TOTB 2025 Older Paper

ANSWERS

SECTION A General chemistry knowledge

1. Give the number of protons, neutrons and electrons in an atom of $^{31}_{15}P$. [1]

protons 15 neutrons 16 electrons 15

2. At room temperature a substance is a solid that does not conduct electricity.
It melts at a high temperature and does conduct electricity when molten.
The structure and bonding in the solid is; [1]

- [ ] simple covalent molecular
- [ ] giant covalent network / macromolecular
- [×] ionic
- [ ] metallic

3. A student prepares a solution of zinc chloride.
Describe how they could form zinc chloride crystals from the solution. [2]

Heat to evaporate (some) water (1 mark) _____

Allow to cool and crystals to form (1 mark) _____

Words underlined need for each marking point

4. Iron is extracted from iron oxide by reduction with carbon.

$$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$$

Calculate the mass of iron that can be formed from the reduction of 48 g of iron oxide. [2]

Relative atomic mass of Fe = 56

Relative formula mass of Fe_2O_3 = 160

There are several ways to do this question; **A correct answer of 33.6 g scores 2 marks**

Option 1: % by mass of iron in Fe_2O_3 is (112 / 160) × 100 = 70% (1 mark)

Therefore mass of Fe that is made from 48 g is 70% of 48 g = 33.6 g (1 mark)

Option 2: Using reacting masses 320 g of Fe_2O_3 gives 224 g of Fe (1 mark)

Therefore 48 g of Fe_2O_3 gives (48 / 320) × 224 = 33.6 g (1 mark)

Option 3: Using moles n(Fe_2O_3) reacted = 0.30 mol (1 mark)

n(Fe) formed = 0.60 mol = 33.6 g (1 mark)

5. Name an element that is a liquid at room temperature. [1]

bromine or mercury _____

6. Name the transition metal which burns with a blue-green flame. [1]

copper _____

7. **Figure 1** shows a compound found in camping gas.

Name the compound.

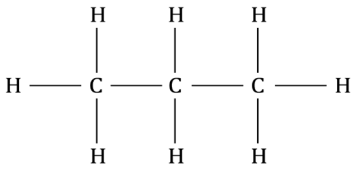


Figure 1

propane _____ [1]

8. Bromide ions are oxidised to bromine by chlorine.

Complete and balance the half equation below to show the oxidation.

Use **e-** to represent an electron. [1]

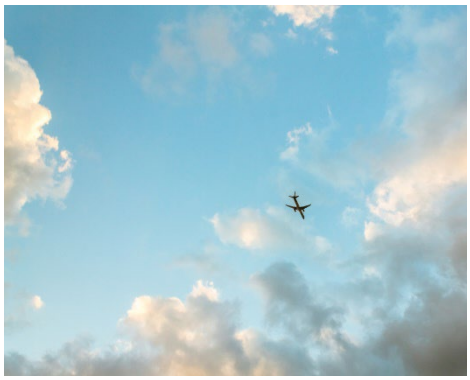
$$2Br^- \rightarrow Br_2 + 2e^-$$

Accept multiples

[Total: 10 marks]

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

9. This question is about the extraction and use of gases from the air.



(a) The air in the atmosphere is a mixture of gases.

Oxygen makes up 21% of the mixture.

Draw **one** line from each other gas to its percentage in the atmosphere. [2]

Gas	Approximate percentage
carbon dioxide	0.04%
nitrogen	78%
oxygen	21%
argon	0.93%

1 correct = 1 mark; all correct = 2 marks

(b) Argon is in Group 0.

(i) Which **two** of the following are true about elements in Group 0. [2]

- [×] They exist as monatomic gases.
- [ ] They exist as diatomic gases.
- [ ] The boiling points of the elements decreases as you go down the group.
- [×] The boiling points of the elements increases as you go down the group.

(ii) Argon is very unreactive.

Explain why.

The electron arrangement of argon is 2, 8, 8. [1]

It has a full outer shell of electrons *or* _____

It doesn't need to lose or gain electrons (to get a full outer shell) _____

Table 1 gives some more information about gases in air;

Gas	Argon	Carbon dioxide	Nitrogen	Oxygen	Water vapour
Formula	Ar	CO_2	N_2	O_2	H_2O
Melting point in °C	-189	-	-210	-218	0
Boiling point in °C	-186	-	-196	-183	100
Sublimation point at 1 atm		-78			

Table 1

(c) Nitrogen is extracted from air for food packaging.

The air is first liquefied.

The nitrogen is then separated using fractional distillation.

(i) The carbon dioxide and water must first be removed as they would freeze when the air is liquefied.

Circle the temperature at which water vapour and carbon dioxide are solid whereas oxygen, nitrogen and argon are gases. [1]

-200 °C **-105 °C** **-10 °C** **105 °C**

Once carbon dioxide and water have been removed, the mixture of gases is cooled and converted into a liquid.

(ii) During the fractional distillation process the liquid mixture of **argon**, **nitrogen** and **oxygen** is allowed to warm up.

In which order are the gases produced? 1 mark for correct order [1]

First nitrogen _____

Second argon _____

Third oxygen _____

(iii) Explain why nitrogen has a low boiling point.

Use an understanding of structure and bonding. [3]

Simple covalent molecule / molecular / bonding (1 mark) _____

Weak (intermolecular) forces between the molecules (1 mark) _____

Require little energy to break (1 mark) _____

One use of nitrogen is in the packaging of crisps.

It maintains the freshness of the crisps and protects them during transport.

(d) An individual packet of crisps has a volume of 500 cm^3.

43% of this volume is nitrogen gas. The remainder is the crisps.

(i) Calculate the volume of nitrogen gas in an individual packet of crisps. [1]

0.43 × 500 cm^3 = 215 cm^3

(ii) The nitrogen used for packaging is delivered to the packaging plant as a liquid.

A tanker delivers 500 m^3 of liquid nitrogen to a packaging plant.

Calculate the volume of 500 m^3 of liquid nitrogen once turned into a gas. [2]

Density of liquid nitrogen = 804 kg/m^3

Density of gaseous nitrogen = 1.25 kg/m^3

Correct answer of 321,600 m^3 = 2 marks

Mass of 500 m^3 of liquid nitrogen = 804 kg/m^3 × 500 m^3 = 402,000 kg (1 mark)

Volume of 402,000 kg of nitrogen as a gas;

= 402,000 kg / 1.25 kg m^{-3} = 321,600 m^3 (1 mark)

Alternative route;

Ratio of volumes as a liquid : gas = 1.25 : 804 (1 mark)

Therefore volume of 500 m^3 once turned into a gas = (500 / 1.25) × 804

= 321,600 m^3 (1 mark)

(iii) Use your answer to (d)(i) and d(ii) to calculate the number of packets of crisps that could be filled from the nitrogen in the tanker.

Give your answer to **4 significant figures**. [2]

1 m^3 = 1,000,000 cm^3

(If you didn't get an answer to part d(ii) assume the volume of 500 m^3 of liquid nitrogen as a gas is 255,000 m^3).

Correct answer of 1,496 million packets = 2 marks

If alternative answer used correct answer of 1,186 million packets = 2 marks

$215\ cm^3 = 2.15 \times 10^{-4}\ m^3$

(1 mark – awarded for unit conversion. Allow conversion of m^3 into cm^3)

No. of packets that can be filled = $321{,}600 / 2.15 \times 10^{-4}$

= 1,495,813,953 packets

= 1,496 million packets

or 1,496,000,000 packets (1 mark. Must be to 4 sig fig)

[Total: 15 marks]

10. This question is about the amount of oxygen in air.

A student sets up the apparatus in **Figure 2** to determine the percentage of oxygen in air.

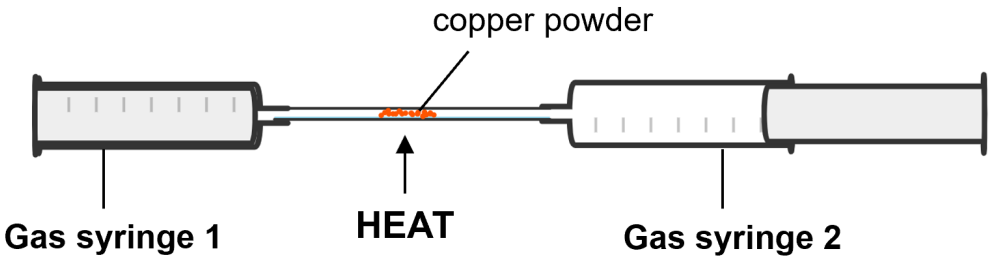


Figure 2

This is the method used:

1. Assemble the apparatus as shown in **Figure 2.**
2. Set the volume of **Gas syringe 1** at 0 cm^3
3. Set the volume of **Gas syringe 2** at 100 cm^3.
4. Pass the air slowly back and forth six times over the heated copper by gently pushing the fuller gas syringe.
5. Allow the apparatus to cool and read the volumes on each gas syringe.

(a) The hot copper powder reacts with the oxygen in the air to form copper(II) oxide, CuO.

Write a balanced symbol equation for the reaction. [1]

$2Cu + O_2 \rightarrow 2CuO$ (1 mark, allow multiples) _____

Table 2 shows the student's results.

	Volume of gas in each syringe in cm^3	
	Gas syringe 1	**Gas syringe 2**
At the start	0	100
At the end	22	61

Table 2

(b) Use the results to determine the percentage of oxygen in air by volume based on their experiment. [2]

Total volume of gas in syringes at end of experiment = 83 cm^3 (1 mark) _____

Therefore volume of the 100 cm^3 that was oxygen = 17 cm^3 _____

Therefore percentage of oxygen in air = **17%** (1 mark) _____

(c) A different student repeats the experiment.

Their results show that the percentage of oxygen in air is 20%.

The actual percentage (the true value) of oxygen in air is 21%.

Which **two** options could be a reason for the difference between the student's results and the true value. [2]

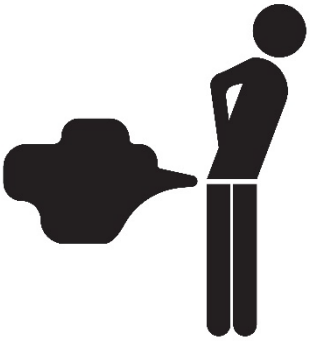
- [×] The equipment was still warm when the final syringe readings were taken.
- [×] The reaction between the copper and the oxygen was incomplete.
- [ ] Some gas escaped from the equipment during the reaction.
- [ ] A large excess of copper powder was used.

1 mark for each correct answer

If more than two chosen deduct one mark for each extra option selected

[Total: 5 marks]

11. This question is about smelly farts!



Passing wind is a normal part of the human body's digestive process.

When we eat, our gut breaks down food and produces gas as a byproduct.

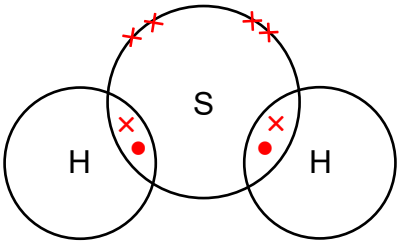
This gas builds up in the intestines and is released as a fart.

Unpleasant odours are caused by molecules that contain sulfur.

Two such molecules are hydrogen sulfide H_2S, and dimethyl sulfide $(CH_3)_2S$.

(a) (i) Complete the dot and cross diagram in **Figure 3** to show the arrangement of the outer shell electrons in a molecule of hydrogen sulfide, H_2S.

The electron arrangement of H is 1. The electron arrangement of S is 2,8,6. [2]



1 mark – shared pair in each overlap area

1 mark – 4 'non-bonding' electrons on sulfur

Figure 3

(ii) Complete the displayed formula of dimethyl sulfide, $(CH_3)_2S$ in **Figure 4**.

Add hydrogen atoms and covalent bonds. [1]

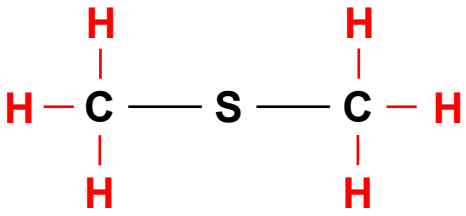


Figure 4

Unpleasant odours reach your nose by the process of **diffusion**.

(b) A teacher carries out a demonstration to show diffusion in two gases – hydrogen chloride, HCl and ammonia, NH_3.

Cotton wool soaked in a concentrated solution of HCl is placed at one end of a clear glass tube. This releases HCl(g).

Cotton wool soaked in a concentrated solution of NH_3 is placed at the other end of the tube. This releases NH_3(g).

The tube is sealed with bungs at either end.

Figure 5 shows the tube once set up.

Figure 5

The teacher tells the class to watch for the formation of a white solid formed when the two gases meet and react.

(i) Complete the equation to show the formula of the white solid formed. [1]

$$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$$ *(ignore charges on ions)*

(ii) The relative rates of diffusion of each of the gases can be approximated by the equation;

$$\frac{rate\ (NH_3)}{rate\ (HCl)} = \sqrt{\frac{molecular\ mass\ (HCl)}{molecular\ mass\ (NH_3)}}$$

Draw on **Figure 5** approximately where you expect the ring of white solid to form in the tube. [1]

Molecular masses; NH_3 = 17, HCl = 36.5

Mark awarded for ring drawn towards HCl from centre.

(Would in fact form approx. 2/5th of the way along from the HCl end.)

(iii) Explain why the rate of diffusion of the gases is not the same as the speed at which the gas molecules travel. [1]

Because individual gas molecules don't move in a straight line / particles are colliding

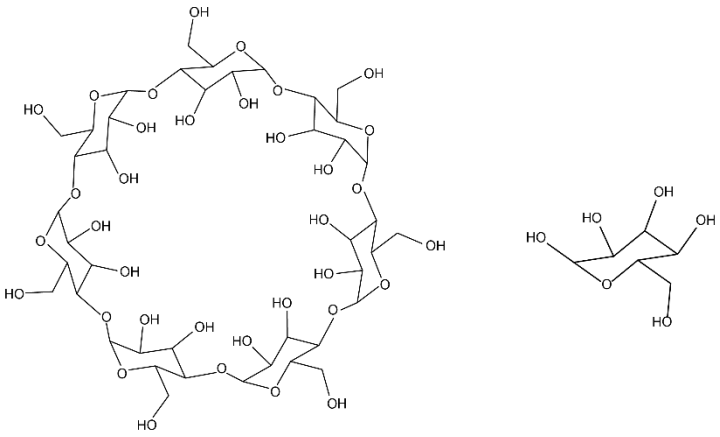
Accept any reasonable answer.

If you are not able to open a window, one way to reduce the unpleasant smell is to remove the molecules responsible for the odour.

(b) The Febreze series of Proctor & Gamble use molecules called cyclodextrins to cage the odourful molecules.

Cyclodextrins are macrocyclic rings formed from glucose molecules.

Figure 6 shows a cyclodextrin molecule and an individual glucose molecule.



cyclodextrin molecule glucose molecule

Figure 6

(i) How many glucose molecules reacted to form the cyclodextrin molecule in **Figure 6**? [1]

7 _____

(ii) The molecular formula of the cyclodextrin molecule in **Figure 6** is $C_{42}H_{70}O_{35}$.

Calculate the relative formula mass of the cyclodextrin in **Figure 6**.

Relative atomic masses in g/mol; C = 12, H = 1 and O = 16. [1]

(42 × 12) + (70 × 1) + (35 × 16) = **1134** _____

(iii) Glucose molecules combine to form cyclodextrin in a **condensation** reaction.

In a condensation reaction for each new bond that forms a small molecule is also made.

Complete the balanced symbol equation for the formation of cyclodextrin.

Give the formula for the small molecule made and balance the equation. [2]

$$7C_6H_{12}O_6 \rightarrow C_{42}H_{70}O_{35} + 7H_2O$$ _____

(1 mark for H_2O as a product; 1 mark for balancing; mark independently)

[Total: 10 marks]