SEC 4E CHEMISTRY 6092

TERM 1 WA1 MARK SCHEME

Question	1	2	3	4	5
Answer	B	C	C	A	B

<table>
<tr><td colspan="4">SECTION B [20 marks]</td><td></td></tr>
<tr><td>6</td><td>(a)</td><td></td><td>
<table>
<tr><td>titration</td><td>first</td><td>second</td><td>third</td></tr>
<tr><td>final reading / cm^3</td><td>25.80</td><td>47.00</td><td>32.30</td></tr>
<tr><td>initial reading / cm^3</td><td>0.00</td><td>21.80</td><td>6.90</td></tr>
<tr><td>volume of acid used / cm^3</td><td>25.80</td><td>25.20</td><td>25.40</td></tr>
<tr><td>best results (✓)</td><td></td><td>✓</td><td>✓</td></tr>
</table>
Deduct (1) for 1 d.p.
average volume of acid used = 25.30 cm^3</td><td>1
1
1</td></tr>
<tr><td></td><td>(b)</td><td></td><td>Moles of HNO_3 = C × V = 0.095 × 0.0253 = 0.0024
Moles of $B(OH)_2$ = 0.0024 / 2 = 0.0012</td><td>1
1</td></tr>
<tr><td></td><td>(c)</td><td></td><td>0.0012 × 10 = 0.012 mol</td><td>1</td></tr>
<tr><td></td><td>(d)</td><td></td><td>Mass of $B(OH)_2$ = 10.94 – 8.89 = 2.05 g
M_r of $B(OH)_2$ = 2.05 / 0.012 = 171</td><td>1
1</td></tr>
<tr><td></td><td>(e)</td><td></td><td>Ar of B = 171 – 17(2) = 137
B is barium</td><td>1
1</td></tr>
<tr><td></td><td></td><td></td><td></td><td>10</td></tr>
<tr><td>7</td><td>(a)</td><td>(i)</td><td>Mass difference between readings decreased during reaction shows that the rate of reaction decreased with time
ALLOW: a mathematical calculation of rate per minute

NOTE: Mass lost increases with time, but the rate of mass lost decreases with time</td><td>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Total mass lost = Total mass of CO_2 produced = 1.10 g
No. of moles of CO_2 produced = $\frac{1.10}{44}$ = 0.025 mol
No. of moles of $CaCO_3$ = 0.025 mol (1:1)
Mass of $CaCO_3$ = 0.025 × 100 = 2.5 g
% by mass of calcium carbonate in the marble sample = $\frac{2.5}{12} \times 100\%$ = 20.8%</td><td>1
1

1</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>Experiments 4 and 5 show that varying the volume of the acid does not affect the reaction time.</td><td>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>More reacting particles have the activation energy / Reacting particles move faster in experiment 3 than 2.
Particles collide more frequently / More (effective) collisions per unit time

HCl is a monobasic acid / produces 1 H^+ ion per acid molecule
H_2SO_4 is a dibasic acid / produces 2 H^+ ions per acid molecule
ALLOW: H_2SO_4 produces more H^+ ions than HCl
More H^+ ions per unit volume / Higher concentration of H^+ ions in experiment 4 (or 5) than experiment 3.
Particles collide more frequently / More (effective) collisions per unit time</td><td>1
1

1

1
1</td></tr>
<tr><td></td><td></td><td></td><td></td><td>10</td></tr>
</table>

SECTION C [10 marks]				
8	**(a)**		Any three: (MUST quote figures from graph) supply rate is a maximum at 3.6 dm^3/min for the 1st minute supply rate decreases steadily to 1.2 dm^3/min after 3.5 minutes supply rate decreases further to 0.7 dm^3/min after 5 minutes supply rate remains constant at 0.7 dm^3/min for next 6 minutes	**3**
	(b)	**(i)**	average rate of reaction = gradient = (32 – 24) / 5 = 1.6 (ALLOW 1.5 – 1.7)	**1**
		(ii)	moles of NaN_3 = 130 / 65 = 2 (1) moles of N_2 formed in reaction 1 = 3 (1) moles of Na formed in reaction 1 = 2 moles of N_2 formed in reaction 2 = 0.2 total moles of N_2 = 3 + 0.2 = 3.2 (1) total volume of N_2 = 3.2 × 24 = 76.8 dm^3 (1)	**4**
	(c)		Any two: (ALLOW other reasonable responses) Both involve decomposition (of solid reactants) Both require a high temperature to start the reaction Both involve irreversible reactions Both involve very fast reactions Both produce harmful / dangerous side products	**2**
				10

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

mtd ①:

100g	S	O
mass	50g	50g
÷ Ar	1.56	3.125
÷ Smaller ratio	1	2

∴ Ans: SO_2

mtd ②: (Trial and error)

M_r, SO = 48

$\%S = \frac{32}{48} \times 100\% \neq 50\%$

M_r, SO_2 = 64

$\%S = \frac{32}{64} \times 100\% = 50\%$

∴ Ans: SO_2

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:

M_r, Cr_2O_3 = 2(52) + 3(16) = 152

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

$\frac{76 \times 1000}{152} \times \frac{4}{2} \times 52 = 52kg$ #

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.

	HCl	**H_2**	**Cl_2**
before	200	20	0
after	***x***	100	80

80 cm^3 produced

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

$HCl(g) : Cl_2(g)$

2 : 1

160 cm^3 : 80 cm^3

∴ $x = 200 - 160$

$= 40 cm^3$ #

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:

1 mole 1 mole

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

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

Limiting reactant : NaOH (aq)

NaOH (aq) : Fe(OH)3 (s)

6 : 2

1 : $\frac{1}{6} \times 2 = \frac{1}{3}$ #

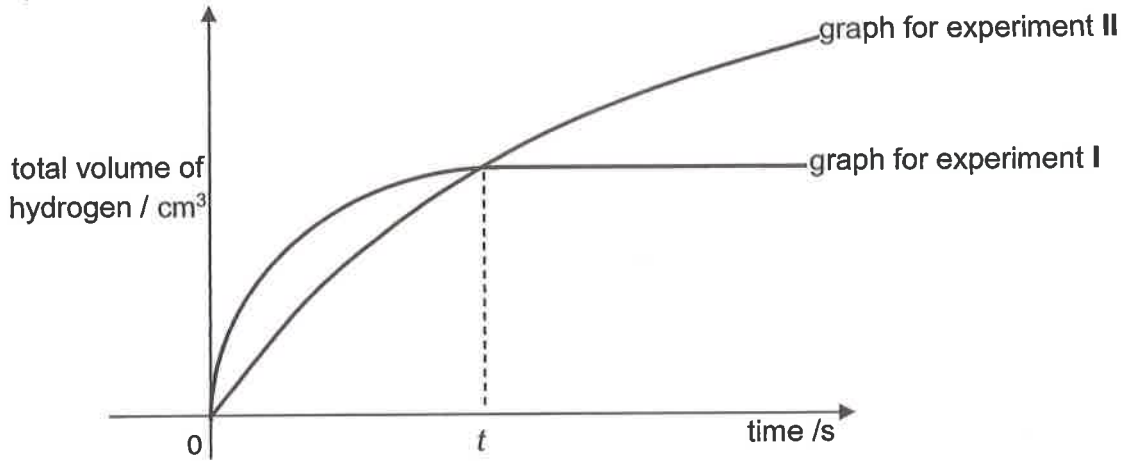
A $\frac{1}{3}$

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*.

gradient

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	B	C	C	A	B

For Examiner Use

Section B

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

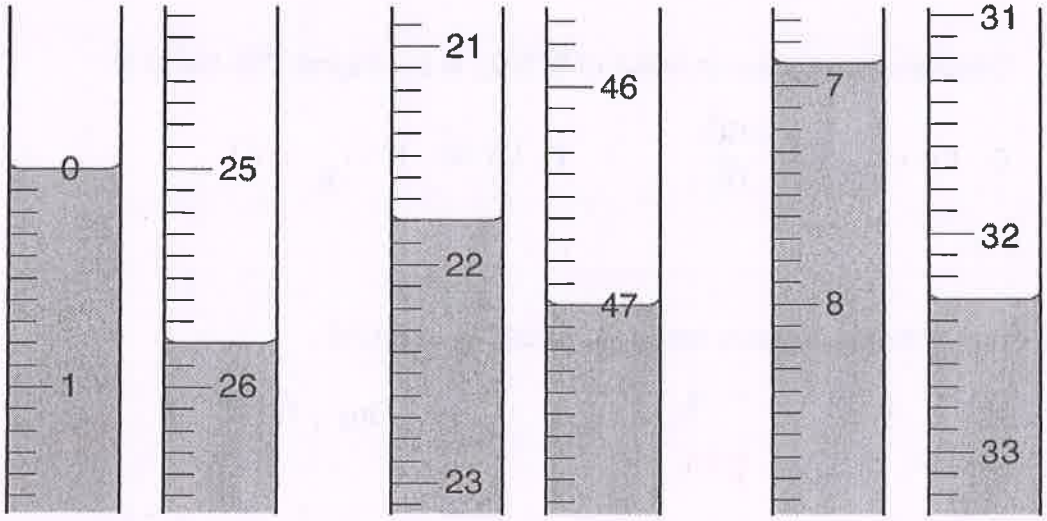
6 A student was given a sample of a metal hydroxide of formula, **B**$(OH)_2$.
The student was asked to identify the element **B** by titrating an aqueous solution of **B**$(OH)_2$ with 0.095 mol/dm^3 nitric acid.

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.



first titration | second titration | third titration

(a) Use the diagrams to complete the table.

titration	first	second	third
final reading / cm^3	25.80	47.00	32.30
initial reading / cm^3	0.00	21.80	6.90
volume of acid used / cm^3	25.80	25.20	25.40
best results (✓)		✓	✓

-[1] if id.

[1]

No 2 ✓
-[1]

Using the best results, average volume of acid used = 25.30 [1] cm^3 [3]

For Examiner 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**.

$V, HNO_3 = 25.30 cm^3$ $\quad V, S = 25.0 cm^3$

$C, HNO_3 = 0.095 mol/dm^3$

$B(OH)_2 : HNO_3$

$1 : 2$

$mol, HNO_3 = C \times V$

$= 0.095 \times \frac{25.30}{1000}$

$= 0.00240 mol$ [1]

$\therefore mol, B(OH)_2 = \frac{0.00240}{2}$

$= 0.00120 mol$ # [1]

[2]

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

$0.00120 \times \frac{250}{25} = 0.0120 mol$ # [1]

[1]

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

$mass, B(OH)_2 = 10.94g - 8.89g$

$= 2.05g$ [1]

$Mr, B(OH)_2 = \frac{170.8}{(171)}$ # [1]

$0.0120 mol \text{ — } 2.05g$

$1 mol \text{ — } 170.8g$ (171)

[2]

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

Ar of B = $170.8 - 2[16+1]$

$= 136.8$

≈ 137 [1]

Element **B** is ..... Barium, Ba [1]

Not to give without working.

[2]

[Total: 10]

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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.

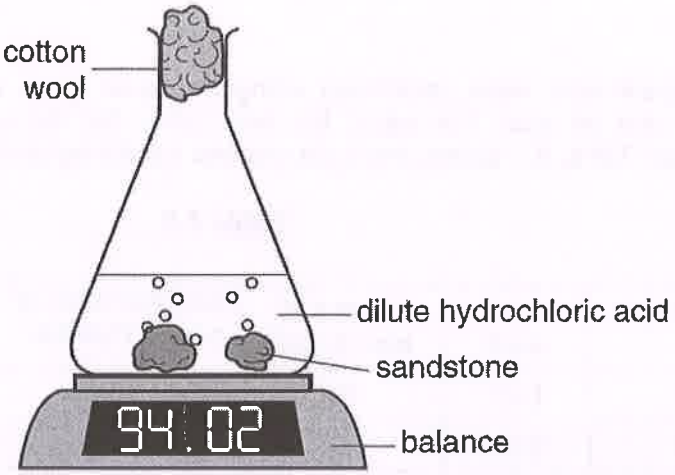


Table 8.1 shows the results.

Table 8.1

time / min	total mass lost / g
0	0.00
2	0.32 ↑ 0.32g
4	0.56 ↑ 0.24g
6	0.77 ↑ 0.21g
8	0.93 ↑ 0.16g
10	1.04 ↑ 0.11g
12	1.10 ↑ 0.06g
14	1.10 ↑ 0g
16	1.10

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

difference in mass lost per minute decreases [1]

.....

..... [1]

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

Total loss in mass = 1.10g [1]
due to CO_2 ↑

mol, CO_2 = $\frac{1.10}{44}$ = 0.025 [1]

$CO_2(g) : CaCO_3(s)$
1 : 1

∴ mol, $CaCO_3$ = 0.025
mass, $CaCO_3$ = 2.5g

%mass, $CaCO_3$
= $\frac{2.5}{12} \times 100\%$
= 20.8% (shown) [1]

For Examiner Use

[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 / °C	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?

using experiment 4 and 5, H_2SO_4. [1]

volume different but same acid, concentration, temperature, time taken same [1]

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

Expt 3,5 { HCl, monobasic ; H_2SO_4, dibasic } [1] H^+ in H_2SO_4 > H^+ in HCl [1]

① [reacting particles] per unit volume OR concentration.

Expt 2,3, HCl: Higher T/°C [1] ② T/°C

particles possess greater K.E / more particles possess Ea [1]

∴ collide more frequently / greater # effective collisions per unit time [1]

[4] [5]

[Total: 10]

For Examiner Use

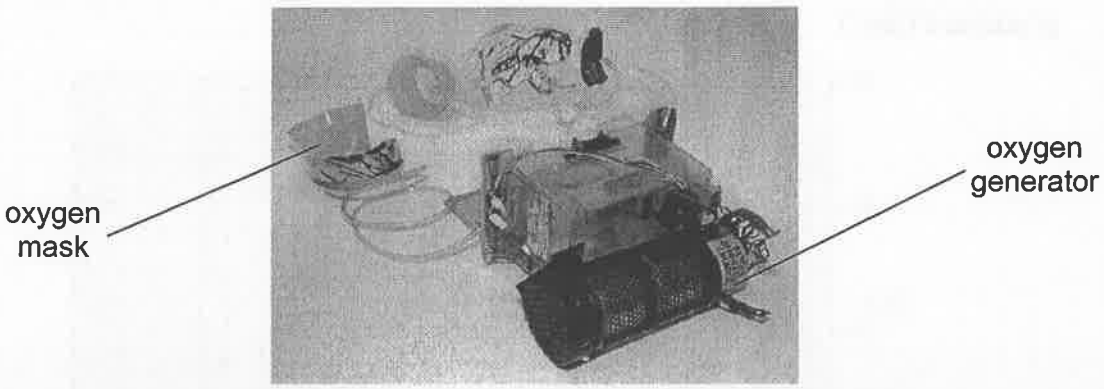
Section C

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

8 Life-Saving Devices

Oxygen Generators

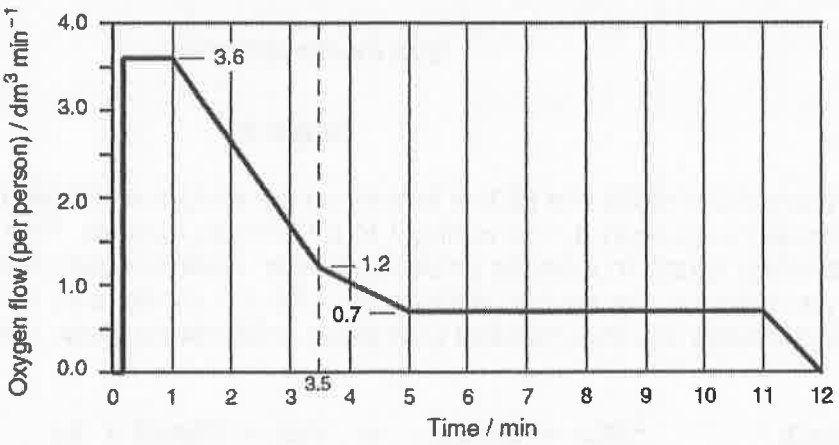
Rather than carrying heavy high-pressure oxygen cylinders, most aircraft rely on chemically generated oxygen in the event of an emergency.



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.

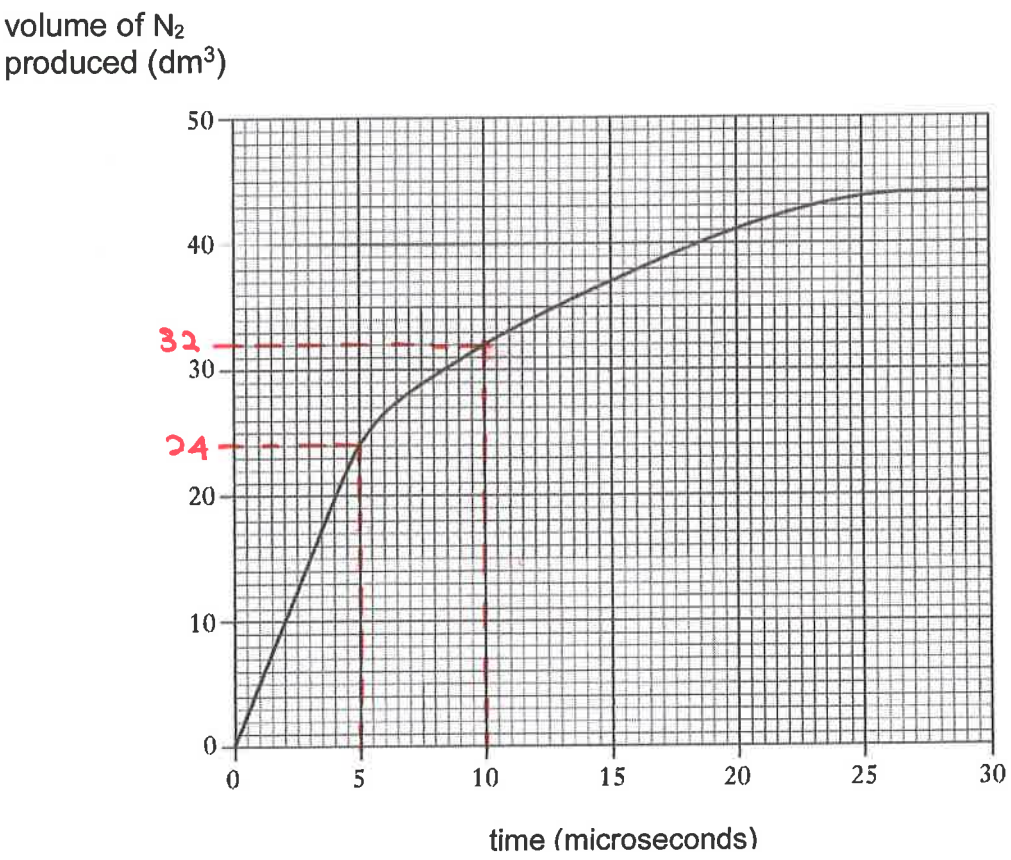
Sodium azide, NaN_3 can decompose at 300°C to produce sodium metal and nitrogen gas. The signal from the deceleration sensor ignites the gas-generator mixture by an electrical impulse, creating the high-temperature condition necessary for NaN_3 to decompose.

For Examiner Use

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**.

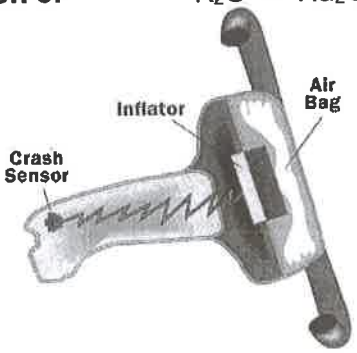


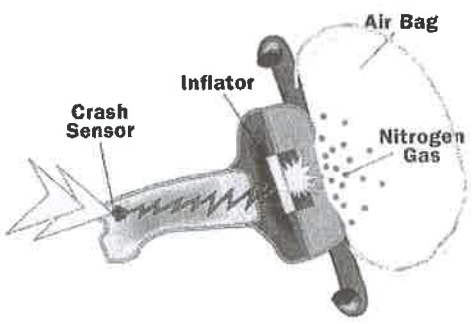
Graph 2

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.

Any 3 (must quote figures from graph)

Supply rate maximum at 3.6 dm^3/min for 1st minute

decreases (steadily) to 1.2 dm^3/min after 3.5 min

decreases (further) to 0.7 dm^3/min after 5 min

remains constant (at 0.7 dm^3/min) until 11th min

[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.

Graph 2

$\frac{32-24}{10-5} = 1.6\ dm^3$/microseconds.

Allow 1.5 – 1.7 dm^3/microseconds.

[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.

Reaction ①

M_r, NaN_3 = 65

mol, NaN_3 = $\frac{130}{65}$ = 2 [1]

$NaN_3 : N_2$

2 : 3

[1]

∴ 3 mol, N_2 produced

or 72 dm^3

Reaction ②

2 mol NaN_3 in ①

produced 2 mol, Na

In ②: Na : N_2

10 : 1

fr ① 2 : 0.2 [1]

0.2 mol, N_2 produced

or 4.8 dm^3

∴ total vol, N_2

= 72 + 4.8

= 76.8 dm^3 [1]

[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.

Any 2 :

① (thermal) decomposition

② irreversible (reactions)

③ very fast

ACCEPT :- Endothermic reaction

- Require high T/°C to start rxn

- Both produce harmful/dangerous side products.

[2]

[Total: 10]

**********End of Paper**********