TOTB 2025 Younger Paper

ANSWERS

SECTION A General chemistry knowledge

1. Label the changes of state **A** and **B** represented by the arrows on **Figure 1**. [2]

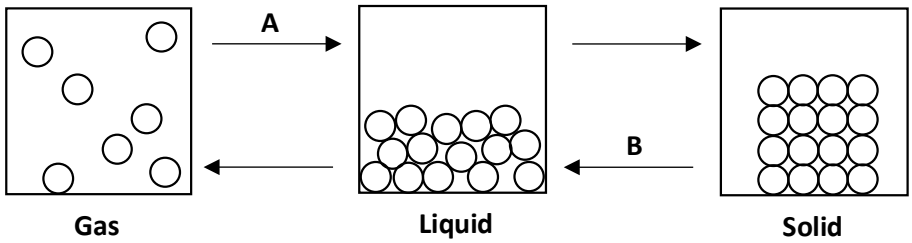

Figure 1

A = condensation (1 mark) **B** = melting (1 mark)

2. Describe the test for **hydrogen** gas. [1]

Add a lit splint and the gas burns with a pop

Both the splint and observation required for the mark

3. Complete the word equations for the reactions; [2]

sodium hydroxide + nitric acid → sodium nitrate (1 mark) + water

iron oxide + carbon → iron + carbon dioxide / carbon monoxide / carbon oxide (1 mark)

4. Zinc sulfate is a compound containing the elements zinc, sulfur and one other element.

Name the other element in zinc sulfate. [1]

oxygen

5. Match the chemical to the everyday item it is found in.

Draw **one line** from each chemical to where it is found. [2]

Chemical	Found in
calcium carbonate, $CaCO_3$	baking soda
sodium hydrogencarbonate, $NaHCO_3$	bleach
Sodium hypochlorite, NaOCl	chalk

All 3 lines needed for 2 marks; 1 line correct = 1 mark

6. Which of the following is **not** a greenhouse gas? [1]

- [ ] carbon dioxide
- [x] argon
- [ ] water vapour
- [ ] methane

7. Name the piece of glassware in **Figure 2**. [1]

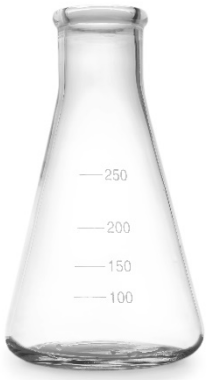

Figure 2

conical flask _____

SECTION B Questions linked to this year's theme of Air

8. This question is about hot air balloons.

(a) Air is a mixture of gases

One gas in air is oxygen.

Oxygen is an element.

(i) What is meant by 'an **element**'? [1]

A substance that contains only one type of atom

(ii) Another element makes up 78% of air. Name the element. [1]

Nitrogen

In a hot air balloon air trapped inside a balloon is heated with a burner positioned under the balloon.

(b) Complete the sentences to explain how heating the air causes the hot air balloon to rise.

Use words from the box.

You may use each word more than once. [3]

increases	**decreases**	**stays the same**

When the air is heated, the volume of the air increases.

The mass of the air stays the same.

As a result the density of the air decreases and the balloon rises.

[Total: 5 marks]

9. This question is about calculating the percentage of oxygen in air.

When iron rusts, water and oxygen in the air react with the iron to form hydrated iron oxide.

(a) Write a word equation for iron rusting. [1]

iron + oxygen + water → hydrated iron oxide _____

_____

The rusting of iron can be used to find the percentage of oxygen in air.

A student set up the apparatus in **Figure 3a**.

As the iron wool rusts, oxygen is removed from the air and water is drawn up the measuring cylinder.

The student left the apparatus in **Figure 3a** for one week.

Figure 3b shows the apparatus after the week.

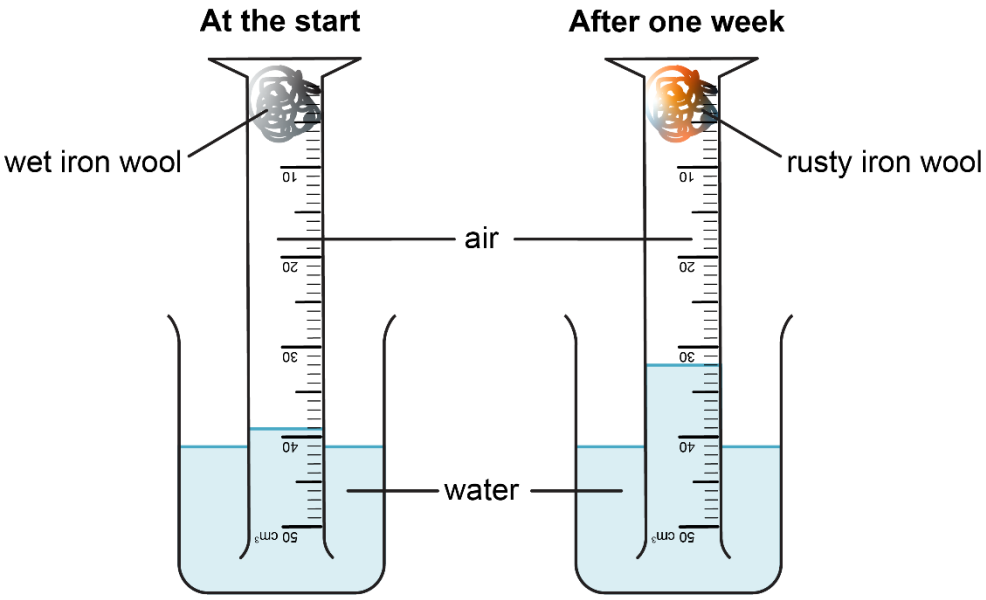

Figure 3a **Figure 3b**

(b) (i) Complete **Table 1** to show the volume of air in the measuring cylinder in **Figure 3b**.

You can assume the volume occupied by the iron wool is zero. [1]

	Volume of air in cm^3
Figure 1a – at the start	39
Figure 1b – after one week	32

Table 1

(ii) Calculate the percentage of oxygen in the air based on the student's results. [2]

Volume of oxygen = 39 – 32 = 7 cm^3 (1 mark for calculating change)_____

As a percentage = (7 / 39) × 100 = 18% (1 mark for correct conversion to %)___

Allow 17.9%, 17.95%, 18.0%

Allow error carried forward from incorrect reading off Fig 3b

(c) A different student repeats the experiment.

Their results show that the percentage of oxygen in air is 12%.

The true value for the percentage of oxygen in air is 21%.

Give **one** reason why the student's results were below the true percentage. [1]

Any suggestion that indicates that not all the oxygen in the air had been used up in the reaction with the iron _____

_____

[Total: 5 marks]

10. This question is about reactions involving oxygen.

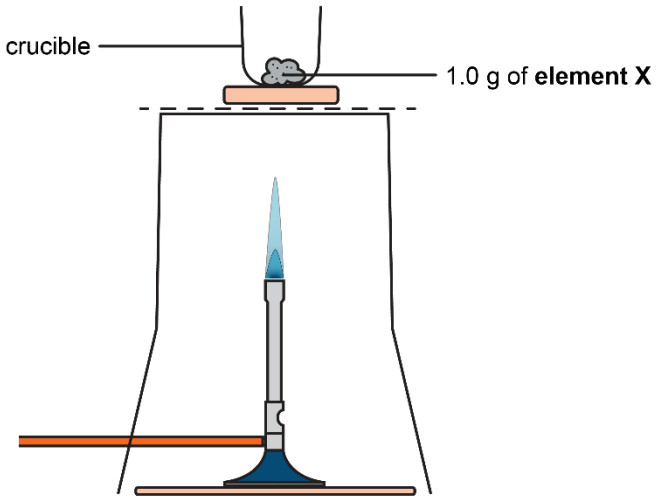

Figure 4

A student investigates the reaction of **three elements**, **X**, **Y** and **Z** with oxygen.

This is the method used;

1. Record the mass of an empty crucible.
2. Add 1.0 g of **element X** in powder form to the crucible.
3. Set up the equipment as in **Figure 4**.
4. Heat the crucible strongly for 5 min using a blue Bunsen flame.
5. Allow the crucible and contents to cool.
6. Record the mass of the crucible and contents.
7. Repeat the steps 1 to 6 with **element Y** and **element Z**.

The student's results are shown in **Table 2**:

	Element X	**Element Y**	**Element Z**
Mass of crucible empty in g	12.7	12.7	12.6
Mass of crucible plus 1.0 g of the element in g	13.7	13.7	13.6
Mass of crucible plus contents after heating for 5 min in g	13.0	13.7	14.1
Change in mass during reaction in g	-0.7	0.0	0.5

Table 2

(a) Complete the table by calculating the change in mass when **element Z** was heated. [1]

(b) The student concludes that **Element Y** does **not** react with air.

What evidence from **Table 2** supports their conclusion? [1]

It did not change in mass during heating _____

_____

_____

The two elements that did react were known to be magnesium and carbon.

(c) Which element is **carbon**?

Circle your choice. [3]

Element X **Element Z**

Explain your answer.

M1 **Element X** correctly identified.

M2 The mass of the contents of the crucible for **element X** decreased during the reaction

M3 because carbon reacts with oxygen to produce carbon dioxide which is a gas

which would escape from / leave the crucible *(all details underlined need for M3)*

(d) (i) Which element is **magnesium**?

Circle your choice. [2]

Element X **Element Z**

Explain your answer.

M1 Element Z identified and the mass of the contents of the crucible increased during the reaction

M2 Magnesium reacts to produce magnesium oxide which is a solid _____

or _____

The magnesium bonds with / joins with / combines with the oxygen atoms _____

(ii) Give **one** observation made during the reaction when magnesium is heated. [1]

A bright white light / white smoke / white solid _____

_____

[Total: 8 marks]

11. This question is about air pollution.

(a) (i) A student visited a steam railway.

The steam engines burn coal to release energy as heat.

The heat produced is used to convert water into steam.

338000 MJ of energy is needed to convert 1 m^3 of water at 20 °C into steam.

The complete combustion of 1 kg of coal provides 16 MJ of energy.

The boiler of the steam train contains 35 m^3 of water.

Calculate the mass of coal needed to convert all the water in the boiler into steam.

You can assume no energy is lost. [2]

Total energy needed to convert 35 m^3 of water to steam

= 35 × 338000 MJ

= 11,830,000 MJ (1 mark)

Mass of coal needed = 11,830,000 MJ / 16 MJ

= 739,375 kg

Allow answers rounded to 739,000 kg

Correct answer with no working or using an alternative method = 2 marks

(ii) More coal was needed than the engineer had calculated.

Suggest **two** reasons why. [2]

Any two from;

Incomplete combustion of the coal

Energy lost to the surroundings

The coal was not pure / contained impurities

Accept other reasonable answers

Atmospheric chemists measure the amount of **particulate matter** suspended in the air.

Particulate matter includes carbon (soot) and dust from roads and industry.

(b) **Figure 5** shows how the levels of particulate matter in London changed between 1700 and 2016.

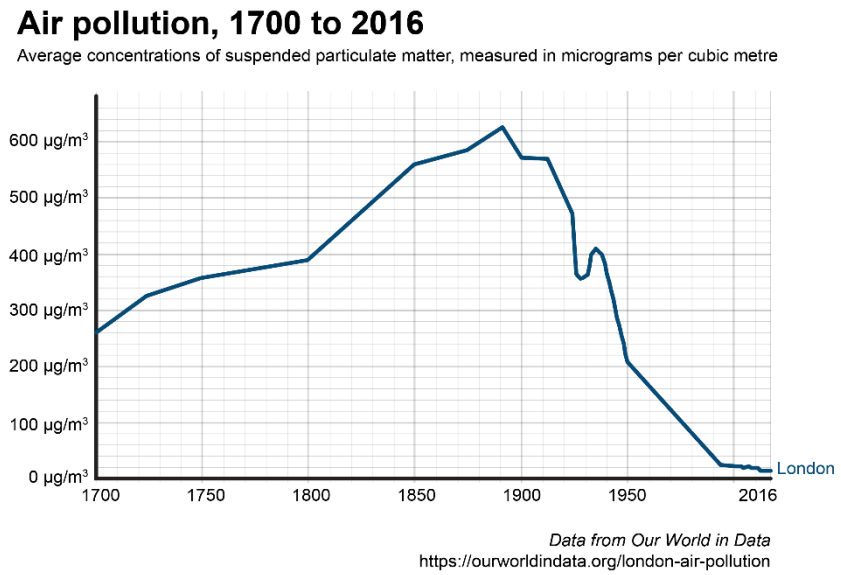

Figure 5

(i) Calculate the **increase** in particulate matter between 1700 and 1890. [2]

1 mark for correct reading of values in **1700** and **1890**;

1700 allow 260 -270 µg/m^3; **1890** allow 620-630 µg/m^3

1 mark for calculating the increase using their values (expected answer *360* µg/m^3)

(ii) Give one problem caused by increased levels of particulate matter in the environment. [1]

Breathing or respiratory difficulties / unsightly / dirt on roads / global dimming ___

_____

The levels of particulate matter dropped significantly after 1890.

(iii) Which option could explain the changes shown in levels of particulate matter seen after 1890? [1]

- [×] Businesses that produced excessive smoke were fined by the government
- [ ] The industrial revolution.
- [ ] An increase in coal production from UK mines.

Fossil fuels such as coal contain sulfur impurities.

When the fossil fuels are burnt the sulfur is released as sulfur dioxide, SO_2.

(c) (i) How many **atoms** are there in a single molecule of SO_2? [1]

3 atoms (1 sulfur atom and 2 oxygen atoms)

(i) Once released into the atmosphere, sulfur dioxide reacts with water and air to form sulfuric acid.

Balance the symbol equation for the reaction; [1]

$$SO_2(g) + ½O_2(g) + H_2O(l) \rightarrow H_2SO_4(l)$$

or

$$2SO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 2H_2SO_4(l)$$

(d) Sulfuric acid damages buildings made of limestone.

Limestone contains calcium carbonate.

The sulfuric acid in the rainwater reacts with the calcium carbonate in the limestone.

Calcium sulfate, water and carbon dioxide are produced.

(i) Complete the word equation for the reaction of sulfuric acid with calcium carbonate. [1]

calcium carbonate + sulfuric acid → calcium sulfate + carbon dioxide + water

(ii) Name the type of reaction that occurs.

Choose **one** option. [1]

- [×] neutralisation
- [ ] thermal decomposition
- [ ] oxidation
- [ ] combustion

[Total: 12 marks]