GCSE · AQA · Chemistry

2 hours · 18 questions

Exam Questions

Amount of Substance & Gas Volume

Amount of Substance in Relation to Volumes of Gases

Easy (5 questions)	/29
Medium (6 questions)	/32
Hard (7 questions)	/46
Total Marks	**/107**

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Easy Questions

1 (a) This question is about gas volumes.

What volume does one mole of any gas occupy at room temperature and pressure?

Give your answer in cm^3 and dm^3.

Answer

The volume that one mole of any gas occupies at room temperature and pressure is:

- 24,000 cm^3; [1 mark]
- 24 dm^3; [1 mark]

[Total: 2 marks]

- At the same temperature and pressure, one mole of any gas will occupy the same volume as one mole of any other gas
- These values are specific values given for room temperature and pressure

(2 marks)

(b) What are the temperature and pressure implied with room temperature and pressure?

Room temperature = _________ ^{o}C

Room pressure = _________ atm

Answer

The temperature and pressure implied with room temperature and pressure are:

- Room temperature = 20 ^{o}C; [1 mark]
- Room pressure = 1 atm; [1 mark]

[Total: 2 marks]

(2 marks)

(c) State **one** equation to calculate the amount of gas in moles.

Answer

One equation to calculate the amount of gas in moles is:

- Amount of gas = $\frac{\text{volume (in dm}^3)}{24}$

  OR

  Amount of gas = $\frac{\text{volume (in cm}^3)}{24000}$; [1 mark]

[Total: 1 mark]

- For these questions, you will either be calculating the amount of gas in moles or the volume of gas
  - **Careful:** When calculating volumes of gas, check whether you are working in cm^3 or dm^3

(1 mark)

2 (a) Ethanol, C_2H_5OH, undergoes complete combustion to form carbon dioxide and water.

Complete the balanced symbol equation for the complete combustion of ethanol.

$$\_\_\_ \ C_2H_5OH + \_\_\_ \ O_2 \rightarrow \_\_\_ \ CO_2 + \_\_\_ \ H_2O$$

Answer

The balanced symbol equation for the complete combustion of ethanol is:

$C_2H_5OH + \mathbf{3}\ O_2 \rightarrow \mathbf{2}\ CO_2 + \mathbf{3}\ H_2O$

- **2** CO_2 + **3** H_2O; [1 mark]
- C_2H_5OH + **3** O_2; [1 mark]

[Total: 2 marks]

- The two carbons in ethanol can form 2 CO_2
  - $C_2H_5OH + \_\_\_ \ O_2 \rightarrow \mathbf{2}\ CO_2 + \_\_\_ \ H_2O$
- There is a total of six hydrogens in ethanol, which can form 3 H_2O
  - $C_2H_5OH + \_\_\_ \ O_2 \rightarrow \mathbf{2}\ CO_2 + \mathbf{3}\ H_2O$
- This gives a total of seven oxygens in the products (right-hand side)
  - The oxygen in ethanol accounts for one of these
  - This means that there must be 3 O_2 to give the other six oxygens
  - $C_2H_5OH + \mathbf{3}\ O_2 \rightarrow \mathbf{2}\ CO_2 + \mathbf{3}\ H_2O$

(2 marks)

(b) Which of the chemicals in the reaction equation are gases at room temperature and pressure?

Answer

The chemicals in the reaction equation that are gases at room temperature and pressure are:

- Oxygen / O_2
  AND
  Carbon dioxide / CO_2; [1 mark]

[Total: 1 mark]

- You should know that oxygen and carbon dioxide are gases at room temperature and pressure
  - You are also expected to know the tests for both of these gases

(1 mark)

(c) The complete combustion of ethanol is performed at room temperature and pressure.

Draw a circle around the correct word to complete the sentences.

9 moles of oxygen produce [2 moles / 3 moles / 6 moles / 9 moles] of carbon dioxide.

A volume of $\boxed{\begin{array}{l} 24\ dm^3 \\ 72\ dm^3 \\ 144\ dm^3 \\ 24000\ cm^3 \end{array}}$ of carbon dioxide is released.

Answer

The correct completed sentences are:

- 9 moles of oxygen produce **6 moles** of carbon dioxide; [1 mark]
- A volume of **144 dm^3** of carbon dioxide is released; [1 mark]

[Total: 2 marks]

- This question highlights the importance of being able to balance equations
- A correctly balanced equation shows a ratio of 3 O_2 : 2 CO_2
  - Therefore, 9 O_2 will produce 6 CO_2
- One mole of CO_2 occupies 24 dm^3 at room temperature and pressure
  - So, 6 moles of CO_2 will occupy 6 x 24 = 144 dm^3

(2 marks)

3 (a) 0.0625 moles of methane is burnt in air according to the following equation:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

How many moles of oxygen are required for this combustion reaction?

Tick (✓) **one** box.

0.03125	
0.0625	
0.125	

Answer

How many moles of oxygen are required for this combustion reaction?

0.03125	
0.0625	
0.125	✓; [1 mark]

[Total: 1 mark]

- The equation shows that every one molecule of methane reacts with two molecules of oxygen
- Therefore, 0.0625 moles of methane will react with 2 x 0.0625 moles of oxygen

(1 mark)

(b) If the reaction is completed at room temperature and pressure, what volume, in dm^3, of methane is being burned?

Answer

The volume of methane being burned is:

- Volume = moles x 24
  OR
  Volume = 0.0625 x 24; [1 mark]

- Volume = 1.5 dm^3; [1 mark]

[Total: 2 marks]

- This question clearly states "at room temperature and pressure" otherwise you would have to assume this as you would not be able to complete the question otherwise

- **Careful:** The question asks for dm^3 so make sure that you multiply by 24

(2 marks)

(c) If the reaction was completed at room temperature and pressure, what volume, in dm^3, of carbon dioxide is produced?

Answer

The volume of carbon dioxide produced is:

- 1.5 dm^3; [1 mark]
  This answer must match your answer from part (b)

[Total: 1 mark]

- The equation shows that for every one molecule of methane burned, one molecule of carbon dioxide is formed

- This means one mole of methane would form one mole of carbon dioxide

- Since the volume of any gas at room temperature and pressure is the same, 1.5 dm^3 of methane will produce 1.5 dm^3 of carbon dioxide

(1 mark)

(d) Assuming that all the chemicals involved in the reaction are in the gaseous state, the balanced symbol equation is:

$$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)$$

Draw a circle around the correct answer to complete the sentence.

Burning 2500 cm^3 of methane produces a **total** volume of	2500 cm^3 5000 cm^3 7500 cm^3

Answer

The correct complete sentence is:

- Burning 2500 cm^3 of methane produces a total volume of 7500 cm^3; [1 mark]

[Total: 1 mark]

- The ratio is 1 CH_4 : 1 CO_2
  - Therefore, 2500 cm^3 of CO_2 will be produced
- The ratio is 1 CH_4 : 2 H_2O
  - Therefore, 5000 cm^3 of H_2O will be produced
- This gives a total volume of 2500 + 5000 = 7500 cm^3

(1 mark)

4 (a) Helium is a gas at room temperature and pressure.

Calculate the number of moles in a 38.4 g sample of helium.

Relative atomic mass (A_r): He = 4

Use the equation:

$$\text{Moles} = \frac{\text{mass}}{A_r}$$

Answer

The number of moles in a 38.4 g sample of helium is:

- $\text{Moles} = \frac{\text{mass}}{A_r} = \frac{38.4}{4} = 9.6$; [1 mark]

[Total: 1 mark]

- Any time you are given a mass of a known chemical, you can calculate the number of moles using the mass and atomic / molar mass

(1 mark)

(b) What volume of gas, in cm^3 and dm^3, does 38.4 g of helium occupy?

Answer

To calculate the volume of gas, in cm^3 and dm^3, that 38.4 g of helium occupies:

Volume = moles x 24000 for cm^3

- Volume = 9.6 x 24000 = 230400 cm^3; [1 mark]

Volume = moles x 24 for dm^3

- Volume = 9.6 x 24 = 230.4 dm^3

  OR

  Volume in dm^3 = $\frac{\text{volume in cm}^3}{1000} = \frac{230400}{1000}$ = 230.4 dm^3; [1 mark] *A maximum of one mark is allowed for the correct answers with incorrect units, e.g. 230400 dm^3*

[Total: 2 marks]

- **Careful:** Make sure that you keep track of whether you are working in cm^3 or dm^3 as this can cost you marks

(2 marks)

(c) Chlorine, Cl_2, is a gas at room temperature and pressure.

Calculate the number of moles in a 376.3 g sample of chlorine.

Relative atomic mass (A_r): Cl= 35.5

Use the equation:

$$\text{Moles} = \frac{\text{mass}}{M_r}$$

Answer

The number of moles in a 376.3 g sample of chlorine is:

- $\text{Moles} = \frac{\text{mass}}{M_r} = \frac{376.3}{71}$; [1 mark]
- Moles = 5.3; [1 mark]

[Total: 2 marks]

- **Careful:** If the gas contains more than one atom then you have to use the molecular mass

(2 marks)

(d) What volume of gas, in cm^3 and dm^3, does 376.3 g of chlorine occupy?

Answer

To calculate the volume of gas, in cm^3 and dm^3, that 376.3 g of chlorine occupies:

Volume = moles x 24000 for cm^3

- Volume = 5.3 x 24000 = 127200 cm^3; [1 mark]

Volume = moles x 24 for dm^3

- Volume = 5.3 x 24 = 127.2 dm^3

  OR

  Volume in dm^3 = $\frac{\text{volume in cm}^3}{1000} = \frac{127200}{1000}$ = 127.2 dm^3; [1 mark] *A maximum of one mark is allowed for the correct answers with incorrect units, e.g. 127200* dm^3

[Total: 2 marks]

- **Careful:** Make sure that you keep track of whether you are working in cm^3 or dm^3 as this can cost you marks

(2 marks)

5 (a) Carbon dioxide and water are formed when propane undergoes complete combustion.

The equation for the reaction is:

$$C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4\ H_2O\ (l)$$

Calculate the number of moles in 55.44 g of propane.

Relative molecular mass (M_r): $C_3H_8 = 44$

Answer

The number of moles in 55.44 g of propane is:

- $\text{Moles} = \dfrac{\text{mass}}{M_r} = \dfrac{55.44}{44}$; [1 mark]
- Moles = 1.26; [1 mark]

[Total: 2 marks]

(2 marks)

(b) What volume of gas, in dm^3, does 55.44 g of propane occupy?

Answer

The volume of gas that 55.44 g of propane occupies is:

- Volume = moles x 24
- Volume = 1.26 x 24 = 30.24 dm^3; [1 mark]
  Your answer to part (a) x 24 can score the mark by transferred error / error carried forward

[Total: 1 mark]

- **Remember:** Volume = moles x 24 if you are working in dm^3 and moles x 24000 if you are working in cm^3

(1 mark)

(c) What volume of carbon dioxide is produced when 55.44 g undergoes complete combustion?

Answer

The volume of carbon dioxide produced when 55.44 g undergoes complete combustion is:

- 30.24 x 3 = 90.72 dm^3; [1 mark]
  Your answer to part (b) x 3 is accepted as a transferred error / error carried forward

[Total: 1 mark]

- From the equation, you can see that one mole of propane produces 3 moles of carbon dioxide
- Therefore, 1 dm^3 of propane will produce 3 dm^3 of carbon dioxide which is applied to 30.24 dm^3 of propane

(1 mark)

(d) In another combustion experiment, 1.3 dm^3 of propane is combusted in the presence of 8.0 dm^3 of oxygen.

Calculate the volume of oxygen that is left unreacted.

Give your answer in cm^3.

Answer

To calculate the volume of oxygen that is left unreacted:

- 1.3 dm^3 of propane reacts with 6.5 dm^3 of oxygen
  OR
  Idea of 1 : 5 ratio for propane : oxygen; [1 mark]
- 8.0 - 6.5 = 1.5 dm^3; [1 mark]
- 1500 cm^3; [1 mark]

[Total: 3 marks]

- For this question, you have to use the ratio of propane : oxygen from the chemical equation
  - This is 1 : 5
- You can then calculate the volume of oxygen required in dm^3
- You then have to subtract your answer from the 8.0 dm^3 given in the question
- The final mark of this question is making sure that you give an answer in cm^3 as specified in the question

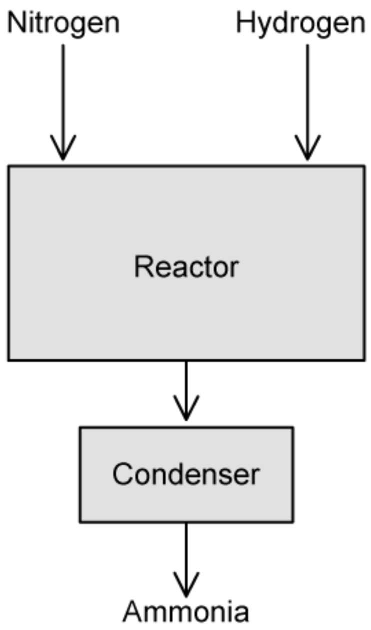
(3 marks)

Medium Questions

1 (a) Nitrogen and hydrogen react together in the Haber process to produce ammonia.

Figure 1 shows a flow diagram for the process

Figure 1



A gaseous mixture of NH_3, N_2 and H_2 leaves the reactor where the ammonia is separated and the hydrogen and nitrogen are recycled back into the reactor. The reactor has a temperature of 450 ^{o}C and a pressure of 200 atmospheres.

What does Avogadro's Law state about all three gases?

Answer

Avogadro's Law states that:

- At the same temperature and pressure; [1 mark]
- Equal volumes of gases occupy the same volume of space; [1 mark]

[Total: 2 marks]

(2 marks)

(b) The gases have the following boiling points:

Gas	Boiling Point (^{o}C)
Ammonia	-33
Nitrogen	-196
Hydrogen	-253

Suggest how ammonia can be separated from the other gases.

Answer

Ammonia can be separated by:

- Cooling the mixture of gases
  OR
  Condensing the mixture of gases; [1 mark]
- To -34 ^{o}C; [1 mark]
  2Accept any number below -34 ^{o}C but above -196 ^{o}C

[Total: 2 marks]

- By cooling the mixture of gases to −34 ^{o}C, the ammonia will condense and can be separated
- The mixture should not be cooled below −196 ^{o}C as this would also condense the nitrogen

(2 marks)

(c) The equation for the Haber process is:

$$N_2\,(g) \quad + \quad 3H_2\,(g) \quad \rightleftharpoons \quad 2NH_3\,(g)$$

Calculate the volume of ammonia produced from the complete reaction of 795 dm^3 of hydrogen.

Answer

To calculate the volume of ammonia produced:

- $795 \text{ x } \frac{2}{3}$

  OR

  $795 \div 3 \times 2;$ [1 mark]

- = 530 dm^3; [1 mark]

[Total: 2 marks]

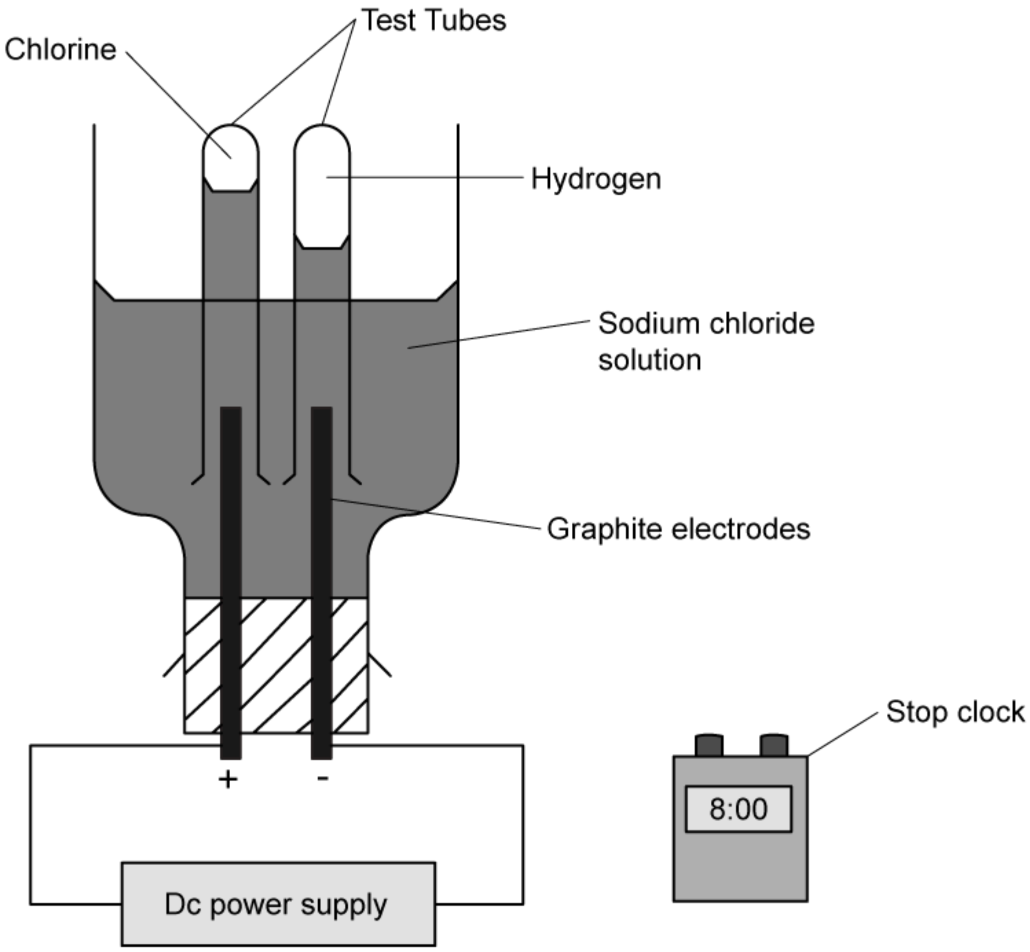
- You need to look at the ratio of the hydrogen to ammonia in the equation
- In this case, it is 3:2

(2 marks)

2 (a) A student investigated the electrolysis of a solution of sodium chloride by measuring how the volume of gases produced changes with time.

Figure 1 shows the apparatus used in the investigation.

Figure 1



The student made an error in designing and setting up the apparatus for this investigation.

Identify the error and suggest what needs to be changed.

Answer

The error is:

- Test tubes cannot measure volume
  OR
  Test tubes have no graduation / scale; [1 mark]

- Use instead a measuring cylinder; [1 mark]
  Accept use of burette, gas syringe or Hoffmann voltameter

[Total: 2 marks]

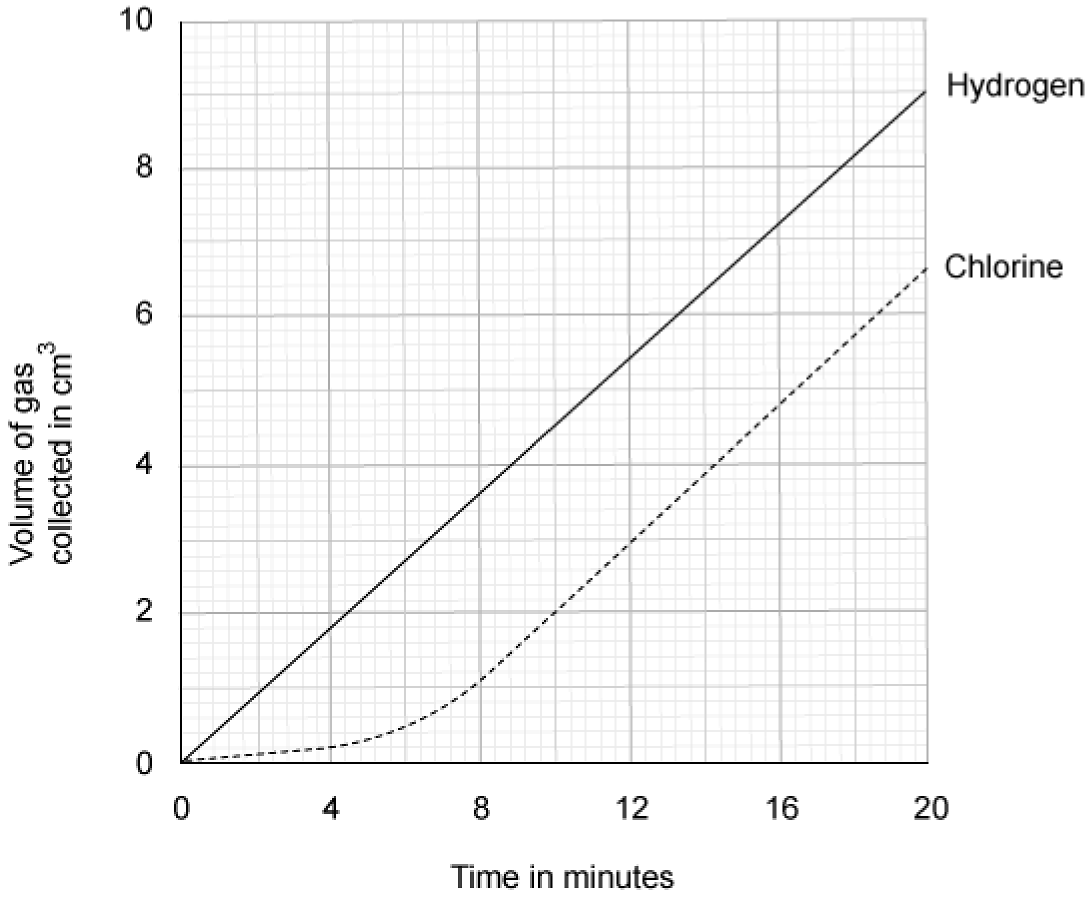
(2 marks)

(b) The student soon adjusted the apparatus and was able to perform the investigation correctly.

The student measured the volumes of gases produced every minute for 20 minutes and constructed a graph of these results.

Figure 2 shows the graph of the investigation.

Figure 2



Using the graph, describe the trends shown in the results.

Answer

The trends in results are:

Any **three** from:

- The rate of collection of hydrogen is 0.45 cm^3 per minute; [1 mark]
- The volume of hydrogen collected is directly proportional to the time
  OR
  The volume of hydrogen collected occurs at a constant rate; [1 mark]

- The amount of chlorine collected increases up to the eighth minute; [1 mark]
  Allow any value from 6-8 mins

- After 8 minutes the rate of collection of chlorine is the same as that of hydrogen; [1 mark]

- After 8 minutes the rate of collection of chlorine is 0.48 cm^3 per minute; [1 mark]

- After 8 minutes the volume of chlorine collected occurs at a constant rate; [1 mark]

[Total: 3 marks]

(3 marks)

(c) The number of moles of each gas produced at each electrode is the same and no gas escapes from the apparatus however there is a difference in the amount of gas collected.

Suggest **one** reason for the difference in volume of each gas collected.

Answer

The volume of each gas is different because:

- The chlorine reacts with the water
  OR
  The chlorine dissolves in the solution; [1 mark]

[Total: 1 mark]

(1 mark)

(d) Using **Figure 2**, calculate the amount in moles of chlorine collected after 16 minutes.

The volume of one mole of any gas at room temperature and pressure is 24.0 dm^3

State your answer in standard form.

Answer

To calculate the number of moles of chlorine formed is:

- Volume of chlorine gas after 16 mins= 4.8 cm^3; [1 mark]
- Convert the volume to dm^3 : 4.8 / 1000= 0.0048 dm^3; [1 mark]
- Calculate the number of moles: 0.0048 / 24 = 0.0002 mol; [1 mark]
- Write answer as standard form: 2.0 x 10^{-4} mol; [1 mark]

[Total: 4 marks]

- Don't forget to convert your answer to standard form at the end

(4 marks)

3 What is the volume occupied by 5.6 g of nitrogen gas at RTP?

Relative atomic masses (A_r): N= 14

A. 2.4 dm^3

B. 4.8 dm^3

C. 9.6 dm^3

D. 12 dm^3

Answer

The correct answer is B because:

- **Step 1**: Calculate the amount of nitrogen in moles

$$\text{amount of } N_2 = \frac{\text{mass in g}}{\text{molar mass in g/mol}}$$

$$= \frac{5.6 \text{ g}}{28 \text{ g/mol}} = 0.20 \text{ mol}$$

- **Step 2**: Calculate the volume of nitrogen

volume of N_2 = moles x molar volume in dm^3/ mol

= 0.20 x 24 = **4.8 dm^3**

(1 mark)

4 (a) This question is about calculating the volumes of gases produced in different reactions.

What volume of hydrogen is produced from the reaction of 2.5 g of magnesium with excess sulfuric acid?

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$$

Relative atomic mass (A_r): Mg = 24

Answer

The volume of hydrogen is calculated by:

- Moles of Mg = $\frac{2.5}{24} = 0.104$ mol; [1 mark]
- From the balanced equation the molar ratio of Mg to H_2 is 1 : 1; [1 mark]
- So 0.104 moles Mg gives 0.104 moles H_2; [1 mark]
- 1 mole H_2 = 24 dm^3 , therefore 0.104 moles H_2 = 0.104 x 24 = 2.496 dm^3 [1 mark]

[Total: 4 marks]

- **Remember:** $\text{No of moles (mol)} = \frac{\text{mass (g)}}{\text{molar mass (g/mol)}}$

(4 marks)

(b) What volume of steam is produced from the combustion of 2.000 kg of methane in excess oxygen?

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Relative formula mass (M_r): CH_4 = 16

Answer

The volume of steam produced is:

- Moles of CH_4 = $\frac{2000}{16} = 125$ mol; [1 mark]
- From the balanced equation the molar ratio of CH_4 to H_2O is 1 : 2; [1 mark]
- So 125 mole CH_4 gives 250 moles H_2O; [1 mark]
- 1 mole H_2O = 24 dm^3 , therefore 250 moles H_2O = 250 x 24 = 6000 dm^3; [1 mark]

[Total: 4 marks]

- **Remember:**
  - Convert kg to g to calculate the number of moles
  - To calculate the volume of a gas use number of moles x 24 dm^3

(4 marks)

(c) What mass of iodine is required to react with hydrogen to produce 67.20 dm^3 of hydrogen iodide?

$$I_2 + H_2 \rightarrow 2\,HI$$

Relative atomic mass (A_r): I = 127

Answer

The mass of iodine required is calculated by:

- Moles of HI = $\frac{67.20}{24} = 2.8$ mol; [1 mark]
- From the balanced equation the molar ratio of I_2 to HI is 1 : 2; [1 mark]

- So moles of $I_2 = \frac{2.8}{2} = 1.4$ mol; [1 mark]

- M_r of I_2 = 2 x 127 = 254; [1 mark]

- So mass of I_2 is 1.4 x 254 = 355.6 g; [1 mark]

[Total: 5 marks]

(5 marks)

5 The reaction between nitrogen and hydrogen produces ammonia.

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

What volume of ammonia is produced from 565 cm^3 of hydrogen?

A. 1130 cm^3

B. 377 cm^3

C. 283 cm^3

D. 847 cm^3

Answer

The correct answer is B because:

- Gases react together in simple volume proportions, the same as the mole ratios in the balanced equation

- The mole ratio of H_2: NH_3 is 3 : 2 or 1 : $\frac{2}{3}$

$$\text{Volume of ammonia} = \frac{2}{3} \times 565\ \text{cm}^3 = 377\ \text{cm}^3$$

(1 mark)

6 A gas cylinder has a volume of 264 dm^3.

What mass of hydrogen does it contain?

Relative atomic masses (A_r): H=1

A. 22 g

B. 11 g

C. 24 g

D. 264 g

Answer

The correct answer is A because:

- **Step 1:** Calculate the amount of gas in the cylinder

moles = $\frac{\text{volume in dm}^3}{24\ \text{dm}^3/\text{mol}}$

amount of gas= $\frac{264\ \text{dm}^3}{24\ \text{dm}^3/\text{mol}} = 11\ \text{mol}$

- **Step 2:** Calculate the mass of hydrogen (remember to use H_2 not H)

mass = moles x molar mass

mass of H_2 = 11 mol x 2 g/mol = 22 g

(1 mark)

Hard Questions

1 (a) This question is about electrolysis.

In the electrolysis of molten potassium bromide, separate reactions occur at the electrodes.

Write **two** balanced half equations for the reactions that occur at the anode and the cathode.

Answer

The balanced half equations for the reactions that occur at the anode and the cathode are:

- Anode: $2Br^- \rightarrow Br_2 + 2e^-$; [1 mark]
- Cathode: $K^+ + e^- \rightarrow K$; [1 mark]
- Correctly identifies the bromide reaction as occurring at the anode and the potassium ion reaction as occurring at the cathode; [1 mark]

[Total: 3 marks]

- The question asks for two balanced half equations which would suggest two marks
- There is a third mark – *for the reactions that occur at the anode and the cathode*
    - It is likely that you will have to identify which equation relates to which electrode
    - This is why the words anode and cathode have been used

(3 marks)

(b) During the electrolysis of molten potassium bromide, 3.12 g of potassium was formed.

Calculate the number of moles of bromine formed in the reaction.

Relative atomic masses (A_r): K = 39, Br = 80

Answer

To calculate the number of moles of bromine formed in the reaction:

- $2KBr \rightarrow 2K + Br_2$
  OR
  Idea that there are 2 moles of potassium for every one mole of bromine (from ionic equations in part (a); [1 mark]

- Moles of potassium = $\frac{3.12}{39}$ = 0.08 moles; [1 mark]

- Moles of bromine = $\frac{0.08}{2}$ = 0.04 moles; [1 mark]

[Total: 3 marks]

- This question cannot be completed without:
  - Either writing a balanced symbol equation
  - Or recognising that the number of electrons in the two half equations are unbalanced so you have to double the potassium equation
- Once you have identified the ratio of potassium : bromine you can apply this to the number of moles of potassium in order to calculate the number of moles of bromine

(3 marks)

(c) 11.3% of the bromine produced in the reaction escapes the container.

Calculate the volume, in dm^3, of bromine in the container.

Answer

To calculate the volume, in dm^3, of bromine in the container:

Option 1

- 0.04 x 24000 = 960 cm^3; [1 mark] *Allow error carried forward using the number of moles from part (b)*

- $\frac{960}{100} \times (100 - 11.3)$ = 851.52 cm^3
  AND

$$\frac{851.52}{1000}$$ = 0.852 dm^3; [1 mark]

Option 2

- 0.04 x 24 = 0.96 dm^3; [1 mark] *Allow error carried forward using the number of moles from part (b)*
- $\frac{0.96}{100} \times (100 - 11.3)$ = 0.852 dm^3; [1 mark]

[Total: 2 marks]

- **Careful:** The 11.3% is how much bromine vapour is lost, not how much bromine vapour remains in the container

(2 marks)

(d) When molten sodium chloride was electrolysed, 0.28 g of sodium was formed at one electrode.

Calculate the volume of gas, in cm^3, that was produced at room temperature and pressure.

Relative atomic masses (A_r): Na = 23, Cl = 35.5

Answer

To calculate the volume of gas, in cm^3, that was produced at room temperature and pressure:

- $2NaCl \rightarrow 2Na + Cl_2$; [1 mark]
- Moles of sodium = $\frac{0.28}{23} \div 2$ = 0.006087moles

  AND

  Moles of chlorine = 0.006087 moles; [1 mark]
- Volume of chlorine = 0.006087 x 24000 = 146 cm^3; [1 mark]

[Total: 3 marks]

- **Careful:** There are 2 moles of sodium in the equation which you need to account for in your calculation

- These questions should follow a similar pattern
    - Balanced symbol equation
    - Moles of one element
    - Use the ratio from the balanced equation to calculate the moles of the second element
    - Calculate the volume of the second element

(3 marks)

2 (a) This question is about combustion.

A 0.050 mol sample of a hydrocarbon was burned in excess oxygen.

To determine the identity of the hydrocarbon, the type of combustion used is important.

Which type of combustion should be used to determine the identity of the hydrocarbon? Explain your reasoning.

Answer

The type of combustion must be known in order to determine the identity of the hydrocarbon because:

- The products of combustion will be used to determine the number of carbon and hydrogen atoms in the hydrocarbon; [1 mark]
- Complete combustion produces water and carbon dioxide; [1 mark]
- Incomplete combustion produces water and carbon monoxide or carbon; [1 mark]

[Total: 3 marks]

- Hydrocarbons contain only hydrogen and carbon
- When they combust, the products depend on the type of combustion
    - Complete combustion produces only water and carbon dioxide
    - Incomplete combustion produces water and carbon monoxide or carbon depending on the amount of oxygen available in the reaction
- Therefore, the only certain way to know the number of carbon atoms in the hydrocarbon is to combust it in the presence of excess oxygen
- This means that only water and carbon dioxide will be formed

(3 marks)

(b) 3.6 dm^3 of carbon dioxide were produced during the complete combustion of the 0.050 mol sample of a hydrocarbon.

Calculate the number of moles of carbon dioxide released.

Answer

To calculate the number of moles of carbon dioxide released:

- $\frac{3.6}{24}$ = 0.15 moles
  OR
  $\frac{3600}{24000}$ = 0.15 moles; [1 mark]

[Total: 1 mark]

- The 24 $dm^3\ mol^{-1}$ is the molar gas volume at room temperature and pressure (RTP).

- It means that 1 mole of any gas occupies 24 dm^3 at room temperature and pressure

- $\text{moles} = \frac{\text{volume (in } dm^3)}{24\ (dm^3 / mol)}$

(1 mark)

(c) When the hydrocarbon was burned 1.204×10^{23} molecules of water were produced.

Calculate the number of moles of hydrogen atoms in 1.204×10^{23} molecules of water.

Answer

To calculate the number of moles of hydrogen atoms in 1.204×10^{23} molecules of water:

- Moles of water: $\frac{1.204 \times 10^{23}}{6.02 \times 10^{23}}$ = 0.2 moles; [1 mark]

- Moles of hydrogen atoms: 0.2 x 2 = 0.4 moles; [1 mark]

[Total: 2 marks]

- One mole of any substance contains 6.02×10^{23} particles of the substance

- Therefore, 1.204×10^{23} must be divided by 6.02×10^{23} to get the number of moles of water

- **Careful:** Water contains two atoms of hydrogen so you will need to double the number of moles of water to get the number of moles of hydrogen

(2 marks)

(d) The amount of hydrocarbon burned was 0.050 mol.

Calculate the molecular formula of the hydrocarbon.

Answer

To calculate the molecular formula of the hydrocarbon:

- Number of carbon atoms: $\frac{0.15}{0.05}$ = 3; [1 mark]
  Allow error carried forward using your answer from part (b)

- Number of hydrogen atoms: $\frac{0.4}{0.05}$ = 8; [1 mark]
  Allow error carried forward using your answer from part (c)

- Therefore, the formula of the hydrocarbon is C_3H_8; [1 mark]

[Total: 3 marks]

- In parts (b) and (c) you have calculated the number of moles of carbon and hydrogen released as carbon dioxide and water respectively from a 0.050 mol sample of the hydrocarbon
  - This means that the 0.15 moles of carbon dioxide came from 0.050 moles of hydrocarbon
    - Therefore, there were three carbon atoms in the hydrocarbon
  - This means that the 0.4 moles of water came from 0.050 moles of hydrocarbon
    - Therefore, there were eight hydrogen atoms in the hydrocarbon

(3 marks)

3 (a) Sodium carbonate reacts with dilute hydrochloric acid:

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

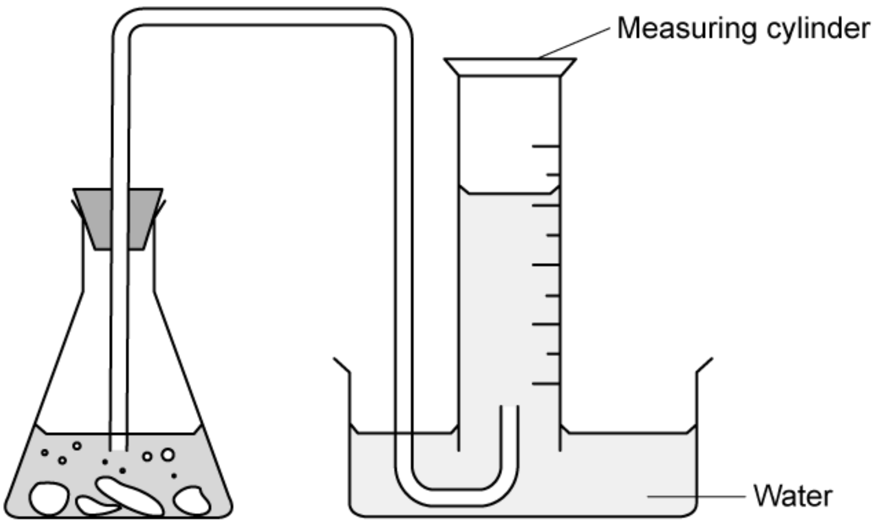
A student investigated the volume of carbon dioxide produced when different masses of sodium carbonate were reacted with dilute hydrochloric acid.

This is the method used.

1. Place a known mass of sodium carbonate in a conical flask.
2. Measure 10 cm^3 of dilute hydrochloric acid using a measuring cylinder.
3. Pour the acid into the conical flask.
4. Place a bung in the flask and collect the gas until the reaction is complete.

The student has set the apparatus incorrectly as shown in **Figure 1**.

Figure 1



Identify the error and describe what would happen if the student used the apparatus.

Answer

The error in the student's apparatus is:

- The delivery tube is in the acid; [1 mark]

- Acid could leave the (conical flask)
  OR
  Acid could go into the water
  OR
  Acid could go up the delivery tube; [1 mark]

[Total: 2 marks]

- Questions like these have appeared in previous exams
- Examiners comment about:
  - The number of students that fail to spot the error
  - The even greater number of students that miss how the question simply asks "what would happen" and start making irrelevant points

(2 marks)

(b) The student corrected the error and collected the results shown in **Table 1**.

Table 1

Mass of sodium carbonate in g	0.07	0.12	0.23	0.29	0.34	0.54	0.59	0.65
Volume of carbon dioxide gas in cm^3	16.0	27.5	52.0	65.0	77.0	95.0	95.0	95.0

Suggest why the volume of carbon dioxide collected reaches a maximum of 95.0 cm^3.

Answer

The volume of carbon dioxide collected reaches a maximum of 95.0 cm^3 because:

- All of the acid has reacted
  OR
  The reaction is complete / has finished; [1 mark]

[Total: 1 mark]

- This is not really a hard-level question but it is a question that gets some overcomplicated answers
- You should always try and state the basics and then add the detail after

(1 mark)

(c) Describe how the student could accurately determine the minimum mass of sodium carbonate required to produce 95.0 cm^3 of carbon dioxide.

Answer

To accurately determine the minimum mass of sodium carbonate required to produce 95.0 cm^3 of carbon dioxide, the student should:

- Repeat the experiment using masses in the range of 0.34 g to 0.54 g; [1 mark]
- Using the same volume / 10 cm^3 of hydrochloric acid; [1 mark]
- Using the same concentration of hydrochloric acid; [1 mark]

[Total: 3 marks]

- The student has to get more results between 0.34 g and 0.54 g
- That alone will not be enough for three marks, so you have to consider how the experiment is repeated to ensure validity

(3 marks)

(d) The carbon dioxide was collected at room temperature and pressure.

Calculate the number of atoms of oxygen present in the 95.0 cm^3 of carbon dioxide produced.

Give your answer to three significant figures.

Answer

To calculate the number of atoms of oxygen present in the 95.0 cm^3 of carbon dioxide produced:

- Number of moles of carbon dioxide: $\frac{95.0}{24000}$ = 0.0039583 moles

  OR

  Number of moles of carbon dioxide: $\frac{0.095}{24}$ = 0.0039583 moles; [1 mark]

- Number of molecules of carbon dioxide: 0.0039583 x 6.02 x 10^{23} = 2.3829 x 10^{21}; [1 mark]

- Number of atoms of oxygen: 2.3829 x 10^{21} x 2 = 4.77 x 10^{21}; [1 mark]
  Answer must be to three significant figures for this mark

[Total: 3 marks]

- Although a question combining the Avogadro constant and calculating gas volumes is unlikely it is not impossible and would be a significant test of most student's skills

- For this calculation, you could:

  - Calculate the number of moles of oxygen, based on $C + O_2 \rightarrow CO_2$, which would still be 0.0039583 moles due to the 1 : 1 ratios and then the rest of the calculation continues as shown in marking points 2 and 3

(3 marks)

4 Air bags contain sodium azide (NaN_3) which decomposes on heating to form sodium and nitrogen.

$$2NaN_3 \rightarrow 2Na + 3N_2$$

What volume of nitrogen would be produced from 13 g of sodium azide?

Relative atomic mass (*Ar*): N = 14

Relative formula mass (M_r): NaN_3 = 65

A. 4.8 dm^3

B. 7.2 dm^3

C. 48 dm^3

D. 72 dm^3

Answer

The correct answer is B because:

- **Step 1:** Calculate the amount of sodium azide:

$$\text{moles} = \frac{\text{mass in g}}{\text{molar mass in g/mol}}$$

$$\text{amount of } NaN_3 = \frac{13.0 \text{ g}}{65.0 \text{ g/mol}} = 0.2 \text{ mol}$$

- **Step 2:** Deduce the amount of N_2 from the balanced equation:

the mole ratio of NaN_3 : N_2 is 2: 3

therefore the amount of N_2 = 0.2 x $\frac{3}{2}$ = 0.3 mol

- **Step 3:** Calculate the volume of nitrogen:

volume of gas = moles x 24 dm^3 / mol

volume of N_2 = 0.3 x 24 = **7.2 dm^3**

(1 mark)

5 (a) This question is about power stations.

Coal-fired power stations are being phased out as the supply of coal decreases and greater restrictions on emissions are implemented.

Coal typically contains between 0.2% and 5% sulfur by dry weight.

Calculate the average number of moles of sulfur in 75 tonnes of coal.

Relative atomic mass (A_r): S = 32

1 tonne = 1 x 10^6 g

Answer

To calculate the average number of moles of sulfur in 75 tonnes of coal:

- Average percent of sulfur: $\frac{(0.2+5)}{2}$ = 2.6%; [1 mark]
- Average mass of sulfur: $\frac{75}{100} \times 2.6$ = 1.95 tonnes; [1 mark]
- Number of moles of sulfur: $\frac{1.95 \times 10^6}{32}$ = 60937.5 moles; [1 mark]

[Total: 3 marks]

- **Remember:** To calculate the number of moles, the mass must be converted from tonnes to grams

(3 marks)

(b) Calculate the volume of sulfur dioxide released from the combustion of 75 tonnes of typical coal.

Answer

To calculate the volume of sulfur dioxide released from the combustion of 75 tonnes of typical coal:

- $S + O_2 \rightarrow SO_2$; [1 mark]
- Volume of sulfur dioxide = 60937.5 moles x 24 = 1462500 dm^3; [1 mark]
  Accept error carried forward from part (a) for the number of moles of sulfur dioxide

[Total: 2 marks]

- The answer will be a large number because you have been working with tonnes

(2 marks)

(c) Natural gas is replacing coal in some power stations.

The typical sulphur content of natural gas is 5.5×10^{-6} g / dm^3.

An articulated fuel tanker truck can carry up to 36000 dm^3 of natural gas.

Calculate the volume, in cm^3, of sulfur dioxide that could be released by combusting the 36000 dm^3 of natural gas carried in the tanker truck.

Answer

To calculate the number of moles of sulfur contained in the tanker truck:

- Mass of sulfur: 36000 x 5.5 x 10^{-6} = 0.198 g; [1 mark]
- Moles of sulfur: $\frac{0.198}{32}$ = 6.1875 x 10^{-3} moles; [1 mark]
- Volume of sulfur dioxide: 6.1875 x 10^{-3} x 24 x 1000 = 148.5 cm^3; [1 mark]

[Total: 3 marks]

- **Remember:** You are working with 5.5 x 10^{-6} or 0.0000055 g of sulfur per dm^3
- This means that your final answer for this question could be very small even though you are working with a 36000 dm^3 tanker
- For the calculation, you established that the ratio of sulfur : sulfur dioxide is 1 : 1 in part (b), so the number of moles of sulfur = the number of moles of sulfur dioxide

(3 marks)

6 Hydrogen can be produced by reacting methane with steam:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

What volume would the products occupy at RTP after reacting 32 g of methane with excess steam?

Relative atomic masses (*Ar*): C = 12 H = 1 O = 16

A. 24 dm^3

B. 72 dm^3

C. 96 dm^3

D. 192 dm^3

Answer

The correct answer is D because:

- **Step 1:** Calculate the amount of methane

$$\text{moles} = \frac{\text{mass in g}}{\text{molar mass in g/mol}}$$

$$\text{amount of } CH_4 = \frac{32 \text{ g}}{16 \text{ g/mol}} = 2 \text{ mol}$$

- **Step 2:** Calculate the total number of moles of gaseous products

$2CH_4 + 2H_2O \rightarrow 2CO + 6H_2$

therefore there are 2 + 6 = 8 moles of gaseous products

- **Step 2:** Calculate the volume of gases

volume = moles x 24 dm^3/mol

volume = 8 moles x 24 dm^3/mol = **192 dm^3**

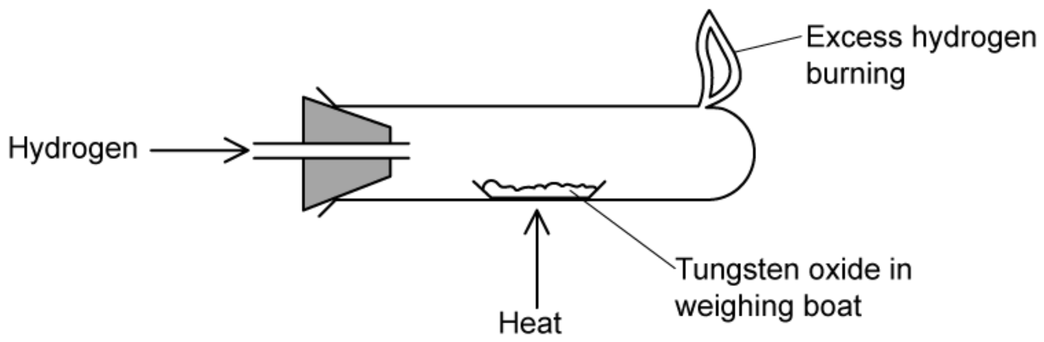
(1 mark)

7 (a) This question is about the reduction of tungsten oxide, WO_3.

A teacher reduces tungsten oxide to tungsten using the following method and the equipment shown in **Figure 1**.

- Record the mass of the weighing boat
- Add tungsten oxide and record the mass again
- Heat the weighing boat and tungsten oxide strongly for two minutes and then allow to cool
- Record the mass of the weighing boat and its contents

Figure 1



Write the balanced symbol equation, including state symbols, for the reduction of tungsten oxide by hydrogen.

Answer

The balanced symbol equation, including state symbols, for the reduction of tungsten oxide by hydrogen is:

WO_3 (s) + $3H_2$ (g) → W (s) + $3H_2O$ (l)

- Correct chemical formulae
  AND
  Correctly balanced; [1 mark]
- All state symbols correct; [1 mark]

[Total: 2 marks]

- Since the tungsten oxide is being reduced to tungstsen, it will lose all the oxygen
- The hydrogen will be oxidised by gaining oxygen to form water
  - $WO_3 + H_2 \rightarrow W + H_2O$
- The equation then needs balancing and the state symbols adding

(2 marks)

(b) State **one** addition to the method to check that the tungsten oxide has been completely reduced.

Answer

One addition to the method to check that the tungsten oxide has been completely reduced is:

- Heat the tungsten oxide to a constant mass; [1 mark]

[Total: 1 mark]

- This is a common question for ensuring the reaction is complete

(1 mark)

(c) In industry, tungsten oxide is reduced on a large scale using hydrogen.

Using your equation from part (a), calculate the minimum volume, in dm^3, of hydrogen that is required to react with 13.92 tonnes of tungsten oxide.

Relative atomic masses (A_r): W = 184, O = 16, H = 1

1 tonne = 1×10^6 g

Answer

To calculate the minimum volume, in dm^3, of hydrogen that is required to react with 13.92 tonnes of tungsten oxide:

- Molar mass of tungsten oxide: 184 + (3 x 16) = 232; [1 mark]
- Moles of tungsten oxide: $\frac{13.92 \times 10^6}{232}$ = 60000 moles; [1 mark]
- Moles of hydrogen: 60000 x 3 = 180000 moles; [1 mark] *Allow error carried forward using the ratio of $WO_3 : H_2$ identified in part (a)*
- Volume of hydrogen: 180000 x 24 = 4320000 dm^3; [1 mark]

[Total: 4 marks]

- Do not be put off by the fact that your final answer is such a large number

- Examiners are now writing questions that give very large and very small answers

(4 marks)