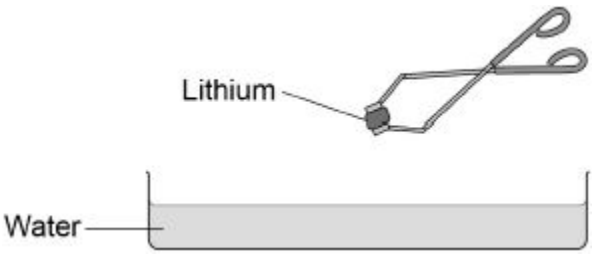
1 This question is about Group 1 elements.

A teacher demonstrated the reaction of Group 1 elements with water.

Figure 1 shows the apparatus.

Figure 1



(a) What name is given to Group 1 elements?

Tick **one** box.

Alkali metals ☐

Halogens ☐

Noble gases ☐

Non-metals ☐

(1)

(b) The teacher wore safety glasses and used tongs to handle the elements.

Suggest **one** other safety precaution the teacher should take.

_____

_____

(1)

Table 1 shows the teacher's results.

Table 1

Element	Observations
Lithium	• bubbles form • lithium moves slowly on surface
Sodium	• bubbles form • sodium moves quickly on surface • sodium melts to form a ball
Potassium	• bubbles form • potassium moves very quickly on surface • potassium melts to form a ball • a lilac flame is seen

(c) Describe the trend in reactivity in Group 1.

Give **two** observations from **Table 1** which provide evidence for the trend.

_____

_____

_____

_____

_____

_____

(3)

(d) Rubidium is a Group 1 element.

Rubidium is below potassium in the periodic table.

Suggest why the teacher did **not** demonstrate the reaction between rubidium and water.

_____

_____

(1)

(e) Complete the balanced equation for the reaction between sodium and water.

$$\_\_\_\_\_\ Na + \_\_\_\_\_ H_2O \longrightarrow \_\_\_\_\_\ NaOH + H_2$$

(1)

(f) What is the name of the compound with the formula NaOH?

Tick **one** box.

Sodium dioxide ☐

Sodium hydrate ☐

Sodium hydroxide ☐

Sodium oxide ☐

(1)

Table 2 shows the diameter of atoms of Group 1 elements.

Element	**Diameter of atom in nanometres**
Lithium	0.304
Sodium	0.372
Potassium	**X**
Rubidium	0.496
Caesium	0.530

(g) Predict value **X** in **Table 2**.

X = _____ nanometres

(1)

(h) 1 nanometre is 10^{-9} metres.

What is the diameter of a lithium atom in metres?

Tick **one** box.

3.04×10^{-8} m ☐

3.04×10^{-9} m ☐

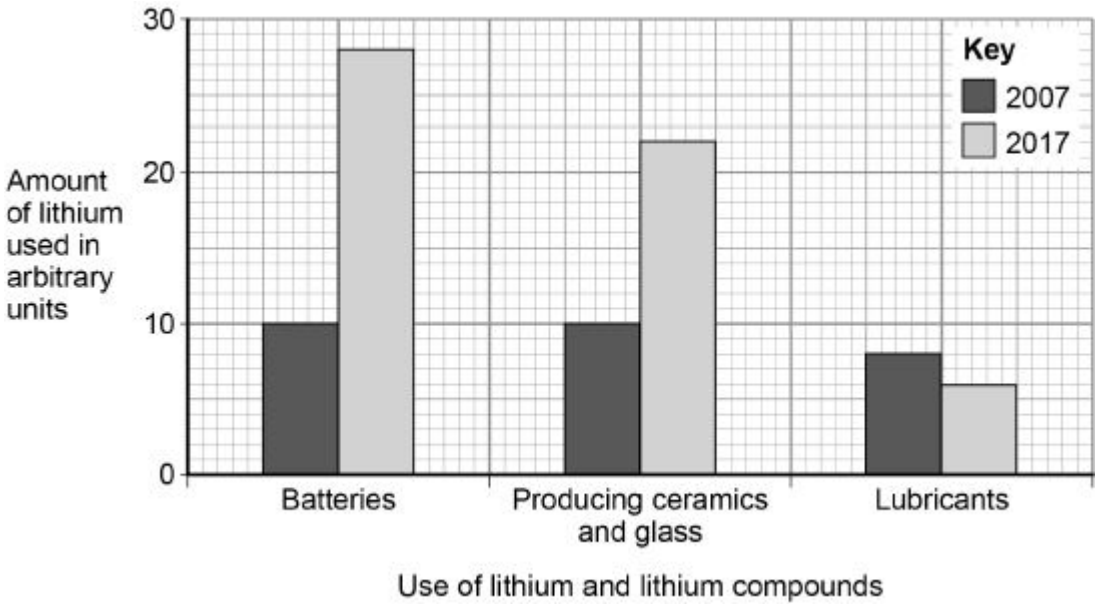
3.04×10^{-10} m ☐

3.04×10^{-11} m ☐

(1)

Figure 2 shows the use of lithium and lithium compounds in 2007 and 2017.

Figure 2



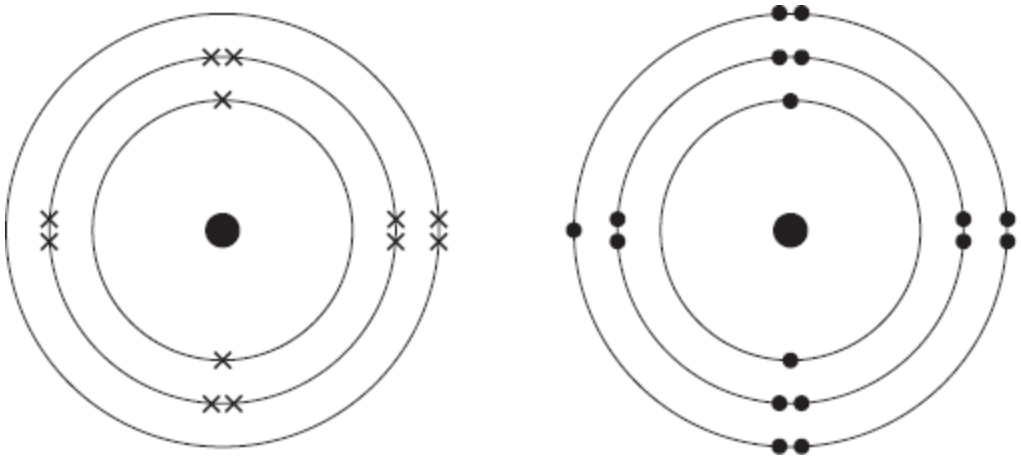
(i) Describe how the use of lithium and lithium compounds changed between 2007 and 2017.

You must include data from **Figure 2** in your answer.

(3)

(Total 13 marks)

2 (a) The diagram shows an atom of magnesium and an atom of chlorine.



Magnesium **Chlorine**

Describe, in terms of electrons, how magnesium atoms and chlorine atoms change into ions to produce magnesium chloride ($MgCl_2$).

(4)

(b) Calculate the relative formula mass (M_r) of magnesium chloride ($MgCl_2$).

Relative atomic masses (A_r): magnesium = 24; chlorine = 35.5

Relative formula mass (M_r) = _____

(2)

(Total 6 marks)

3 (a) Methane is burned in a plentiful supply of oxygen.

Which is the correct balanced chemical equation?

Tick **one** box.

$CH_4 + O_2 \rightarrow CO_2 + H_2O$ ☐

$CH_4 + 2O_2 \rightarrow CO_2 + H_2O$ ☐

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ ☐

$CH_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$ ☐

(1)

(b) Burning fuels causes atmospheric pollution.

Write **one** effect for each pollutant in **Table 1**.

Table 1

Pollutant	Effect
Carbon monoxide	
Sulfur dioxide	
Particulates	

(3)

(c) Methane, petrol and coal are fuels.

Table 2 shows information about these fuels.

Table 2

Fuel	State	Energy content in kJ per g	Mass in mg of CO_2 produced for one kJ of energy released
Methane	Gas	52	53
Petrol	Liquid	43	71
Coal	Solid	24	93

Evaluate the use of the fuels.

Use in the information in **Table 2** and your knowledge.

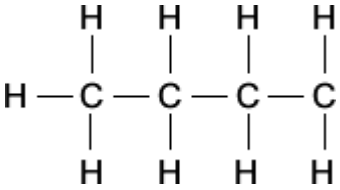
(6)

(Total 10 marks)

4 Crude oil is a mixture of hydrocarbons. Most of these hydrocarbons are alkanes.

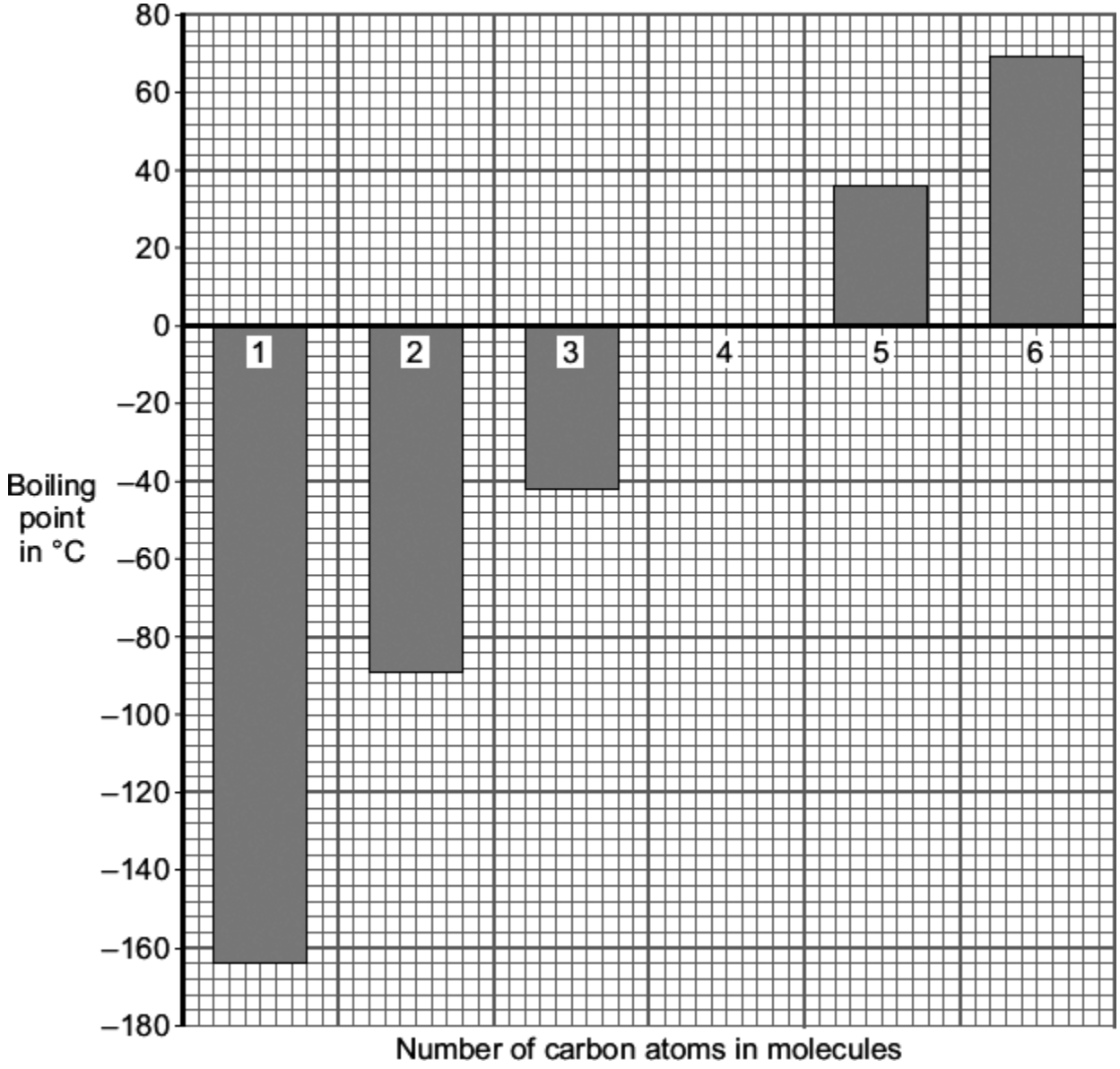
(a) The general formula of an alkane is C_nH_{2n+2}

Complete the structural formula for the alkane that has **six** carbon atoms in its molecules.



(1)

(b) The boiling points of alkanes are linked to the number of carbon atoms in their molecules.



(i) Describe the link between the number of carbon atoms in an alkane molecule and its boiling point.

_____

_____

(1)

(ii) Suggest **two** reasons why all of the alkanes in the bar chart are better fuels than the alkane with the formula $C_{30}H_{62}$

1. _____

_____

2. _____

_____

(2)

(c) During the last 200 million years the carbon cycle has maintained the percentage of carbon dioxide in the atmosphere at about 0.03 %.
Over the last 100 years the percentage of carbon dioxide in the atmosphere has increased to about 0.04 %.
Most of this increase is caused by burning fossil fuels to heat buildings, to generate electricity and to power our transport.
Fossil fuels contain carbon that has been locked up for millions of years.

(i) Burning fossil fuels, such as petrol, releases this locked up carbon. Balance the chemical equation for the combustion of one of the alkanes in petrol.

$$2\ C_8H_{18} + 25\ O_2 \longrightarrow \_\_\_\_\ CO_2 + \_\_\_\_\ H_2O$$

(1)

(ii) Where did the carbon that is locked up in fossil fuels come from?

_____

_____

(1)

(iii) The burning of fossil fuels has caused the percentage of carbon dioxide in the atmosphere to increase to above 0.03 %.
Explain why.

_____

_____

_____

_____

_____

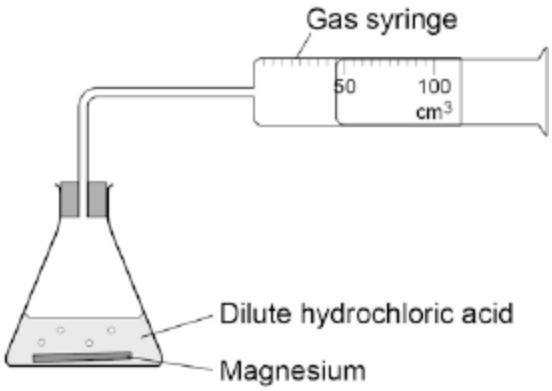
_____

(2)

(Total 8 marks)

5 A student investigated the rate of the reaction between magnesium and dilute hydrochloric acid. The student used the apparatus shown in **Figure 1** to collect the gas produced.

Figure 1



(a) Outline a plan to investigate how the rate of this reaction changed when the concentration of the hydrochloric acid was changed.

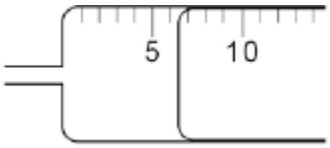
- Describe how you would do the investigation and the measurements you would make.
- Describe how you would make it a fair test.

You do **not** need to write about safety precautions.

(6)

(b) **Figure 2** shows the gas syringe during one of the experiments.

Figure 2



What is the volume of gas collected?

Tick **one** box.

5.3 cm^3 ☐

6.0 cm^3 ☐

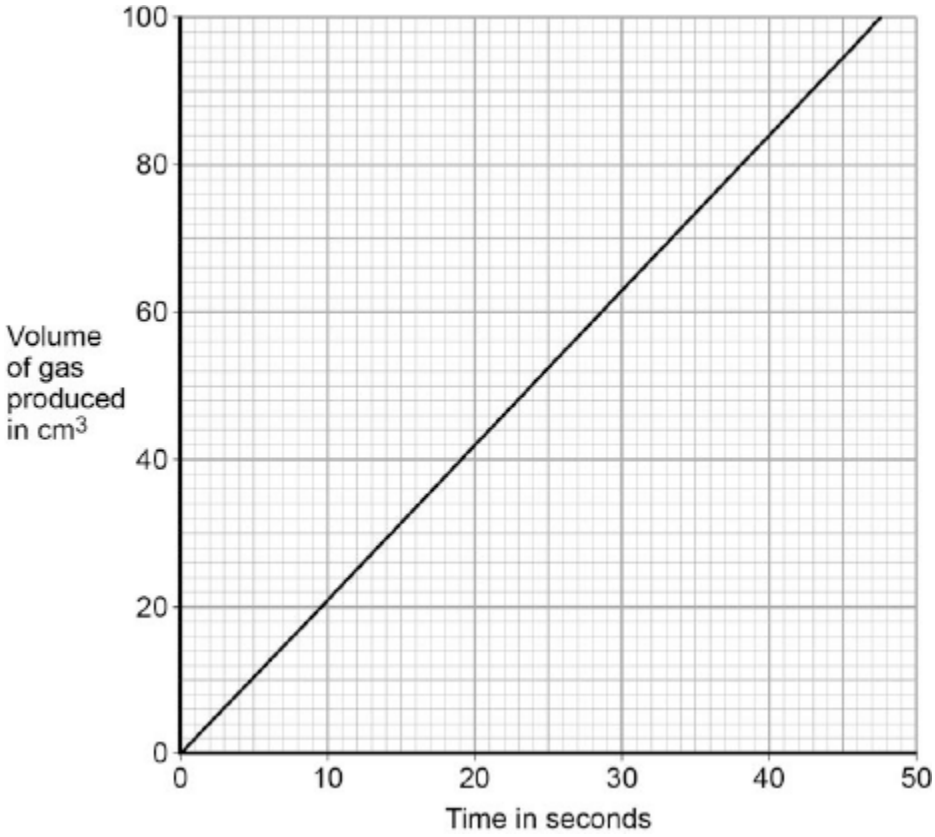
6.5 cm^3 ☐

7.0 cm^3 ☐

(1)

(c) **Figure 3** shows the student's results for one concentration of hydrochloric acid.

Figure 3



The table below shows the student's results when the concentration was two times greater than the results on **Figure 3**

Time in seconds	Volume of gas produced in cm^3
0	0
10	35
15	52
20	80
30	87

Plot the results in the table above on the grid in **Figure 3**.
Draw a line of best fit.

(3)

(d) Give **one** conclusion about how the rate of reaction changed when the concentration of hydrochloric acid was changed.

_____

_____

(1)

(Total 11 marks)

6

The equation for a reaction to produce hydrogen is:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

(a) Explain why changing the pressure does **not** affect the yield of hydrogen at equilibrium.

_____

_____

(1)

(b) Suggest why the best yield of hydrogen at equilibrium is obtained at **low** temperatures.

_____

_____

(1)

(c) The temperature used in industry needs to be high enough for the reaction to take place quickly. Explain, in terms of particles, why the rate of reaction increases when the temperature is increased.

_____

_____

_____

_____

_____

_____

(3)

(d) Scientists have developed catalysts which allow the reaction to take place quickly at lower temperatures. How could this be good for the manufacturer and for the environment?

_____

_____

_____

_____

(2)

(Total 7 marks)

7 (a) The formula for the chemical compound magnesium sulphate is $MgSO_4$.

Calculate the relative formula mass (M_r)of this compound. (Show your working.)

_____

_____

_____

_____

(2)

(b) Magnesium sulphate can be made from magnesium and dilute sulphuric acid.

This is the equation for the reaction.

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$$

Calculate the mass of magnesium sulphate that would be obtained from 4g of magnesium. (Show your working.)

_____

_____

_____

_____

_____

_____

Answer_____ g

(2)

(Total 4 marks)

8 A company manufactures ethanol (C_2H_5OH).

The reaction for the process is:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -45 \text{ kJ per mole}$$

The temperature and pressure can be changed to increase the yield of ethanol at equilibrium.

(a) Explain what is meant by equilibrium.

(3)

(b) (i) How would increasing the temperature change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

(2)

(ii) How would increasing the pressure change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

(2)

(c) A catalyst is added to increase the rate of the reaction.

Explain how adding a catalyst increases the rate of a chemical reaction.

_____

_____

_____

_____

(2)

(Total 9 marks)

9 This question is about iron.

Iron reacts with dilute hydrochloric acid to produce iron chloride solution and one other product.

(a) Name the other product.

_____

(1)

(b) Suggest how any unreacted iron can be separated from the mixture.

_____

_____

(1)

Magnesium reacts with iron chloride solution.

$$3\ Mg + 2\ FeCl_3 \longrightarrow 2\ Fe + 3\ MgCl_2$$

(c) 0.120 g of magnesium reacts with excess iron chloride solution.

Relative atomic masses (A_r): Mg = 24 Fe = 56

Calculate the mass of iron produced, in mg

Mass of iron = _____ mg

(5)

(d) Explain which species is reduced in the reaction between magnesium and iron chloride.

$$3\ Mg + 2\ FeCl_3 \longrightarrow 2\ Fe + 3\ MgCl_2$$

Your answer should include the half equation for the reduction.

(3)

(Total 10 marks)

Mark schemes

1

(a) alkali metals

1

(b) any **one** from:
- small piece of metal
- large volume of water
- use a (safety) screen
- keep a safe distance (between teacher / students and apparatus)

1

(c) reactivity increases down the group

1

any **two** from:
- speed increases (down the group)
- sodium / potassium melts but lithium does not
- flame is seen with potassium, but no flame with lithium / sodium

2

(d) rubidium is too reactive

allow reaction would be violent

1

(e) $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

allow correct multiples

1

(f) sodium hydroxide

1

(g) an answer in the range 0.373−0.495 (nanometres)

1

(h) 3.04×10^{-10} m

1

(i) batteries increased from 10 to 28
or
batteries increased by 18

allow batteries increased approximately ×3

1

producing ceramics and / or glass increased from 10 to 22
or
producing ceramics and / or glass increased by 12

allow ceramics and / or glass increased by approximately ×2

1

lubricants decreased from 8 to 6
or
lubricants decreased by 2

allow lubricants decreased by a quarter

1

*if no other marks awarded allow **1** mark for batteries and glass / ceramics increased, lubricants decreased, with no or incorrect data*

[13]

2 (a) magnesium <u>loses electrons</u>

there are four ideas here that need to be linked in two pairs.

1

<u>two electrons</u>

1

<u>chlorine gains electrons</u>

*magnesium <u>loses</u> electrons and chlorine <u>gains</u> electrons scores **2** marks.*

1

<u>two atoms of chlorine</u>

magnesium <u>loses</u> <u>two</u> electrons and <u>two chlorines</u> each <u>gain</u> one electron will score full marks.

1

(b) 95

*correct answer with or without working gains **2** marks*

*if answer incorrect, allow 24 + 35.5 + 35.5 for **1** mark*

2

[6]

3 (a) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

1

(b) toxic

accept causes death

1

acid rain
or
respiratory problems

accept respiratory problems / asthma

1

global dimming

1

(c)

Level 3: A judgement, strongly linked and logically supported by a sufficient range of correct reasons, is given.	5-6
Level 2: Some logically linked reasons are given. There may also be a simple judgement.	3-4
Level 1: Relevant points are made. They are not logically linked.	1-2
No relevant content	0
Indicative content • methane is the best fuel because it gives more energy per gram than coal, and gives less carbon dioxide per kJ of energy produced • petrol is best because it being a liquid is easier to handle than gas or coal - although the energy content is lower than the others, it gives out less carbon dioxide than coal • methane has more energy per gram than coal • coal produces most carbon dioxide • coal can produce sulfur dioxide	

6

[10]

4

(a) complete diagram with 2 carbon atoms and 5 hydrogen atoms each C–C and each C–H linked by a single line (bond)

1

(b) (i) the greater the number of (carbon) atoms (in an alkane molecule) the greater its boiling point **or** vice versa

allow as the (carbon) chain gets longer the boiling point increases

ignore melting points

*do **not** accept reference to greater number of molecules*

1

(ii) *they = hydrocarbons from the graph*
it = $C_{30}H_{62}$

any **two** from:

- low boiling point / volatile
  accept they are gases or liquids
- low viscosity
- high flammability
  accept easier to burn / ignite
- small molecules
  accept short chains
  ignore number of carbon atoms
- burn completely
  ignore speed of burning

2

(c) (i) 16 (CO_2) + 18 (H_2O)

1

(ii) (carbon dioxide in the Earth's early) atmosphere
accept from volcanoes (millions of years ago)
or *from <u>dead</u> plants / animals*
allow dead sea creatures
ignore shells

1

(iii) <u>increase</u> in burning / use of fossil fuels

1

locked up carbon (carbon dioxide) is released
allow carbon / carbon dioxide from millions of years ago is released
accept extra carbon dioxide is not 'absorbed' (by the carbon cycle)

1

[8]

5 (a) **Level 3 (5–6 marks):**
A coherent method is described with relevant detail, which demonstrates a broad understanding of the relevant scientific techniques and procedures. The steps in the method are logically ordered with the dependent and control variables correctly identified. The method would lead to the production of valid results.

Level 2 (3–4 marks):
The bulk of a method is described with mostly relevant detail, which demonstrates a reasonable understanding of the relevant scientific techniques and procedures. The method may not be in a completely logical sequence and may be missing some detail.

Level 1 (1–2 marks):
Simple statements are made which demonstrate some understanding of some of the relevant scientific techniques and procedures. The response may lack a logical structure and would not lead to the production of valid results.

0 marks:
No relevant content

Indicative content

- remove bung and add magnesium
- start stopclock / timer
- measure volume of gas at fixed time intervals
- repeat with different concentrations of acid
- control volume of acid
- control initial temperature of acid
- control amount / mass / length / particle size of magnesium

6

(b) 6.5 cm^3

1

(c) all points plotted correctly

*allow **1** mark for 4 points plotted correctly*

2

best fit straight line drawn

1

(d) when the concentration of acid increased the rate of reaction increased or vice versa

answer must use the terms 'rate of reaction' linked to 'concentration'

1

[11]

6 (a) same number of (gaseous) molecules / moles / volume on both sides of the equation

allow particles for molecules

*do **not** accept atoms*

ignore amount

1

(b) (forward) reaction is exothermic

accept reverse answer

1

(c) any **three** from:

- particles gain energy
- particles move faster

  allow particles collide faster / quicker

  ignore move more / vibrate more
- particles collide more **or** more collisions
- more of the collisions are successful **or**
  more of the particles have the activation energy **or**
  particles collide with more force / energy

3

(d) any **two** from:

- more product (obtained in shorter time)

  accept better yield (of product)
- less fuel needed

  accept less energy / heat / electricity needed

  or

  lower fuel costs

  ignore cheaper unqualified
- less pollution caused by burning fuels

  or

  less specified type of pollution caused by producing heat / burning fuels

  *allow correct specified pollutants caused by burning fossil fuels eg CO_2 / greenhouse gases **or** correct effect of burning fossil fuels eg global warming*

  accept thermal / heat pollution
- using less fuel conserves resources

  accept sustainable

  accept fossil fuels are non-renewable

2

[7]

7 (a) Mg S O_4

24 + 32 + 16 (×4) or 64 / evidence of all A_r's

gains 1 mark

but (M_r) = 120

gains 2 marks

2

(b) evidence that 24(g) magnesium would produce 120(g) mapesiurn sulphate

gains 1 mark

or correct scaling by 1/6

but 20(g) magnesium sulphate

gains 2 marks
[credit error carried forward from (a) with full marks in (b)]

2

[4]

8 (a) the forward and backward reactions occur

allow reversible

1

at (exactly) the same rate

1

in a closed system

allow therefore the concentrations / amounts of the reactants and products remain the same

1

(b) (i) increasing the temperature would lower the yield of ethanol **or** the (position of) equilibrium moves to the left

*if student has stated that increasing the temperature increases the yield then award **0** marks*

1

since the backwards reaction is endothermic **or** the forward reaction is exothermic

1

(ii) increasing the pressure would increase the yield of ethanol **or** the (position of) equilibrium moves to the right

*if student has stated that increasing the pressure decreases the yield then award **0** marks*

1

because the position (of equilibrium) moves in the direction of the lower number of moles (of gas)

2 (moles / molecules / volumes / particles) on lhs / 1 (mole / molecule / volume / particle) on rhs

1

(c) (a catalyst) provides an alternative pathway

1

with lower activation energy

or

(a catalyst) lowers the activation energy (1)

so less energy is needed to react **or** more particles react (1)

1

[9]

9

(a) hydrogen **or** H_2

allow hydrogen gas
ignore H without the 2 subscript

1

(b) filtration / filter

*allow magnet **or** decant*
ignore heating

1

(c) (Mg) $\frac{0.12}{24}$ or 0.005 (moles)

mark is for ÷ by 24

1

(Fe) $\frac{2}{3} \times 0.005 = 0.00333 \times 56$

mark is for $\times \frac{2}{3}$

1

(mass Fe) = 0.00333 × 56

mark is for × 56

1

= 0.1866 (g)

1

= 187 (mg)

1

*an answer of 280 (mg) scores **4** marks*

*an answer of 0.280 scores **3** marks (no ratio from equation)*

*184 scores **0** [= (3 × 24) + (2 × 56)]*

OR

$$(\text{Mg}) = \frac{0.12}{(3 \times 24 =)72} \text{ (1)}$$

$$= 0.00166 \textbf{ or } \frac{1}{600} \text{ (moles) (1)}$$

(mass of Fe) = 0.00166

$$\textbf{or } \frac{1}{600} \times 112(2 \times 56) \text{ (1)}$$

= 0.1866 (g) (1)

187 (mg) (1)

OR

72 g Mg ⟶ 112g Fe (1)

$$1 \text{ g Mg} \rightarrow \frac{112}{72} \textbf{ or } 1.56 \text{ g Fe (1)}$$

$$0.12 \text{ g Mg} \rightarrow \frac{112}{72} \times 0.12 \text{ (1)}$$

= 0.1866 (g) (1)

= 187 (mg) (1)

*an answer of 185−190 (mg) scores **5** marks*

*an answer of 0.185−0.19 scores **4** marks*

(d) Fe^{3+}

1

(because) reduction is gain <u>of electrons</u>

allow change in oxidation state / (+)3 to 0

1

$Fe^{3+} + 3e^{(-)} \longrightarrow Fe$

1

[10]