# TOTB 2023

## Younger Paper

**Answers**

<table>
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<th>Question</th>
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<td>Section A</td>
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<td>11</td>
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<td><strong>TOTAL</strong></td>
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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:
   \[ \text{H}_2\text{SO}_4(\text{aq}) + \text{CuO(}s\text{)} \rightarrow \text{CuSO}_4(\text{aq}) + \text{H}_2\text{O(l)} \]
   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
   
   ![Figure 1](image)

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

The equation for the reaction is \( \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \).

Calculate the mass of carbon dioxide produced. \( 44 \text{ g} \) [1]

8. Balance the symbol equation: \( 2 \text{ Fe(OH)}_3 \rightarrow (\text{Allow 1 if given here}) \text{ Fe}_2\text{O}_3 + 3 \text{ H}_2\text{O} \) [1]
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.

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

<table>
<thead>
<tr>
<th></th>
<th>Energy in Gigawatts, GW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fossil fuels</strong></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0</td>
</tr>
<tr>
<td>Oil</td>
<td>0</td>
</tr>
<tr>
<td>Gas</td>
<td>13.0</td>
</tr>
<tr>
<td><strong>Sustainable sources</strong></td>
<td></td>
</tr>
<tr>
<td>Solar photovoltaic</td>
<td>0.5</td>
</tr>
<tr>
<td>Wind</td>
<td>15.5</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td>0.5</td>
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<tr>
<td><strong>Other sources</strong></td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>4.5</td>
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<tr>
<td>Biomass</td>
<td>0.5</td>
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<tr>
<td>Other</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>34.90</td>
</tr>
</tbody>
</table>

Data taken from https://grid.iambite.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](image)

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 CO₂ 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.

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]

   $$ \text{lithium} + \text{water} \rightarrow \text{lithium hydroxide} + \text{hydrogen} $$

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]

\[ 2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \]  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]

\[
\text{Density} = \frac{\text{mass}}{\text{volume}} \\
= \frac{1 \text{ kg}}{12 \text{ m}^3} \\
= 0.083 \text{ kg} / \text{m}^3
\]
Figure 6 shows how the density of hydrogen changes with pressure.

ii. Describe the trend shown in Figure 6.

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 m³

M1 125 L = 0.125 m³

M2 Density = 5 kg / 0.125 m³ = 40 kg / m³

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, CH₄, and carbon dioxide, CO₂.

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 CO₂.

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.

![Diagram of biogas purification process]

**Figure 7**

1. **Scrubber 1** removes the impurity *H₂S*. [1]

2. **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.  

   In any order;  
   oxygen  
   fuel  
   heat  
   All three needed for mark

   ii. Write a word equation for the complete combustion of methane.  

       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.  

       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.  

   \[ 6000 \text{ m}^3 \times 24 \text{ h} \times 16 \text{ days} = 2304000 \text{ m}^3 \]

   [Total: 9 marks]