

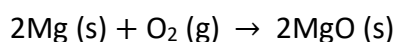
Mole Calculations – Hard

Mark Scheme



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1. Magnesium reacts with oxygen gas. Magnesium oxide is formed from this reaction.
The balanced equation for this reaction is:



- a. Calculate how much magnesium is needed to make 20 g of magnesium oxide?
Circle the letter of the correct answer.

B – is the only correct answer.	(1)
	Total: 1 mark

- b. How many moles are present in 26.88 g of SO_2 . Circle the letter of the correct answer.

A – is the only correct answer.	(1)
	Total: 1 mark

- c. One mole of oxygen gas, $\text{O}_2 \text{ (g)}$, occupies a volume of 24 dm^3 .
What volume does 8 g of $\text{O}_2 \text{ (g)}$ occupy? Circle the letter of the correct answer.

C – is the only correct answer.	(1)
	Total: 1 mark

- d. How many atoms are present in 0.75 mols of water?
Take Avogadro's constant as 6.02×10^{23} . Circle the letter of the correct answer.

B – is the only correct answer.	(1)
	Total: 1 mark

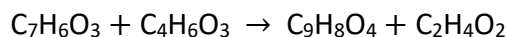
- e. Methane burns in oxygen to form carbon dioxide and water.

What mass of oxygen is needed to fully combust 18 g of methane? Circle the letter of the correct answer.

C – is the only correct answer.	(1)
	Total: 1 mark

(Total for Question 1 is 5 marks)

2. Salicylic acid ($C_7H_6O_3$) and ethanoic anhydride ($C_4H_6O_3$) are reacted together to produce aspirin ($C_9H_8O_4$) and ethanoic acid ($C_2H_4O_2$). The equation for the reaction is:



What mass of salicylic acid, $C_7H_6O_3$, is needed to produce 1.32 g of aspirin?

Moles of $C_9H_8O_4 = \text{mass} \div \text{Mr}$	
Moles of $C_9H_8O_4 = 1.32 \div 180 = \frac{11}{1500} \text{ mol}$	(1)
Moles of $C_7H_6O_3 = \frac{11}{1500} \text{ mol}$	(1)
Mass of $C_7H_6O_3 = \text{mol} \times \text{Mr}$	
Mass of $C_7H_6O_3 = \frac{11}{1500} \times 138$	
Mass of $C_7H_6O_3 = \mathbf{1.012 \text{ g}}$	(1)
	Total: 3 marks

(Total for Question 2 is 3 marks)

3. A student is doing an experiment reacting hydrogen sulfide with oxygen gas.

What mass of oxygen is needed to react with 42.5 g of hydrogen sulfide (H_2S)?

Moles of $H_2S = \text{mass} \div \text{Mr}$	
Moles of $H_2S = 42.5 \div 34 = 1.25 \text{ mol}$	(1)
Moles of $O_2 = \frac{1.25}{2} \times 3 = 1.875 \text{ mol}$	(1)
Mass of $O_2 = \text{mol} \times \text{Mr}$	
Mass of $O_2 = 1.875 \times 32$	
Mass of $O_2 = \mathbf{60 \text{ g}}$	(1)
	Total: 3 marks

(Total for Question 3 is 3 marks)

4. Calcium carbonate can be thermally decomposed to make calcium oxide and carbon dioxide.

Determine the mass of calcium carbonate needed to make 418 g of calcium oxide.

Give your answer to 3 significant figures.

Moles of $CaO = \text{mass} \div \text{Mr}$	
Moles of $CaO = 418 \div 56 = \frac{209}{28} \text{ mol}$	(1)
Moles of $CaCO_3 = \frac{209}{28} \text{ mol}$	(1)
Mass of $CaCO_3 = \text{mol} \times \text{Mr}$	
Mass of $CaCO_3 = \frac{209}{28} \times 100$	
Mass of $CaCO_3 = \mathbf{746 \text{ g}}$ to 3 significant figures	(1)
	Total: 3 marks

(Total for Question 4 is 3 marks)

5. Hydrogen sulfide, H₂S, burns in oxygen, O₂, to form sulfur dioxide, SO₂, and water.

a. Write the **balanced symbol** equation for this reaction.

2H ₂ S + 3O ₂ → 2SO ₂ + 2H ₂ O	(3)
Accept correct multiples of this equation.	
	Total: 3 marks

b. A student did the reaction in such a way that the hydrogen sulfide is the limiting reactant.
Explain what is meant by the term limiting reactant.

An answer to include the following:	
A limiting reactant is the reactant in a chemical reaction that is used up first and limits the amount of product that can be formed.	(1)
Or a reactant that is used up first/ that we run out of first.	
	Total: 1 mark

c. What effect does a limiting reactant have on a reaction?

An answer that includes:	
The limiting reactant <u>limits the amount of product that can be formed.</u>	(1)
Accept: differently worded versions of the above that put forward the same meaning.	
	Total: 1 mark

d. Calculate the mass of sulfur dioxide made from 102.3 g of hydrogen sulfide.
Give your answer to 3 significant figures.

Moles of H ₂ S = mass ÷ Mr	
Moles of H ₂ S = 102.3 ÷ 34 = $\frac{1023}{340}$ mol	(1)
Moles of SO ₂ = $\frac{1023}{340}$ mol	(1)
Mass of SO ₂ = mol × Mr	
Mass of SO ₂ = $\frac{1023}{340} \times 64$	
Mass of SO ₂ = 193 g to 3 significant figures	(1)
	Total: 3 marks

(Total for Question 5 is 8 marks)

6. The formula of copper ethanoate is $\text{Cu}(\text{CH}_3\text{COO})_2$.

Calculate the number of atoms that combine together to form 6.5 g of copper ethanoate.

Moles of $\text{Cu}(\text{CH}_3\text{COO})_2 = \text{mass} \div \text{Mr}$	
Moles of $\text{Cu}(\text{CH}_3\text{COO})_2 = 6.5 \div 181.5 = \frac{13}{363}$ or 0.0358 mol	(1)
Number of molecules = mol $\times (6.02 \times 10^{23})$	(1)
Number of molecules = $\frac{13}{363} \text{ mol} \times 6.02 \times 10^{23} = 2.156 \times 10^{22}$	
Number of atoms = $2.156 \times 10^{22} \times 15 = 3.23 \times 10^{23}$	(1)
	Total: 3 marks

(Total for Question 6 is 3 marks)

7. Compounds that contain the element iron, Fe, have many uses.

Calculate the mass of **one atom** of iron. Take Avogadro's constant as 6.02×10^{23}

Give your answer to 3 significant figures.

Mr of Fe = 56	(1)
Mass of 1 atom of Fe = $56 \div 6.02 \times 10^{23}$	(1)
Mass of 1 atom of Fe = $9.30 \times 10^{-23} \text{ g}$	(1)
Correct answer scores 3 marks with or without working.	
	Total: 3 marks

(Total for Question 7 is 3 marks)

8. One of the ways that nitrogen gas can be obtained is through the decomposition of sodium azide, NaN_3 .

Calculate the maximum volume, in cm^3 , of nitrogen gas produced from 50 g of sodium azide.

Mr of $\text{NaN}_3 = 65$	(1)
Moles of $\text{NaN}_3 = \text{mass} \div \text{Mr}$	
Moles of $\text{NaN}_3 = 50 \div 65 = \frac{10}{13} \text{ mol}$	(1)
Moles of $\text{N}_2 = \frac{10}{13} \div 2 = \frac{5}{13}$	
Moles of $\text{N}_2 = \frac{5}{13} \times 3 = \frac{15}{13} \text{ mols}$	(1)
Volume of $\text{N}_2 = \frac{15}{13} \times 24000$	
Volume of $\text{N}_2 = 27692.31 \text{ cm}^3$	(1)
Accept the answer of 27692.30 cm^3	
	Total: 4 marks

(Total for Question 8 is 4 marks)

9. A student was doing an electrolysis practical where 120 mg of zinc was formed at the cathode. Calculate the number of zinc atoms in 120 mg of zinc.

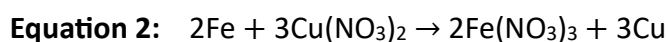
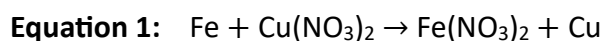
Take Avogadro's constant as 6.02×10^{23}

Convert milligrams to grams $120 \text{ mg} = 0.12 \text{ g}$	(1)
Moles of Zn = mass $\div$ Mr Moles of Zn $= 0.12 \div 65 = \frac{3}{1625} \text{ mol}$	(1)
Number of atoms $= \frac{3}{1625} \text{ mol} \times 6.02 \times 10^{23} = 1.11 \times 10^{21}$	(1)
	Total: 3 marks

(Total for Question 9 is 3 marks)

10. Copper can be extracted from its compounds using iron as iron is more reactive than copper. A student did an experiment where they reacted iron with copper nitrate solution.

Two possible balanced equations for the reaction are:



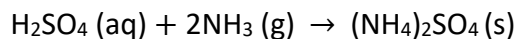
The student found that 4.48 g of iron reacted with excess copper nitrate solution to form 7.62 g of copper.

Using calculations and the masses above, show which equation represents the reaction taking place.

Note: this is effectively a trial and error question. You just see if 4.48 g of iron would make 7.62 g of copper via a mole calculation for each equation.	
Equation 1: Moles of Fe = mass $\div$ Mr Moles of Fe = $4.48 \div 56 = 0.08 \text{ mol}$	(1)
The ratio is 1 to 1 here so that is also the mols of Cu.	(1)
Mass of Cu = mols $\times$ Mr Mass of Cu = $0.08 \times 63.5 = 5.08 \text{ g}$	(1)
So this equation doesn't work. <u>The answer must be equation 2.</u>	
Just so you can see it here is the same working for equation 2. Equation 2: Moles of Fe = $4.48 \div 56 = 0.08 \text{ mol}$ The ratio is 2 to 3 here so we divide by 2 and multiply by 3. Moles of Cu = $0.08 \div 2 \times 3 = 0.12 \text{ mol}$ Mass of Cu = $0.12 \times 63.5 = 7.62 \text{ g}$ This equation produces the correct mass of Cu.	
	Total: 3 marks

(Total for Question 10 is 3 marks)

11. Ammonium sulfate is regularly used as a fertiliser. Ammonium sulfate is made from the reaction of sulfuric acid and ammonia. The equation for the reaction is shown below.



- a. What is the maximum mass of ammonium sulfate that can be made from 2.50 kg of sulfuric acid and 1.50 kg of ammonia?

Moles of $\text{H}_2\text{SO}_4 = \text{mass} \div \text{Mr}$ Moles of $\text{H}_2\text{SO}_4 = 2500 \div 98 = 25.51 \text{ mol}$	(1)
Moles of $(\text{NH}_4)_2\text{SO}_4 = 1500 \div 17 = 88.23 \text{ mol}$	(1)
From the equation we can see that 1 mole of H_2SO_4 reacts with 2 moles of NH_3 . Moles of NH_3 needed = $25.51 \times 2 = 51.02 \text{ mols}$ Therefore the NH_3 is in excess and the H_2SO_4 is limiting.	
Using the mols of the limiting reactant we calculate the maximum mass of ammonium sulfate that could be made. Mass of $(\text{NH}_4)_2\text{SO}_4$ that could be made from 25.51 mol of $\text{H}_2\text{SO}_4 = 25.51 \times 132$ Mass of $(\text{NH}_4)_2\text{SO}_4$ that could be made from 25.51 mol of $\text{H}_2\text{SO}_4 = \mathbf{3367.32 \text{ g}}$	(1)
	Total: 3 marks

- b. State and explain which reactant is the limiting reactant.

<u>Sulphuric acid is the limiting reactant.</u>	(1)
An explanation to include the following: As to react all of the sulphuric acid would require 51.02 mols of ammonia. There is 88.23 mols of ammonia available.	(1)
	Total: 2 marks

(Total for Question 11 is 5 marks)

12. Lead is most commonly extracted from its ore, lead sulfide, PbS .

- a. Write a balanced symbol equation for this reaction.

$3\text{PbS} + 8\text{HNO}_3 \rightarrow 3\text{Pb}(\text{NO}_3)_2 + 2\text{NO} + 4\text{H}_2\text{O} + 3\text{S}$	(2)
Accept correct multiples of this equation.	
	Total: 2 marks

- b. What mass of lead nitrate would be produced if 48 g of lead sulfide reacts completely with nitric acid?
Give your answer to 3 significant figures.

Moles of $\text{PbS} = \text{mass} \div \text{Mr}$ Moles of $\text{PbS} = 48 \div 239 = \frac{48}{239} \text{ mol}$	(1)
Moles of $\text{Pb}(\text{NO}_3)_2 = \frac{48}{239} \text{ mol}$	(1)
Mass of $\text{Pb}(\text{NO}_3)_2 = \frac{48}{239} \text{ mol} \times 331 = 66.50 \text{ g to 3 significant figures.}$	(1)
	Total: 2 marks

- c. In another experiment the student reacted 64 g of lead sulfide with 80 g of nitric acid.
The equation of this reaction is:



Which reactant is the limiting reactant and, using calculations, give a reason for your answer.

Moles of PbS = mass $\div$ Mr Moles of PbS = $64 \div 239 = 0.26778 \text{ mol}$	(1)
Moles of HNO ₃ = mass $\div$ Mr Moles of HNO ₃ = $80 \div 63 = 1.269 \text{ mol}$ 3 mols of PbS reacts with 8 moles of HNO ₃ . Therefore: $0.268 \text{ mol} \times (8 \div 3) = 0.715 \text{ mol}$ of HNO ₃ is required.	(1)
We have 1.27 mol of HNO ₃ , which is more than the 0.715 mol required. Therefore, HNO ₃ is in excess and PbS is the limiting reactant.	(1)
	Total: 3 marks

(Total for Question 12 is 7 marks)