Top of the Bench 2023
Older Paper

Name:

School:

School year:

Answer all questions in the spaces provided.

You are provided with a Periodic table.

Write your answers clearly. Show all working.

Section A contains questions about general chemical knowledge.

Section B contains questions about this year's theme: Sustainable energy

The total marks allocated to the paper are 40 marks (Section A 10 marks, Section B 30 marks)

The time allocated to the paper is 40 minutes.

Question	Mark
Section A	
10	
11	
12	
TOTAL	

SECTION A General chemistry knowledge

1. Give the number of protons, neutrons and electrons in an atom of $^{27}_{13}Al$. [1]

protons _____ neutrons _____ electrons _____

2. Chlorine exists as two isotopes $^{35}_{17}Cl$ and $^{37}_{17}Cl$.

The relative atomic mass of naturally occurring chlorine is 35.5.

Give the ratio of chlorine-35 : chlorine-37 atoms in naturally occurring chlorine. [1]

_____ : _____

3. Calculate the relative formula mass of $Mg(OH)_2$ [1]

Relative atomic masses: Mg = 24; O = 16; H = 1

_____

4. Which **two** words can be used to describe CO_2? [1]

alloy **compound** **element** **molecule**

5. Which element forms an ionic compound with potassium?

Circle **one** answer.

Mg **Si** **S** **Ar** [1]

6. Name the best separating technique to obtain the **solute** from a **solution**. [1]

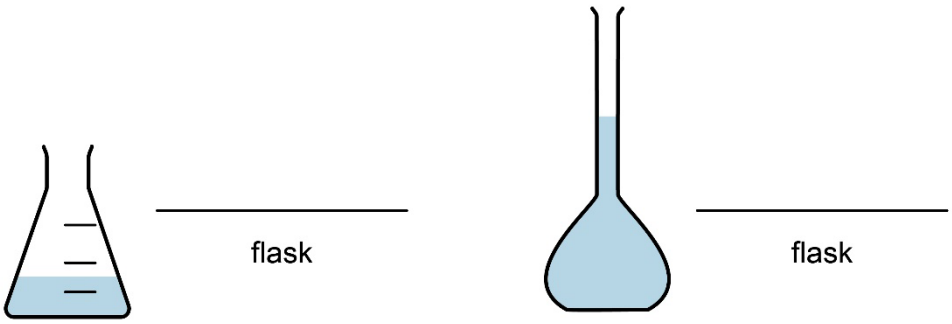
_____

7. Give the chemical symbol of the element named from the Greek word for sun. _____ [1]

8. What is the name given to a reaction where energy is transferred to the surroundings? [1]

_____

9. The image shows two different types of flask. Complete the names of each one. [2]



Turn over for Section B

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

10. 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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Table 1 shows the sources of energy supplied to the United Kingdom at 10 am on a Friday in October 2022.

Table 1

		Energy in Gigawatts, GW
Fossil fuels	Coal	0
	Oil	0
	Gas	12.98
Sustainable sources	Solar photovoltaic	0.43
	Wind	15.37
	Hydroelectric	0.54
Other sources	Nuclear	4.63
	Biomass	0.72
	Other	0.23
	TOTAL	**34.90**

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

a. Calculate the percentage of the total energy that was supplied from;

i. fossil fuels [1]

_____

_____

ii. sustainable sources [2]

_____

_____

b. Fossil fuels release carbon dioxide when they combust.

Carbon dioxide is a greenhouse gas.

Greenhouse gases maintain temperatures on Earth.

i. Describe how carbon dioxide maintains temperatures on Earth. [3]

Increased levels of carbon dioxide in the atmosphere is linked to rising average global temperatures on Earth.

ii. Give one impact of increased global temperatures. [1]

[Total: 7 marks]

11. 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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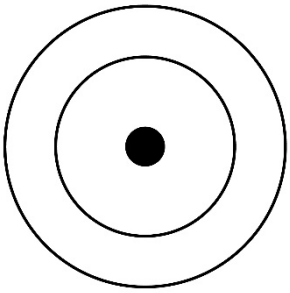
This question is about different methods scientists have developed for storing energy.

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

a. The most common rechargeable batteries contain lithium.

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

Figure 1



ii. Batteries store energy.

Energy is then transferred to portable devices when batteries are discharged.

When a lithium battery is discharged, the lithium atoms form lithium ions.

The equation for the reaction is:

$$Li \rightarrow Li^{+} + 1e^{-}$$

Explain if the lithium is oxidised or reduced in this reaction. [1]

_____

_____

b. Researchers are developing a new type of battery that contains calcium.

i. Complete the half equation to give the charge on the calcium ion formed. [1]

$$Ca \rightarrow Ca^{\_\_} + 2e^-$$

ii. Calcium ions are viewed as preferable for batteries to lithium ions.

Suggest why batteries containing calcium ions could store more energy than batteries containing lithium ions. [1]

_____

_____

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.

The equation for the reaction is:

$$2H_2O \rightarrow 2H_2 + O_2$$

c. i. Write two half equations to represent the reactions that occur at the positive and negative electrode during the electrolysis of water.

Use e- to represent an electron. [2]

Positive electrode_____

Negative electrode _____

ii. Show how the two half equations combine to give the overall equation for the electrolysis of water. [1]

_____

_____

_____

_____

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

[Total: 7 marks]

12. 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 methane and carbon dioxide.

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a. Methane is a **hydrocarbon**. What is a hydrocarbon?

_____ [1]

To be used as a replacement for natural gas for cooking and heating the biogas needs to be purified.

b. One way to remove the **carbon dioxide** from the mixture of methane and carbon dioxide is by passing the biogas through a solution of sodium hydroxide, NaOH.

Sodium carbonate Na_2CO_3 and water are produced.

Write a balanced symbol equation for the reaction.

Include state symbols. [2]

_____

The biogas also includes small quantities of **hydrogen sulfide, H_2S**.

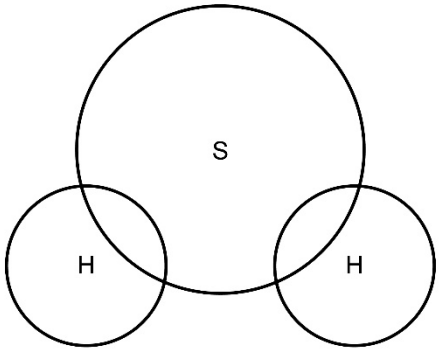
c. Hydrogen sulfide is a simple molecule.

Complete **Figure 2** to show a dot and cross diagram for a hydrogen sulfide molecule.

Show the outer electrons only.

Use dots (•) and crosses (×) to represent the electrons. [2]

Figure 2



The hydrogen sulfide is removed by passing the biogas over an absorbent iron sponge.

The iron sponge consists of wood shavings soaked with hydrated iron oxide, $Fe_2O_3 \cdot H_2O$.

The hydrogen sulfide reacts with the iron oxide to produce iron sulfide, Fe_2S_3.

The equation for the reaction is:

$$\_\_\_\_ Fe_2O_3 \cdot H_2O + 6H_2S \rightarrow \_\_\_\_ Fe_2S_3 + 8H_2O$$

d. The equation is partially balanced.

Complete the balancing by adding numbers where indicated with _____ . [1]

The iron oxide can be regenerated by exposing the iron sulfide to air.

The equation for the reaction is:

$$2Fe_2S_3 + 3O_2 \rightarrow 2Fe_2O_3 + 6S$$

e. Calculate the mass of sulfur produced from the reaction of 128 g of iron sulfide with an excess of oxygen.

Relative atomic masses: Fe = 56; S = 32; O = 16 [3]

_____

_____

_____

_____

f. Once purified the methane can be used as a fuel.

Methane can undergo a combustion reaction.

Figure 3 shows the displayed structures of the reactants and the products.

Figure 3

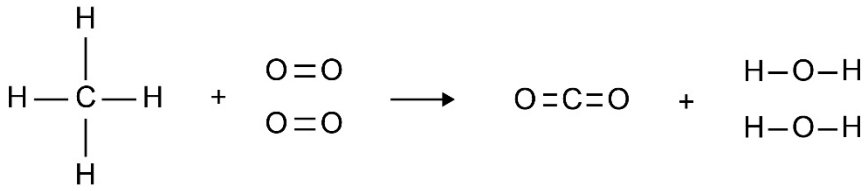


Table 2 shows the bond energies.

Table 2

Bond	Bond energy in kJ/mol
C–H	413
O=O	498
C=O	805
O–H	464

Calculate the overall energy change for the reaction. [3]

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

The torch consumed 6000 m^3 of methane per hour and was kept alight for 16 days.

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

_____

ii. Calculate the total mass in kg of methane burnt during the Olympic games.

Assume the volume of one mole of gas is 24 dm^3. [3]

Relative atomic masses: C = 12; O = 16

_____

_____

_____

_____

[Total: 16 marks]