TOTB 2023

Younger Paper

Answers

Question	Mark
Section A	
9	
10	
11	
TOTAL	

SECTION A General chemistry knowledge

1. Name the element used as a disinfectant in swimming pools. chlorine [1]

2. Name an element that is a liquid at room temperature. mercury or bromine [1]

Allow chemical symbols if given instead of name in Q1 and 2

3. This question is about the reaction between sulfuric acid and copper oxide.

The equation for the reaction is:

$$H_2SO_4(aq) + CuO(s) \rightarrow CuSO_4(aq) + H_2O(l)$$

a. What does the symbol (aq) mean? [1]

aqueous or dissolved in water

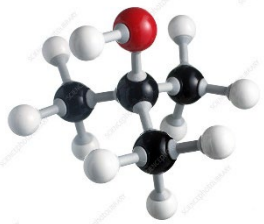
b. What is the type of reaction between sulfuric acid and copper oxide?

Circle **one** word. [1]

displacement **neutralisation** **precipitation**

4. Give the molecular formula of the molecule shown in **Figure 1**. $C_4H_{10}O$ *Allow any order* [1]

Figure 1



Black = carbon

White = hydrogen

Red = oxygen

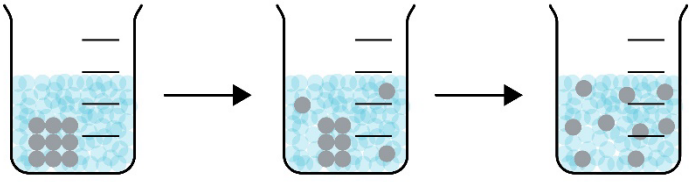
5. Name the **gas** produced when the two chemicals given react; [2]

a. magnesium + hydrochloric acid hydrogen

b. sodium carbonate + hydrochloric acid carbon dioxide

6. Identify the process represented in **Figure 2**. dissolving / forming a solution

Figure 2



[1]

7. 100 g of calcium carbonate undergoes thermal decomposition to produce 56 g of calcium oxide.

The equation for the reaction is $CaCO_3 \rightarrow CaO + CO_2$.

Calculate the mass of carbon dioxide produced. 44 g [1]

8. Balance the symbol equation: 2 $Fe(OH)_3$ → (*Allow 1 if given here)* Fe_2O_3 + 3 H_2O [1]

Turn over for Section B

SECTION B Questions linked to this year's theme of Sustainable Energy

9. This question is about the origin of the UK's energy supply.

The UK obtains its energy from a mixture of fossil fuels and other energy sources including sustainable sources.

An energy source can be described as sustainable if its use today does not impact negatively on the lives of people in the future.

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The data in **Table 1** shows the sources of energy supplied to the UK on a day in October 2022.

Table 1

		Energy in Gigawatts, GW
Fossil fuels	Coal	0
	Oil	0
	Gas	13.0
Sustainable sources	Solar photovoltaic	0.5
	Wind	15.5
	Hydroelectric	0.5
Other sources	Nuclear	4.5
	Biomass	0.5
	Other	0.2
	TOTAL	**34.90**

Data taken from https://grid.iamkate.com/

The question continues on the next page

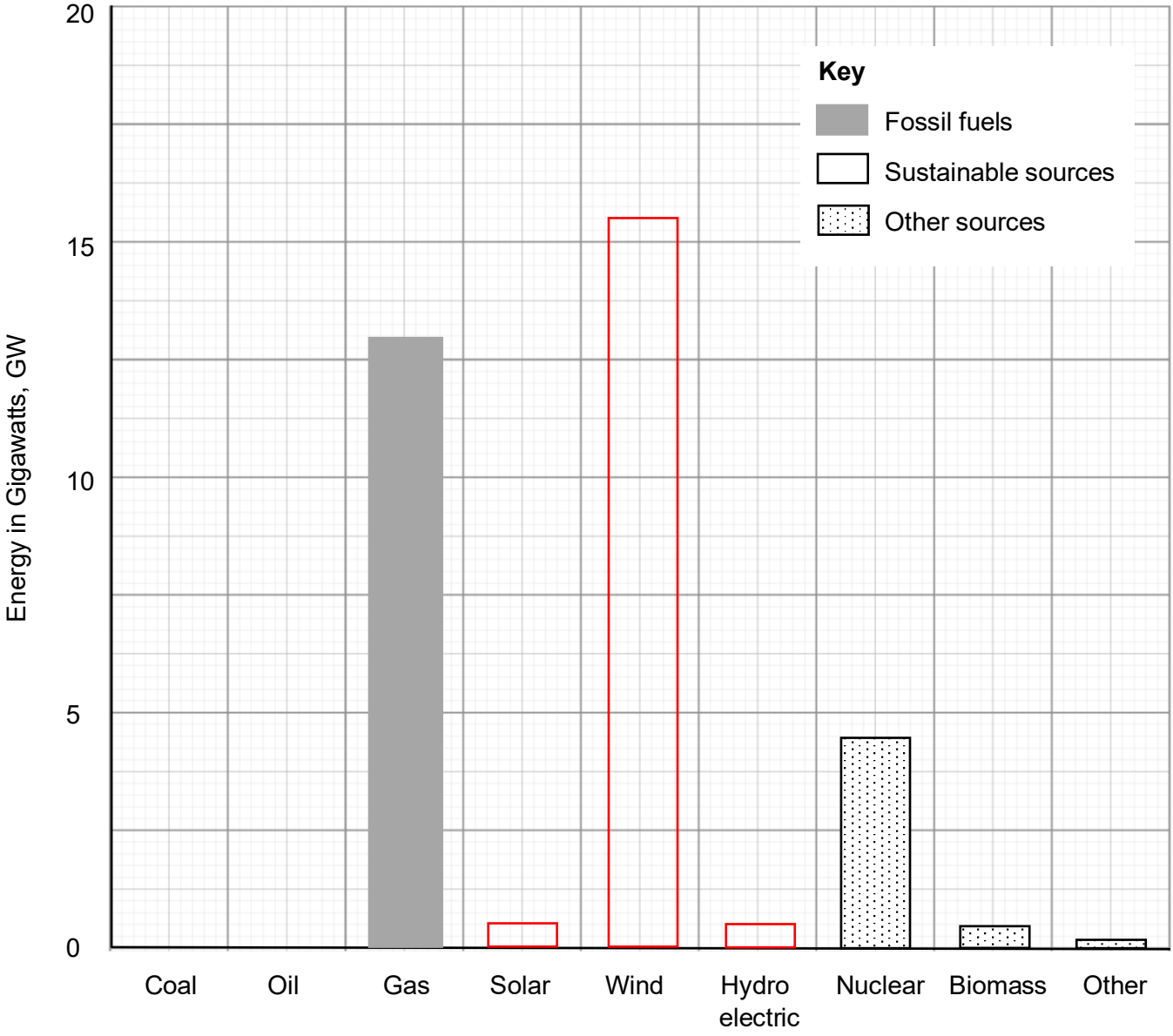
a. Complete the bar chart in **Figure 3**.

Add bars for each of the sustainable sources. [3]

3 bars drawn. Allow a tolerance of +/- half a square.

Deduct 1 mark if no gaps left between bars.

Figure 3



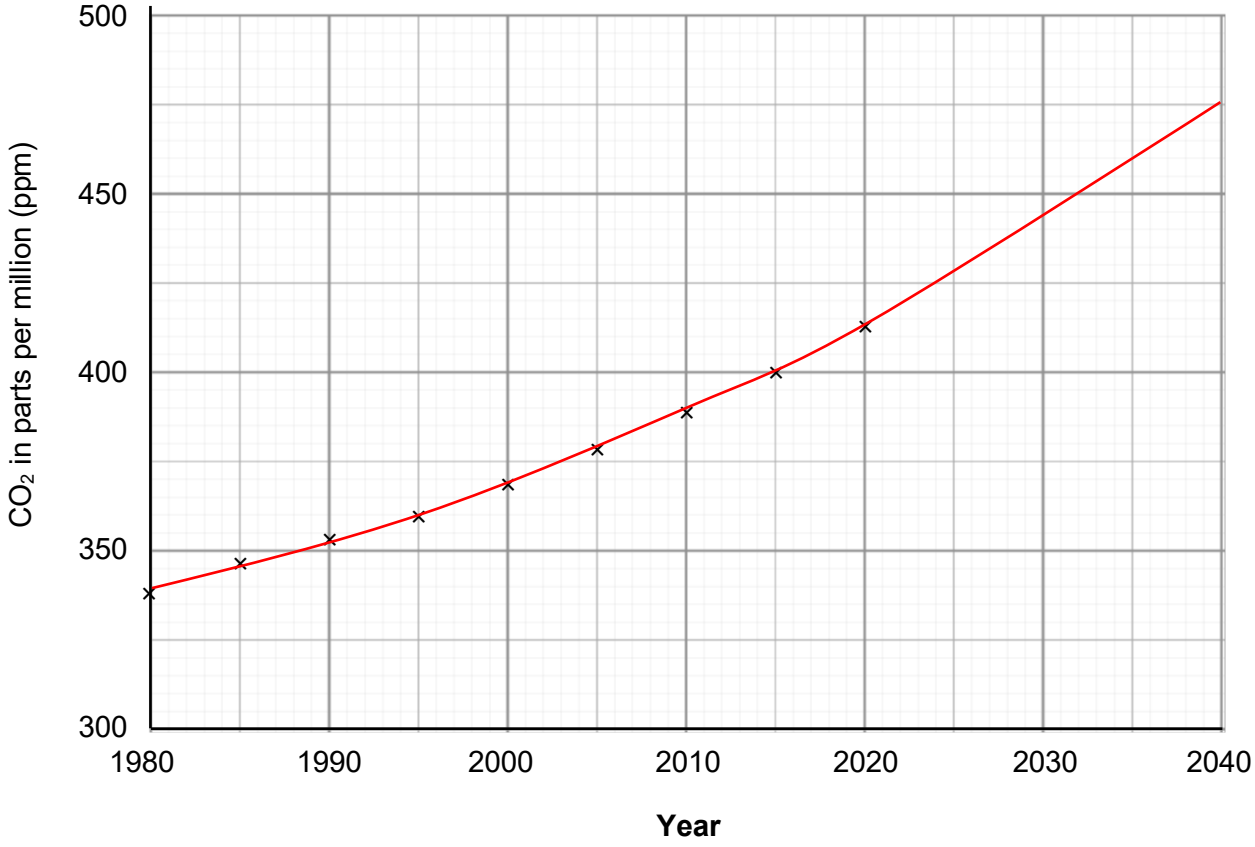
b. Which sustainable source provided the **most** energy? [1]

Wind

c. One reason why fossil fuels are non-sustainable is because they release carbon dioxide when they undergo complete combustion.

Figure 4 shows how the amount of carbon dioxide in the atmosphere has changed since 1980.

Figure 4



i. Draw a smooth **curve** of best fit through the points. Must be a smooth **curve** [1]

ii. Extend your curve of best fit to 2040.

Predict the level of CO_2 in ppm in **2035** if the levels continue to rise in a similar way. [2]

M1 Extension continues smooth curve

M2 Correct value from their extension read off for 2035

The temperature of the Earth is increasing.

Increasing temperatures are caused by the increased levels of carbon dioxide in the atmosphere.

d. Give two impacts of increased global temperatures. [2]

Any **two** from list below or other correct answer;

Rising sea levels / Polar ice caps melting / Extreme weather / Changes to natural habitats affecting ecosystems

10. This question is about energy storage.

Many sustainable sources of energy such as wind turbines and solar panels only generate power if the wind is blowing or the sun is shining.

The ability to store generated energy so that the energy can be used when needed is important.

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This question is about different methods scientists have developed for storing energy.

One way to store the energy produced is in **rechargeable batteries**.

a. The most common rechargeable batteries contain lithium.

Lithium is a group one metal.

i. Give the chemical symbols of **two other** metals in group one. [1]

Any two from Na / K / Rb / Cs / Fr - must be symbols

ii. Group one metals react with water to produce the metal hydroxide and hydrogen.

Write a **word** equation for the reaction of lithium with water. [1]

lithium + water → lithium hydroxide + hydrogen

iii. Group 1 metals become more reactive down the group.

A student reacts small pieces of lithium, sodium and potassium with water.

Describe **one** observation the student makes that shows potassium is the **most reactive** of the three metals. [1]

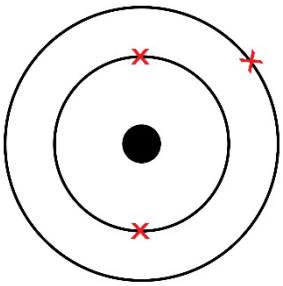
Possible observations include;

- (hydrogen gas) burns with a (lilac) flame
- Potassium explodes
- Potassium moves around the surface the fastest

b. When the battery is used to power a device the lithium atoms are converted into lithium ions.

i. Complete **Figure 5** to show the electronic structure of a lithium **atom**. [1]

Figure 5



ii. Predict the charge on the lithium ion formed. [1]

+1 / Li^{1+} / Li^{+} Do not allow simply positive

An alternative method of energy storage system is to use **hydrogen**.

The energy generated from the sustainable sources is initially used to electrolyse water.

During **electrolysis** water is broken down into hydrogen and oxygen using electricity.

c. Write a balanced **symbol** equation for the electrolysis of water. [2]

$2H_2O \rightarrow 2H_2 + O_2$ M1 Correct symbols M2 Balancing (M2 dependent on M1)

The hydrogen produced by electrolysis is then stored and used as a fuel when needed.

Scientists are developing cars that use hydrogen gas as fuel.

One challenge scientists face is to find a way to safely store the hydrogen.

Compressing hydrogen gas allows hydrogen to be stored more easily.

d. i. At room temperature and pressure 1 kg of hydrogen occupies a volume of 12 m^3.
Calculate the density of hydrogen gas in kg / m^3 under these conditions. [1]

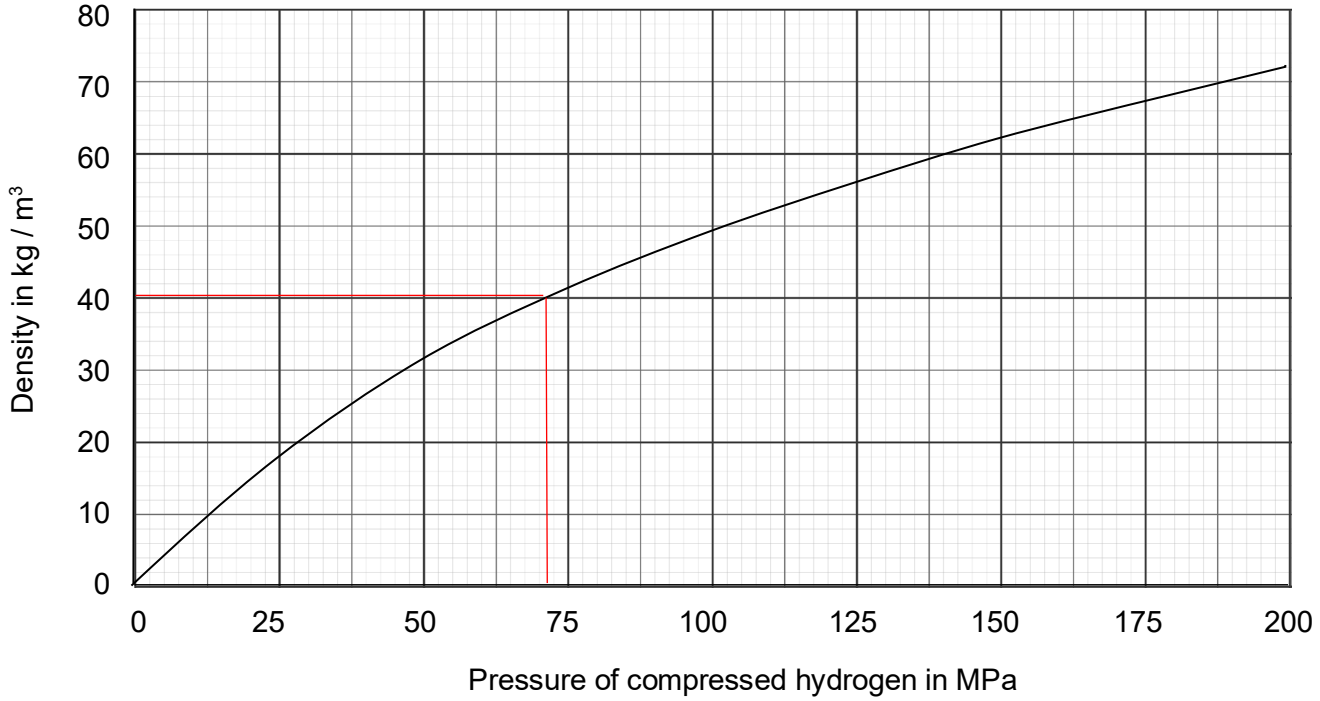
Density = mass / volume

= 1 kg / 12 m^3

= **0.083 kg / m^3**

Figure 6 shows how the density of hydrogen changes with pressure.

Figure 6



ii. Describe the trend shown in **Figure 6**. [1]

As the pressure is increased the density of the hydrogen increases.

Allow the converse.

iii. A car fuel tank has a volume of 125 litres.

A full fuel tank can contain 5 kg of hydrogen.

Determine the pressure the hydrogen is stored at in the fuel tank.

Use **Figure 6**.

1000 litre = 1 m^3 [3]

M1 125 L = 0.125 m^3

M2 Density = 5 kg / 0.125 m^3 = 40 kg / m^3

M3 Correct reading off graph. Allow answers in the range 70 to 72 MPa.

For M3 award error carried forward mark from an incorrect density.

[Total: 12 marks]

11. This question is about Biogas.

Biogas is a renewable fuel produced by the breakdown of organic matter such as food scraps and animal waste.

Biogas consists mainly of the gases methane, CH_4, and carbon dioxide, CO_2.

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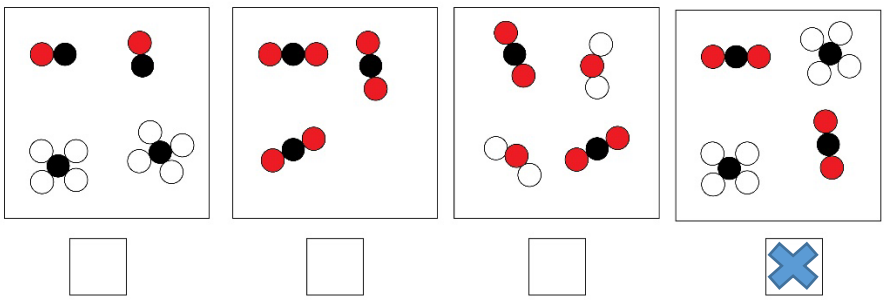
a. i. Methane is a **hydrocarbon**. What is a hydrocarbon? [1]

A molecule that contains carbon and hydrogen only (must give some indication that it only contains these elements)

ii. Carbon dioxide has the chemical formula CO_2.

Select the image that **best** represents biogas.

Tick **one** box. [1]



b. Explain why biogas is described as **renewable**. [1]

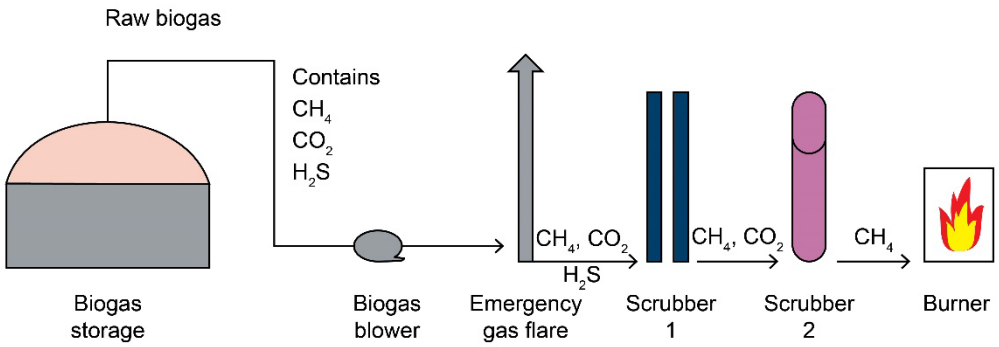
Because it is easily remade

Biogas may also contain small quantities of other impurities.

Biogas must be purified before use.

Figure 7 shows the steps involved in the purification process.

Figure 7



c. i. Give the formula of the impurity removed by **Scrubber 1**. [1]

H_2S

ii. **Scrubber 2** removes the carbon dioxide impurities.

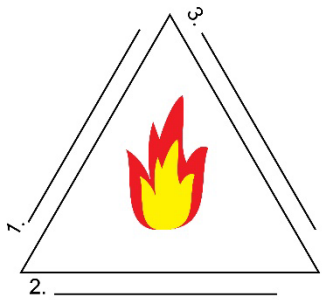
The carbon dioxide reacts with a solution of sodium hydroxide to form sodium carbonate.

What is the pH of a sodium hydroxide solution? [1]

Allow any pH in range 10-14

Once purified the biogas produced can be used as a fuel.

d. i. Complete the fire triangle to show the three factors needed for a fire. [1]



In any order;

oxygen

fuel

heat

All three needed for mark

ii. Write a word equation for the **complete combustion** of methane. [1]

methane + oxygen → carbon dioxide + water

iii. In a limited supply of oxygen, methane will react by **incomplete combustion**.

A toxic gas is produced.

Name the toxic gas. [1]

carbon monoxide

e. The torch at the 2008 Beijing Olympics was fuelled by methane produced from biogas.

It used 6000 m^3 of methane per hour and was kept alight for 16 days.

Calculate the total volume of methane burnt during the Beijing Olympics. [1]

6000 m^3 × 24 h × 16 days = **2 304 000 m^3**

[Total: 9 marks]