mass, with beryllium making up the remainder. Its molecular formula is $Al_2Be_xSi_6O_{18}$. Find the percentage by mass of beryllium in the compound and hence calculate the value of x in this formula. [3]

x = ...

(b) The most common form of carbon is graphite, however the element also exists in the form of diamond.

We can calculate the standard enthalpy change of reaction for making diamond from graphite using Hess' Law.

Reaction	Standard enthalpy change of reaction / kJ mol^{-1}
$C(diamond) + O_2(g) \longrightarrow CO_2(g)$	–395.4
$C(graphite) + O_2(g) \longrightarrow CO_2(g)$	–393.5

(i) State Hess' Law. [1]

.....

.....

Examiner only

(b) The first compound of a noble gas was formed from Xe atoms and PtF_6. It was the ionic compound $Xe^+ PtF_6^-$.

Explain why it is not possible to form a similar ionic compound of argon, $Ar^+ PtF_6^-$. [2]

.....

.....

.....

(c) Helium was identified in the Sun before it was discovered on Earth. When light from the Sun is split into its different colours by a prism, dark lines are observed against a coloured background which show the atomic absorption spectrum of helium. Explain how an atomic absorption spectrum forms. [2]

.....

.....

.....

.....

(d) Xenon trioxide, XeO_3, is a compound which decomposes explosively at 25 °C according to the following equation.

$$2XeO_3(s) \longrightarrow 2Xe(g) + 3O_2(g)$$

Calculate the volume of gas, in dm^3, released by the decomposition of 1 mol of XeO_3 under these conditions. [2]

[1 mol of any gas at 25 °C occupies a volume of 24.0 dm^3]

Volume = ... dm^3

Total [10]

700010
1601

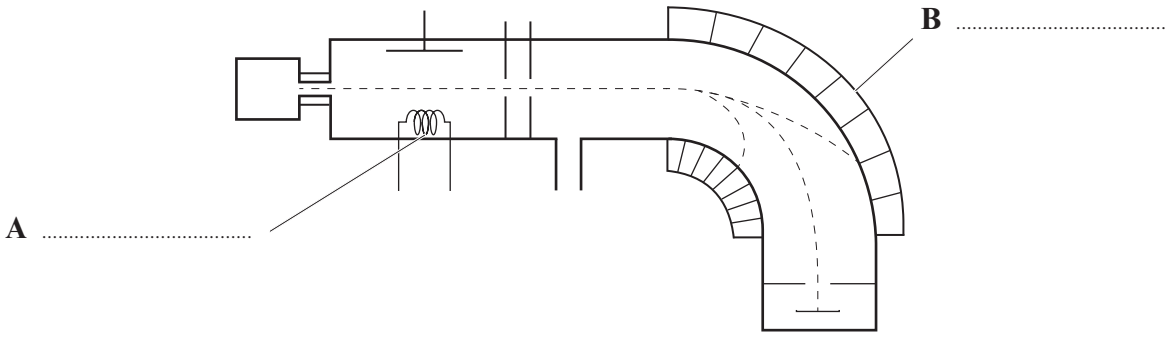
Examiner only

9. Selenium is a Group 6 element that is needed in the human body in trace amounts for the correct functioning of some enzymes. Only small amounts are required as large doses are harmful.

(a) A mass spectrometer can be used to find the relative atomic mass of a sample of selenium. The following diagram shows a typical mass spectrometer.

(i) Label parts **A** and **B**. [1]

(ii) Describe what happens to a sample introduced into the mass spectrometer. [4]
QWC [2]



Examiner only

(b) Some selenium is found amongst the decay products in a nuclear reactor. The mass spectrum found for this sample of selenium had the isotopic composition below.

Isotope	Abundance
^{78}Se	12.2%
^{79}Se	26.4%
^{80}Se	61.4%

Calculate the relative atomic mass of this sample of selenium.
Give your answer to **3 significant figures**. [3]

Relative atomic mass = ...

(c) ^{81}Se is a radioactive isotope of the element selenium, which decays by β-emission with a half life of 18.75 minutes.

(i) The decay of ^{81}Se is shown by the equation below.

$$^{81}Se \longrightarrow {}^{a}X + {}^{0}_{-1}\beta$$

Identify a and X in this equation. [1]

a ..... X .....

(ii) 2.72 g of ^{81}Se is used by a scientist for an experiment. Calculate the mass of ^{81}Se that would remain after 75 minutes. [2]

Mass = ... g

Total [13]

Examiner only

(d) Ethanoic acid, CH_3COOH, is one of the most familiar compounds used as a flavouring and preservative for food. Originally ethanoic acid was produced by oxidation of ethanol by bacteria in the presence of air (route **A** below). Today there are many other possible routes and three of these are shown as routes **B**, **C** and **D** below.

Route	Carbon-containing starting materials	Conditions	Overall equation	Atom economy
A	ethanol		$C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O$	76.9%
B	methanol, carbon monoxide	150 °C, 30 atm	$CH_3OH + CO \rightleftharpoons CH_3COOH$	100.0%
C	butane	150 °C, 55 atm	$2C_4H_{10} + 5O_2 \rightarrow 4CH_3COOH + 2H_2O$	87.0%
D	sugars		$C_6H_{12}O_6 \rightarrow 3CH_3COOH$	

(i) State the atom economy of route **D** for production of ethanoic acid. [1]

.....

(ii) Route **B** is the route most commonly used for producing ethanoic acid today for both financial and *Green Chemistry* reasons. Apply the principles of *Green Chemistry* to the information above to give **two** reasons why route **B** is favoured over route **C**. [2]

1. .....

.....

2. .....

.....

(iii) Route **B** uses a homogeneous catalyst. State what effect the catalyst will have on the position of this equilibrium. [1]

.....

.....

Total [17]

Section B Total [70]

Examiner only

5. Silver tarnishes because it reacts with hydrogen sulfide in the air to form silver sulfide.

A 1.24 g sample of silver sulfide contains 0.16 g of sulfur. Calculate the empirical formula of this compound. **Show your working**. [2]

Empirical formula .....

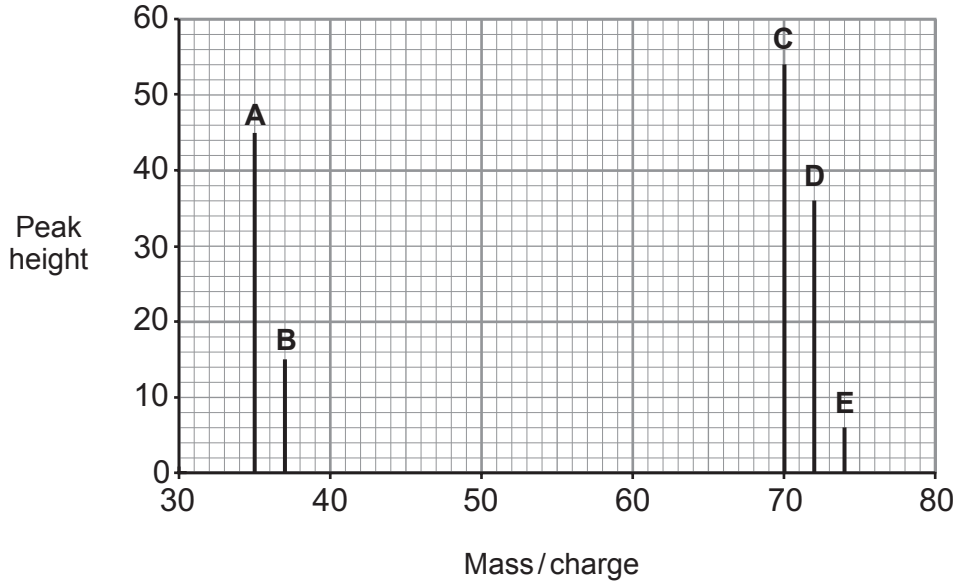
Section A Total [10]

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

6. *(a)* The mass spectrum of chlorine, Cl_2, is shown below.



(i) Identify the positive ions that are responsible for the peaks **B** and **C**. [2]

Peak **B** .....

Peak **C** .....

(ii) Use the mass spectrum to calculate the ratio of peak height **C** : peak height **E**. [2]

Ratio .....

(iii) Explain why the peak heights of **C** and **E** are in this ratio. [2]

.....

.....

.....

.....

.....

Examiner only

(b) Another element in Group 7 is bromine, Br.

Its mass spectrum shows that bromine has two naturally-occurring isotopes. The abundance of each isotope is given below.

Isotope	Percentage abundance / %
^{79}Br	50.69
^{81}Br	49.31

Calculate the relative atomic mass of bromine, giving your answer to **four** significant figures. [2]

Relative atomic mass = ...

Total [8]

Examiner only

(ii) One possible disadvantage of using magnesium hydride arises from its reaction with water.

$$MgH_2(s) + 2H_2O(l) \longrightarrow Mg(OH)_2(s) + 2H_2(g)$$

Suggest why magnesium hydride's reaction with water could be a problem. [1]

.....

.....

(iii) The fuel tank of one type of hydrogen-powered car holds 70 kg of magnesium hydride.
Calculate the volume of hydrogen gas, measured at room temperature and pressure, which would be produced if this amount of magnesium hydride reacted with water. [3]
[1 mol of gas molecules occupies 24 dm^3 at room temperature and pressure]

Volume of hydrogen gas = ... dm^3

(d) Methanol can be produced industrially by passing carbon monoxide and hydrogen over a catalyst at high temperatures and pressures.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91 \text{ kJ mol}^{-1}$$

(i) State how the equilibrium yield of methanol is affected by an increase in temperature and in pressure. [1]

.....

.....

(ii) Explain your answer to part (i). [2]

.....

.....

.....

.....

Examiner only

10. *(a)* Sodium carbonate can be manufactured in a two-stage process as shown by the following equations.

$$NaCl + NH_3 + CO_2 + H_2O \longrightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

Calculate the maximum mass of sodium carbonate which could be obtained from 900 g of sodium chloride. [3]

Maximum mass of sodium carbonate = ... g

(b) Sodium carbonate can form a hydrate, $Na_2CO_3.xH_2O$.

When 4.64 g of this hydrate was heated, 2.12 g of anhydrous Na_2CO_3 remained.

(i) State the mass of water in 4.64 g of the hydrate. [1]

.....

(ii) Calculate the number of moles of sodium carbonate and the number of moles of water in 4.64 g of the original hydrate. Use these values to calculate the value of x in $Na_2CO_3.xH_2O$. [2]

x = ...

QUESTION 10 CONTINUES ON PAGE 16

Examiner only

(c) Hannah is given an impure sample of anhydrous sodium carbonate and she carries out an experiment to determine the percentage of sodium carbonate in the sample.
She finds that she needs 18.0 cm^3 of hydrochloric acid of concentration 0.50 mol dm^{-3} to react completely with 0.55 g of the impure sample. The impurity does not react with hydrochloric acid. The equation for the reaction is given below.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

(i) Calculate the number of moles of HCl used in the titration. [1]

Number of moles of HCl = ... mol

(ii) Deduce the number of moles of Na_2CO_3 that reacted with the HCl. [1]

.....

(iii) Calculate the mass of Na_2CO_3 in the sample. [1]

Mass of Na_2CO_3 *in sample* = ... g

(iv) Calculate the percentage by mass of Na_2CO_3 in the sample. [1]

Percentage by mass = ... %

Total [10]

Section B Total [70]

END OF PAPER

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. Complete the electronic structure for the sulfide ion present in Na_2S. [1]

$1s^2$ .....

2. Which isotope is the standard used in defining relative atomic masses? [1]

.....

3. State **one** example of an industrially or environmentally important heterogeneous catalyst. You should identify the reaction catalysed and name the catalyst. [1]

.....

.....

4. Hydrated sodium carbonate has the formula $Na_2CO_3.10H_2O$.

(a) Calculate the relative molecular mass (M_r) of $Na_2CO_3.10H_2O$. [1]

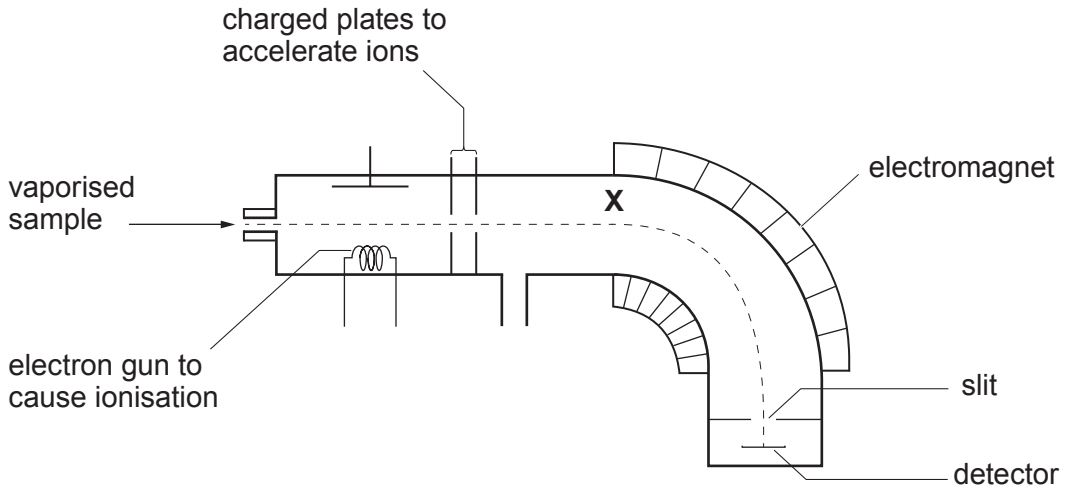
M_r = ...

(b) Calculate the mass of $Na_2CO_3.10H_2O$ needed to make 250 cm^3 of a 0.10 mol dm^{-3} solution. [1]

Mass = ... g

Examiner only

9. The diagram shows the principal parts in one type of mass spectrometer.



(a) (i) The line labelled **X** shows the path of ion **X** passing through the slit and being detected.

Ion **Y** has a higher mass to charge ratio than ion **X**. Draw a line on the diagram to show the path of ion **Y**. [1]

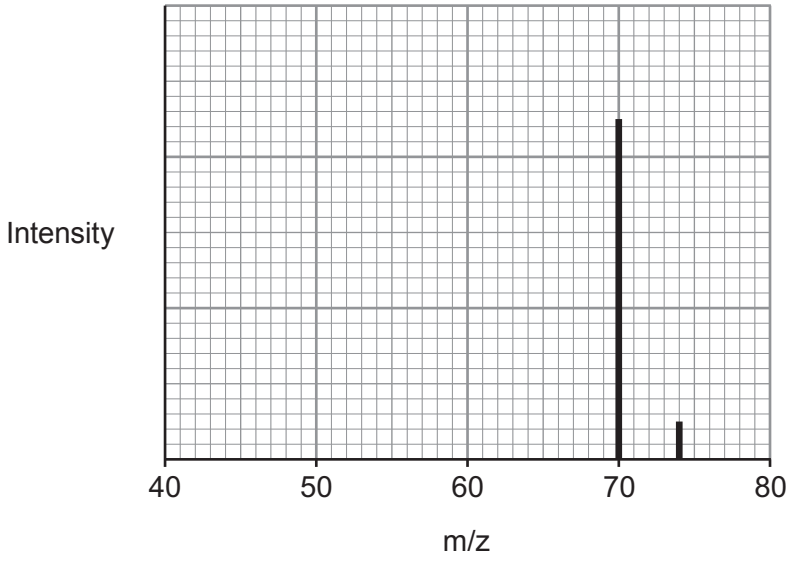
(ii) Without altering the shape of the mass spectrometer, what change could be made to allow ion **Y**, with its higher mass to charge ratio, to pass through the slit and be detected? [1]

.....

.....

Examiner only

(b) The diagram shows an incomplete mass spectrum for a sample of chlorine, Cl_2.



(i) What ion is responsible for the peak at m/z = 74? ..... [2]

(ii) Draw on the spectrum another peak that you would expect to see. You should show the mass to charge ratio at which you would see the peak **and** the height of the peak. [2]

(c) A compound **Z** contains only carbon, hydrogen and chlorine. It is analysed and found to contain 10.04 % carbon and 89.12 % chlorine by mass.

(i) Find the empirical formula of compound **Z**. [3]

Empirical formula .....

(ii) What other information would you need to decide whether this empirical formula is also the molecular formula of **Z**? [1]

.....

(iii) What feature of a mass spectrum gives the information needed in part (ii)? [1]

.....

.....

.....

Total [11]

1091 010009

Examiner only

(c) Hydrazine, N_2H_4, is an unstable liquid that decomposes according to the following equation.

$$N_2H_4(l) \longrightarrow N_2(g) + 2H_2(g)$$

(i) Calculate the volume of gas that could be obtained from 14 kg of hydrazine. Assume that the volume of 1 mol of gas is 24.0 dm^3. [3]

Volume of gas = ... dm^3

(ii) One use of hydrazine is as a fuel in rockets. Apart from any energy changes, state **one** feature of this reaction that suggests it would be useful in rocket propulsion. [1]

.....

.....

(d) Nitrogen (IV) oxide reacts with water.

$$H_2O + 2NO_2 \longrightarrow HNO_2 + HNO_3$$

Both nitric(III) acid, HNO_2, and nitric(V) acid, HNO_3, are described as being acids.

(i) Define an *acid*. [1]

.....

(ii) Complete the equation to show nitric(III) acid behaving as an acid. [1]

$$HNO_2 + H_2O \longrightarrow$$

(iii) When concentrated nitric(V) acid is mixed with concentrated sulfuric acid the reaction shown below occurs.

$$HNO_3 + H_2SO_4 \longrightarrow H_2NO_3^+ + HSO_4^-$$

Explain this reaction in terms of acid-base behaviour. [2]

.....

.....

Total [14]

Examiner only

(d) Other than by using an indicator, how would the student know that hydrochloric acid was in excess? [1]

.....

.....

(e) (i) Use the graph to calculate how many moles of magnesium carbonate reacted with the hydrochloric acid. [2]

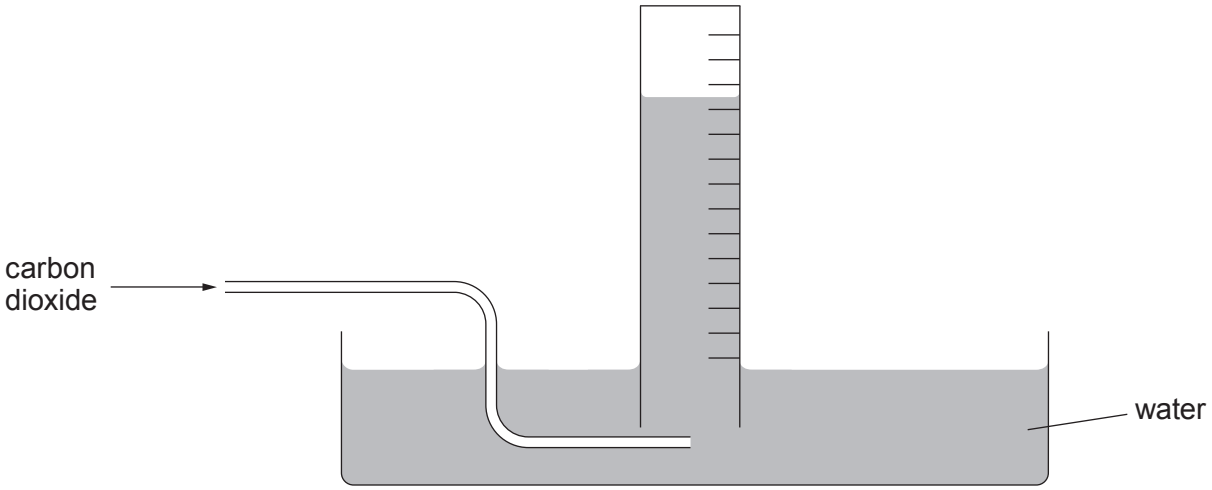
Number of moles $MgCO_3$ = ... mol

(ii) Find the mass of magnesium carbonate that reacted and hence the percentage of magnesium carbonate present in hydromagnesite. [2]

Percentage of magnesium carbonate = ... %

Examiner only

(f) A student wanted to carry out this experiment on another sample of hydromagnesite. He did not have a gas syringe and therefore he decided to collect the carbon dioxide over water in a measuring cylinder.



Explain what effect this would have on the results of the experiment. You should assume that the gas syringe and the measuring cylinder can both be read to the same precision. [2]

.....

.....

.....

.....

(g) When magnesium carbonate is heated it decomposes to make magnesium oxide and carbon dioxide.

$$MgCO_3(s) \longrightarrow MgO(s) + CO_2(g)$$

Magnesium oxide has a very high melting temperature and so can be used to line furnaces.

What is the atom economy for the production of magnesium oxide from magnesium carbonate? [2]

Atom economy = ... %

Total [14]

Section B Total [70]

END OF PAPER