C3aD Moles, Formulae and Equations: Exam Drill

AQA 8464 · Calculator allowed · about 95 minutes

Total Marks

Name: _______________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 This question checks three key terms and values used throughout this topic.

(a) Define the term 'mole' as used in chemistry. (1)

(b) State the value of the Avogadro constant, including its unit. (1)

(c) Define the term 'empirical formula'. (1)

(Total for Question 1 is 3 marks)

2 A student has 8.0 g of sodium hydroxide, NaOH (Mr = 40), and 25 g of calcium carbonate, CaCO3 (Mr = 100).

(a) Calculate the number of moles of sodium hydroxide in the 8.0 g sample. (2)

....

(b) Calculate the number of moles of calcium carbonate in the 25 g sample. (1)

....

(c) State, using your answers to (a) and (b), which sample contains the greater number of moles. (1)

(Total for Question 2 is 4 marks)

3 Sodium reacts with excess chlorine gas to form sodium chloride: 2Na + Cl2 -> 2NaCl. Relative atomic masses: Na = 23, Cl = 35.5. 4.6 g of sodium reacts completely.

(a) State the mole ratio of sodium to sodium chloride shown by the balanced equation. **(1)**

(b) Calculate the number of moles of sodium in 4.6 g of sodium. **(1)**

....

(c) Calculate the mass of sodium chloride, NaCl (Mr = 58.5), produced. Show your working. **(3)**

....

(Total for Question 3 is 5 marks)

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4 A compound contains only carbon, hydrogen and oxygen. A sample of the compound contains 1.2 g of carbon, 0.2 g of hydrogen and 1.6 g of oxygen. Relative atomic masses: C = 12, H = 1, O = 16.

(a) Calculate the number of moles of carbon atoms, hydrogen atoms and oxygen atoms in the sample. **(3)**

....

(b) Use your answers to (a) to determine the empirical formula of the compound. **(2)**

(Total for Question 4 is 5 marks)

5 Required practical: Noah carries out the empirical formula of magnesium oxide practical. His results are: mass of empty crucible + lid = 22.35 g; mass of crucible + lid + magnesium (before heating) = 22.83 g; mass of crucible + lid + magnesium oxide (after heating and cooling) = 23.19 g.

(a) Calculate the mass of magnesium used, and the mass of oxygen gained by the magnesium during the reaction. **(3)**

....

(b) Noah did not lift the crucible lid periodically during heating to let more air in. Suggest the effect this would have on his calculated mass of oxygen gained, and explain why. **(2)**

(Total for Question 5 is 5 marks)

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6 Use the Avogadro constant, 6.02×10^{23} per mole, to answer this question about a 0.25 mol sample of carbon dioxide, CO2.

(a) Calculate the number of carbon dioxide molecules in the 0.25 mol sample. **(2)**

....

(b) Each carbon dioxide molecule contains 2 oxygen atoms. Calculate the total number of oxygen atoms present in the sample. **(2)**

....

(Total for Question 6 is 4 marks)

7 Zinc carbonate decomposes on heating: $ZnCO_3 \rightarrow ZnO + CO_2$. Relative formula masses: $ZnCO_3$ = 125, ZnO = 81. 25.0 g of zinc carbonate is completely decomposed.

(a) Calculate the mass of zinc oxide produced. **(3)**

....

(b) Use conservation of mass, rather than a separate mole calculation, to calculate the mass of carbon dioxide released. **(2)**

....

(Total for Question 7 is 5 marks)

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8 A student carries out the required practical to determine the empirical formula of magnesium oxide, but their calculated ratio of magnesium to oxygen comes out as approximately 1 : 0.5, instead of the expected 1 : 1 (MgO). Evaluate possible practical errors that could explain this result, and suggest how the practical could be improved to give a more accurate ratio.

(Total for Question 8 is 6 marks)

9 Iron reacts with chlorine gas to form iron(III) chloride: Fe + Cl2 -> FeCl3 (unbalanced).

(a) Balance the equation by writing the correct number in front of each formula where needed. **(2)**

(b) Use the balanced equation to calculate the number of moles of chlorine gas needed to react completely with 2.0 mol of iron. **(2)**

....

(Total for Question 9 is 4 marks)

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10 At room temperature and pressure (RTP), one mole of any gas occupies 24 dm^3. Carbon dioxide has Mr = 44.

(a) Calculate the number of moles in 4.4 g of carbon dioxide. **(1)**

....

(b) Calculate the volume, in dm^3, that this carbon dioxide would occupy at RTP. **(2)**

....

(c) State one condition that is assumed by using the value 24 dm^3 per mole. **(1)**

(Total for Question 10 is 4 marks)

Mark scheme · C3aD Moles, Formulae and Equations: Exam Drill

Question 1

- (a) **B1** the amount of substance that contains 6.02×10^{23} particles (atoms, molecules or ions) of that substance, oe
- **(a) Answer: The amount of substance that contains 6.02×10^{23} particles of that substance.**
- (b) **B1** 6.02×10^{23} per mole (mol^{-1}) cao
- **(b) Answer: 6.02×10^{23} per mole.**
- (c) **B1** the simplest whole-number ratio of atoms of each element present in a compound, oe
- **(c) Answer: The simplest whole-number ratio of atoms of each element in a compound.**

Question 2

- (a) **M1** substitutes: moles = 8.0 / 40
- (a) **A1** 0.2 mol cao
- **(a) Answer: 0.2 mol**
- (b) **B1** 0.25 mol (25 / 100) cao
- **(b) Answer: 0.25 mol**
- (c) **B1** the calcium carbonate sample (0.25 mol is greater than 0.2 mol), ecf from (a) and (b)
- **(c) Answer: The calcium carbonate sample, since 0.25 mol is greater than 0.2 mol.**

Question 3

- (a) **B1** 1 : 1 cao
- **(a) Answer: 1 : 1**
- (b) **B1** 0.2 mol (4.6 / 23) cao
- **(b) Answer: 0.2 mol**
- (c) **M1** uses the 1:1 mole ratio to state moles of NaCl = 0.2 mol, ecf from (b)
- (c) **M1** substitutes: mass = 0.2 x 58.5
- (c) **A1** 11.7 g cao
- **(c) Answer: 11.7 g**

Question 4

- (a) **M1** moles C = 1.2 / 12 = 0.1
- (a) **M1** moles H = 0.2 / 1 = 0.2
- (a) **A1** moles O = 1.6 / 16 = 0.1
- **(a) Answer: C: 0.1 mol, H: 0.2 mol, O: 0.1 mol**
- (b) **M1** divides each mole value by the smallest value (0.1) to give the ratio C : H : O = 1 : 2 : 1, ecf from (a)
- (b) **A1** CH2O cao
- **(b) Answer: CH2O**

Question 5

- (a) **M1** mass of magnesium = 22.83 - 22.35 = 0.48 g
- (a) **M1** mass of magnesium oxide formed = 23.19 - 22.35 = 0.84 g
- (a) **A1** mass of oxygen gained = 0.84 - 0.48 = 0.36 g cao
- **(a) Answer: Mass of magnesium = 0.48 g; mass of oxygen gained = 0.36 g**
- (b) **M1** not enough air (oxygen) could enter the crucible for all of the magnesium to fully react (oxidise), oe
- (b) **A1** so the mass of oxygen gained calculated would be lower than the true value (an underestimate), oe
- **(b) Answer: Too little air could enter the crucible for all the magnesium to fully react, so the calculated mass of oxygen gained would be an underestimate.**

Question 6

- (a) **M1** substitutes: 0.25 x (6.02 x 10^{23})
- (a) **A1** 1.505 x 10^{23} molecules cao (accept 1.51 x 10^{23})
- **(a) Answer: 1.505 x 10^{23} molecules**
- (b) **M1** multiplies the number of molecules by 2, ecf from (a)
- (b) **A1** 3.01 x 10^{23} oxygen atoms cao
- **(b) Answer: 3.01 x 10^{23} oxygen atoms**

Question 7

- (a) **M1** calculates moles of ZnCO3: 25.0 / 125 = 0.2 mol
- (a) **M1** uses the 1:1 mole ratio and substitutes: mass ZnO = 0.2 x 81
- (a) **A1** 16.2 g cao
- **(a) Answer: 16.2 g**
- (b) **M1** mass of CO2 = mass of ZnCO3 - mass of ZnO = 25.0 - 16.2, ecf from (a)
- (b) **A1** 8.8 g cao
- **(b) Answer: 8.8 g**

Question 8

- **Level 3** (5-6): A well-reasoned evaluation that identifies at least two plausible causes of the low oxygen ratio, explains how each would produce this specific result, and suggests linked, practical improvements.
- **Level 2** (3-4): At least one plausible cause identified and explained, with at least one relevant improvement suggested, but the evaluation is not fully developed or linked.
- **Level 1** (1-2): Simple, undeveloped statements about sources of error, with little or no explanation of how they affect the ratio, or unlinked improvements.
- **Indicative content:**
  - If the magnesium was not heated for long enough, or the lid was kept closed throughout, too little oxygen could reach the magnesium for it to react (oxidise) completely, so less oxygen combines than expected, giving a mass of oxygen (and ratio) that is too low
  - If the crucible lid was lifted too much or too often, some white magnesium oxide smoke/particles could escape and be lost, reducing the final measured mass and so the calculated mass of oxygen gained
  - The magnesium ribbon may not have been fully cleaned (e.g. an oxide layer already present on the surface before starting) which would not by itself explain a low ratio, but shows the need to control starting conditions
  - Improvement: heat, cool and reweigh the crucible repeatedly until the mass is constant, to ensure the reaction has gone to completion
  - Improvement: use a lid with a small gap (or lift briefly and replace quickly) so that some air can enter to supply oxygen while minimising the loss of solid product
  - Improvement: repeat the whole experiment several times and calculate a mean ratio, to reduce the effect of random errors on the final result

Question 9

- (a) **M1** balances at least one of the two formulae that need a coefficient (3Cl2 or 2FeCl3), oe
- (a) **A1** fully balanced: 2Fe + 3Cl2 -> 2FeCl3 cao
- **(a) Answer: 2Fe + 3Cl2 -> 2FeCl3**
- (b) **M1** uses the mole ratio Fe : Cl2 = 2 : 3, ecf from (a)
- (b) **A1** 3.0 mol cao (2.0 x 3/2)
- **(b) Answer: 3.0 mol**

Question 10

- (a) **B1** 0.1 mol (4.4 / 44) cao
- **(a) Answer: 0.1 mol**
- (b) **M1** substitutes: 0.1 x 24, ecf from (a)
- (b) **A1** 2.4 dm^3 cao
- **(b) Answer: 2.4 dm^3**
- (c) **B1** the gas is at room temperature (about 20 degrees C) and atmospheric pressure (1 atmosphere), oe
- **(c) Answer: The gas is at room temperature and atmospheric pressure.**