Section A

Answer **all** questions.
Write your answers in the boxes provided at the end of the Section.

1 What is the empirical formula of a gas that contains 50% by mass of sulfur and 50% by mass of oxygen?

A SO

B SO_2

C SO_3

D S_2O

2 What is the maximum mass of chromium metal, Cr that can be extracted from 76 kg of chromium(III) oxide, Cr_2O_3? The equation is shown below:

$$2Cr_2O_3 \rightarrow 4Cr + 3O_2$$

A 24 kg **B** 48 kg **C** 52 kg **D** 104 kg

3 Molecules of hydrogen (H_2) and chlorine (Cl_2) are produced when hydrogen chloride (HCl) decomposes. The equation for the decomposition is shown below.

$$2HCl(g) \rightarrow H_2(g) + Cl_2(g)$$

Hydrogen chloride was added to a container which **already** contained some hydrogen.

After the hydrogen chloride has decomposed for some time, the final volumes of hydrogen chloride, hydrogen and chlorine in the container were determined. The volumes, measured in cm^3 at room conditions, before and after the reaction are shown in the table.

	HC*l*	**H_2**	**Cl_2**
before	200	20	0
after	***x***	100	80

What is the value ***x***?

A 0

B 20

C 40

D 160

4 A solution containing one mole of sodium hydroxide is added to a solution containing one mole of iron(III) sulfate. The equation is shown below:

$$Fe_2(SO_4)_3(aq) + 6NaOH(aq) \rightarrow 2Fe(OH)_3(s) + 3Na_2SO_4(aq)$$

What is the number of moles of iron(III) hydroxide precipitated?

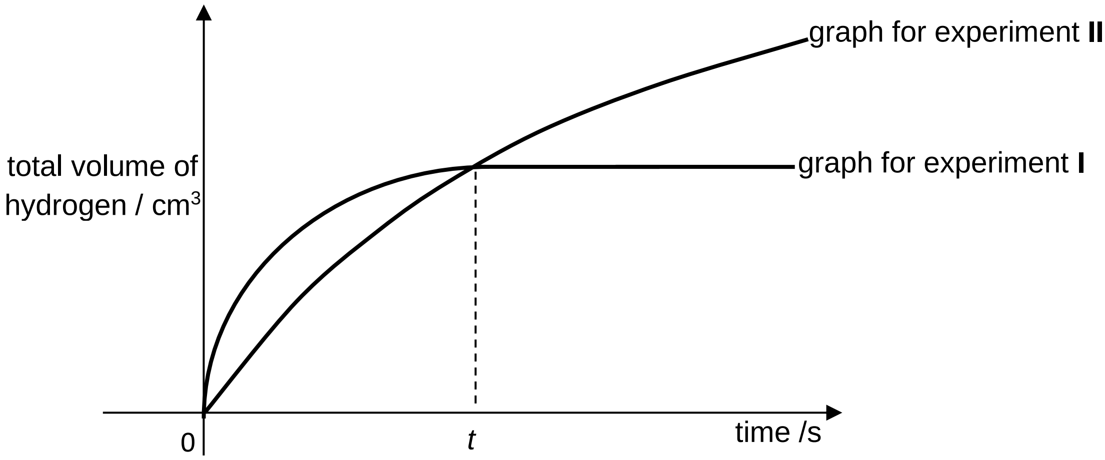
A $\frac{1}{3}$

B $\frac{1}{2}$

C $\frac{1}{6}$

D 3

5 In two experiments to study the rate of reaction between dilute hydrochloric acid and excess zinc powder, the total volume of hydrogen formed was measured at regular time intervals and graphs were plotted from the results.



What can be deduced from the graphs?

1 The acid in experiment **I** was more concentrated than in experiment **II**.

2 After time *t*, the reaction in experiment **II** was still proceeding.

3 The rate of evolution of hydrogen was the same in both experiments at time *t*.

A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

Question	1	2	3	4	5
Answer					

Section B
Answer **all** questions.
Write your answers in the spaces provided.

For Examiner's Use

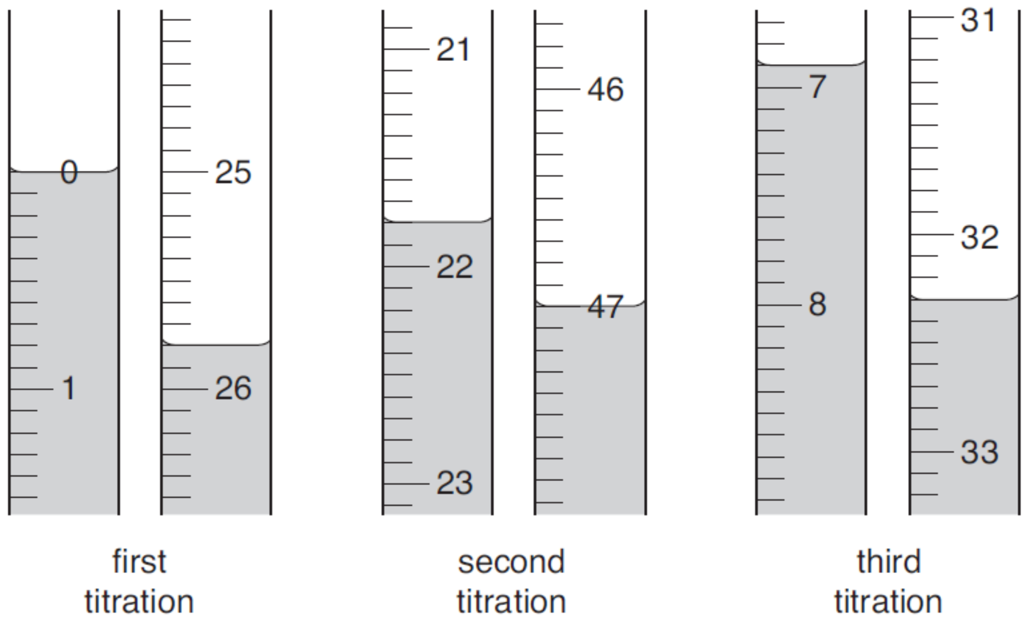
6 A student was given a sample of a metal hydroxide of formula, **B**$(OH)_2$.
The student was asked to identify the element **B** by titrating an aqueous solution of **B**$(OH)_2$ with 0.095 mol/dm^3 nitric acid.

A sample of **B**$(OH)_2$ was placed in a weighed container, which was reweighed.
mass of container + **B**$(OH)_2$ = 10.94 g
mass of container = 8.89 g

The sample of **B**$(OH)_2$ was transferred to a flask and made up to 250 cm^3 with water.
This was solution **S**.

25.0 cm^3 of **S** was transferred to a conical flask.
A few drops of methyl orange indicator were added.
Nitric acid was added from a burette until an end-point was reached.

Three titrations were done. The diagrams below show parts of the burette with the liquid levels before and after each titration.



(a) Use the diagrams to complete the table.

titration	first	second	third
final reading / cm^3	25.80		
initial reading / cm^3	0.00		
volume of acid used / cm^3			
best results (✓)			

Using the best results, average volume of acid used = ……………………… cm^3 [3]

For Examiner's Use

(b) The equation for the reaction is shown.

B$(OH)_2 + 2HNO_3 \rightarrow$ **B**$(NO_3)_2 + 2H_2O$

Calculate the number of moles of the alkali **B**$(OH)_2$ in 25.0 cm^3 of **S**.

[2]

(c) Calculate the number of moles of **B**$(OH)_2$ in the original 250 cm^3 of **S**.

[1]

(d) Hence find the relative molecular mass, M_r of **B**$(OH)_2$.

[2]

(e) Calculate the relative atomic mass, A_r of **B**, and hence identify element **B**.

[2]

Element **B** is ……………………………….

[Total: 10]

For Examiner's Use

7 **(a)** Sandstone contains sand (mainly silicon dioxide) and calcium carbonate.
12.00 g of sandstone was added to an excess of dilute hydrochloric acid.

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

The rate of the reaction was followed by measuring the mass lost during the reaction.

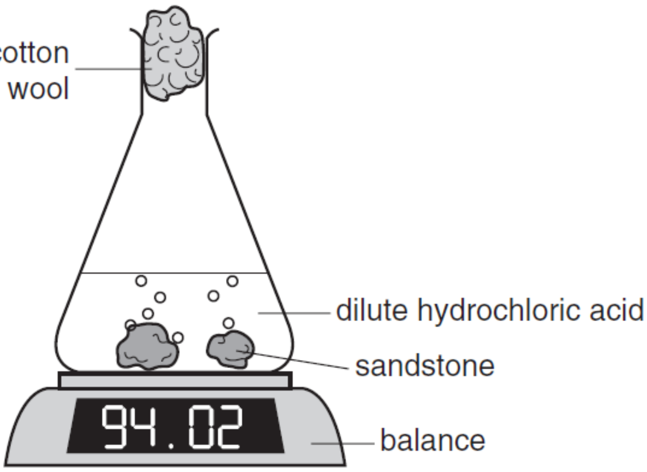


Table 8.1 shows the results.

Table 8.1

time / min	total mass lost / g
0	0.00
2	0.32
4	0.56
6	0.77
8	0.93
10	1.04
12	1.10
14	1.10
16	1.10

(i) How does the data show that the rate of reaction decreased with time?

....

.... [1]

(ii) Show by calculations that the percentage by mass of the calcium carbonate in the sandstone is 20.8%.

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[3]

(b) Four experiments were performed using an equal mass of magnesium metal (an excess) and an acid. For each, the time taken for the reaction to complete was measured. Table 8.2 shows the experimental conditions and the results.

Table 8.2

experiment	acid used	volume of acid in cm^3	concentration of acid in mol/dm^3	temperature / ^oC	time / min
2	HCl	50	1.00	25	9
3	HCl	100	1.00	35	7
4	H_2SO_4	50	1.00	35	5
5	H_2SO_4	100	1.00	35	5

(i) How does the data show that the volume of the acid used does not affect the rate of the reaction?

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.... [1]

(ii) Use ideas about collisions between particles to explain the differences in the reaction rate of the experiments shown in Table 8.2.

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.... [4]

[Total: 10]

For Examiner's Use

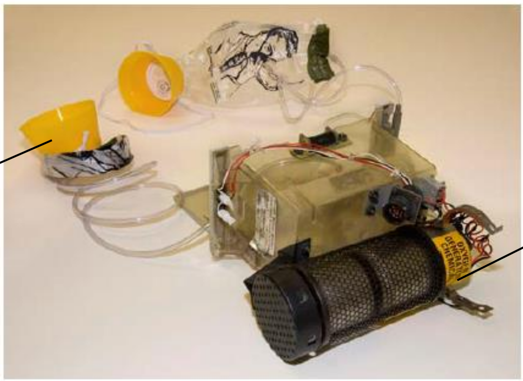
Section C

Answer **all** questions.
Write your answers in the spaces provided.

8 Life-Saving Devices

Oxygen Generators

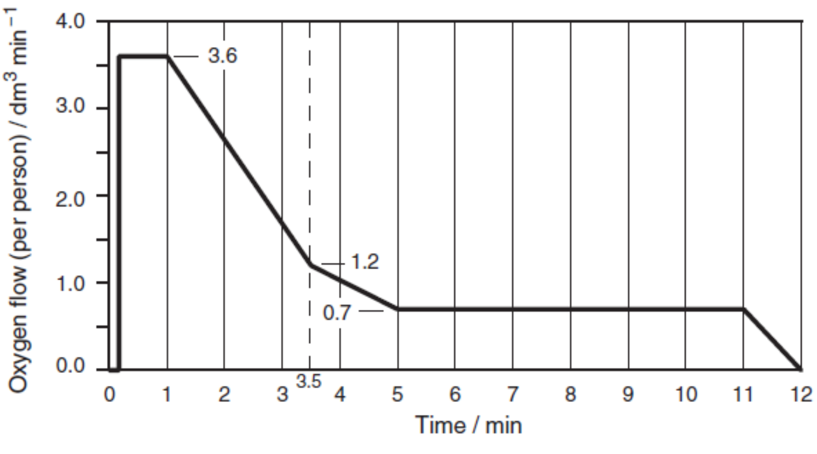
Rather than carrying heavy high-pressure oxygen cylinders, most aircraft rely on chemically generated oxygen in the event of an emergency.



These generators (in the overhead compartments of the aircraft) typically compose of a mixture of sodium chlorate, $NaClO_3$, iron powder, Fe and barium peroxide, BaO_2. Once initiated, the sodium chlorate undergoes thermal decomposition producing oxygen gas. The iron combines with some of the oxygen to sustain the decomposition process. During the production of oxygen, the generator becomes extremely hot and should not be touched.

When a mask is deployed, the flow rate of oxygen gas is designed to change over time as the aircraft descends to a safe altitude. Oxygen supply typically lasts at least 10 minutes.

Graph 1 gives information on the typical supply rate from one such oxygen generator.



Graph 1

10 seconds after activation, the oxygen supply rate reaches its maximum of 3.6 dm^3 / min.

Airbags

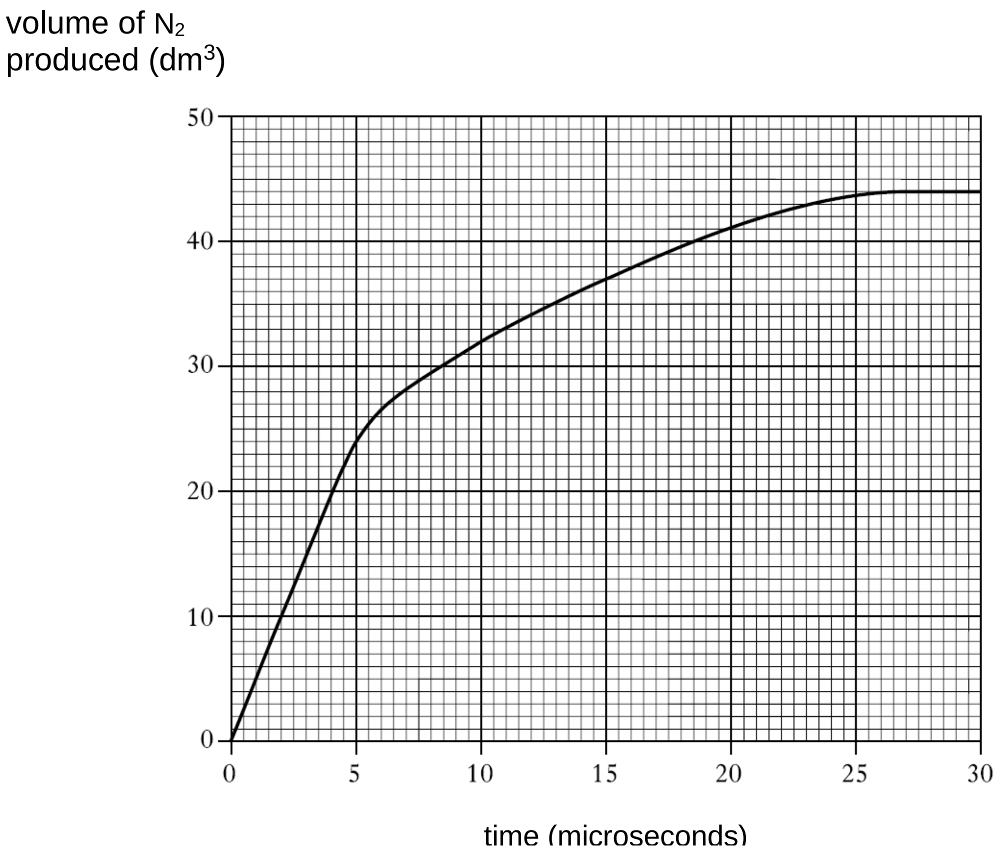
Timing is everything in an airbag's ability to deploy quickly enough to save a life in a head-on collision. An airbag must be able to deploy in a matter of milliseconds from the initial collision impact. Inside the airbag is a gas generator containing a mixture of NaN_3, KNO_3, and SiO_2. When the car undergoes a head-on collision, a series of three chemical reactions inside the gas generator produce gas (N_2) to fill the airbag and convert NaN_3, which is highly toxic, to harmless glass.

Sodium azide, NaN_3 can decompose at 300ºC to produce sodium metal and nitrogen gas. The signal from the deceleration sensor ignites the gas-generator mixture by an electrical impulse, creating the high-temperature condition necessary for NaN_3 to decompose.

The nitrogen gas, N_2 that is produced then rapidly fills the airbag in the vehicle.

Reaction 1: $2NaN_3 \rightarrow 2Na + 3N_2$

Graph 2 gives information on the rate of **Reaction 1**.

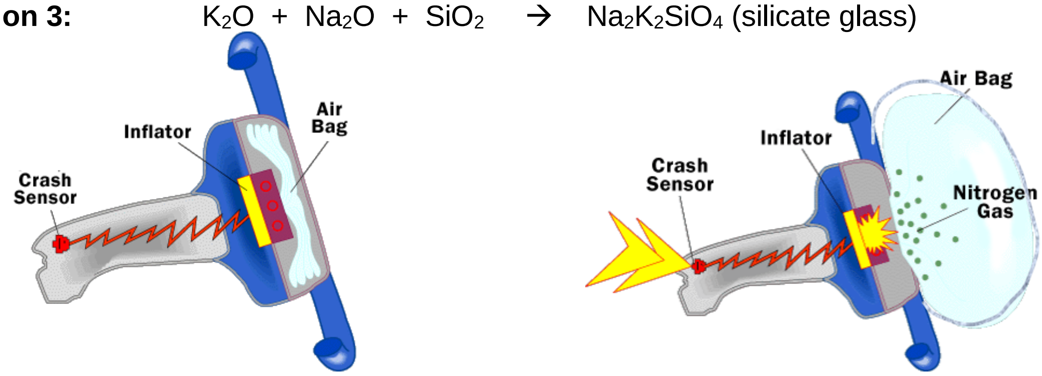


Graph 2

The purpose of the KNO_3 and SiO_2 is to remove the sodium metal (which is highly reactive and potentially explosive) by converting it to a harmless material. First, the sodium reacts with potassium nitrate to produce potassium oxide, sodium oxide, and additional N_2 gas. The N_2 generated in this second reaction also fills the airbag, and the metal oxides react with silicon dioxide in a final reaction to produce solid silicate glass, which is harmless and stable.

Reaction 2: $10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$

Reaction 3: $K_2O + Na_2O + SiO_2 \rightarrow Na_2K_2SiO_4$ (silicate glass)



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(a) Describe, **using data from Graph 1**, how the rate of oxygen supply changes in the first 10 minutes when the oxygen mask is activated.

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.... [3]

(b) **(i)** The average rate of a reaction can be estimated by finding the gradient of the graph. Calculate the average rate of reaction, in dm^3 / microseconds, between 5 and 10 microseconds for **Reaction 1** in the airbag.

[1]

(ii) A typical airbag contains 130 g of sodium azide. Using information from reactions 1, 2 and 3, calculate the **total** volume of nitrogen gas produced at room temperature and pressure as the airbag is inflated.

[4]

(c) One similarity in the chemistry behind the oxygen generator and the airbag is that both involve reactions that release gases.

Describe **two** other similarities in the chemistry of the reactions behind the oxygen generator and the airbag.

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.... [2]

[Total: 10]

End of Paper****