IG.C9 Moles, Molar Mass and Empirical Formula Calculations

Total Marks

EDEXCEL 4CH1 · Calculator allowed · about 60 minutes

Name: _____ Date: ____ / ____ / _____

Answer in full sentences for Questions 1 and 2 only. Use a calculator where allowed. Suggested time 60 minutes.

1 State the meaning of the term relative atomic mass, Ar, as used in quantitative chemistry and read from the periodic table.

(Total for Question 1 is 1 mark)

2 Give the relative formula mass, Mr, of a compound and explain briefly how it is obtained from relative atomic masses read from the periodic table.

(Total for Question 2 is 1 mark)

3 State the value of the Avogadro constant used in the Edexcel IGCSE context, and give its units.

(Total for Question 3 is 1 mark)

4 A student reads the periodic table and finds Ar for sodium is 23 and for oxygen is 16. Calculate the relative formula mass, Mr, of Na2O and show your working.

(Total for Question 4 is 2 marks)

5 Define the mole as an amount of substance in terms of the Avogadro constant, in the context of counting atoms and molecules for calculations.

(Total for Question 5 is 1 mark)

6 State the equation that links amount in moles, mass in grams and relative formula mass, and give its units as required in a calculation.

(Total for Question 6 is 1 mark)

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7 Calculate the number of moles in 24 g of carbon dioxide, CO2. Use Ar: C = 12, O = 16 and show the equation, substitution and final evaluation with units.

(Total for Question 7 is 3 marks)

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8 Show that 0.150 mol of water molecules contains approximately 9.03×10^{22} molecules. Quote the equation used and substitute the Avogadro constant 6.02×10^{23} mol^{-1}.

(Total for Question 8 is 3 marks)

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9 A 10.0 g sample of magnesium oxide was analysed and found to contain 6.12 g of magnesium and 3.88 g of oxygen. Determine the empirical formula of this magnesium oxide. Show the steps: convert masses to moles, find simplest whole number ratio and give the formula.

(Total for Question 9 is 3 marks)

10 An organic compound is analysed and found to contain 40.0% carbon, 6.71% hydrogen and 53.29% oxygen by mass. Determine the empirical formula of the compound. Show working: assume 100 g sample, convert to moles, find simplest whole number ratio and give empirical formula.

(Total for Question 10 is 4 marks)

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11 A volatile compound has empirical formula CH2 and an experimentally determined relative molecular mass Mr of 56.0. Calculate the molecular formula. Show the equation, substitution and final result.

(Total for Question 11 is 3 marks)

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12 A sample contains 0.250 mol of sodium chloride, NaCl. Calculate the mass in grams of this sample. Use Ar: Na = 23.0, Cl = 35.5. Quote the equation, substitute and give the final answer with units.

(Total for Question 12 is 4 marks)

13 A student combusts 0.500 g of an unknown metal and obtains 0.644 g of the metal oxide product. The mass of oxygen combined is therefore 0.144 g. Using Ar: O = 16.0, and a metal Ar of 27.0, determine the empirical formula of the oxide. Show all steps converting masses to moles and finding simplest ratio.

(Total for Question 13 is 6 marks)

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14 A molecule has empirical formula CH and empirical Mr 78. Calculate the molecular formula. Show the empirical Mr calculation, division step and final molecular formula.

(Total for Question 14 is 5 marks)

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15 A hydrated salt is analysed and found to have formula CuSO4.xH2O. A 2.50 g sample of the hydrated salt was heated to remove water and produced 1.60 g of anhydrous CuSO4. Determine the value of x. Use Ar: Cu = 63.5, S = 32.1, O = 16.0, H = 1.01. Show all steps converting masses to moles and finding whole number x.

(Total for Question 15 is 5 marks)

Mark scheme · IG.C9 Moles, Molar Mass and Empirical Formula Calculations

Question 1

- **B1** Ar is the average mass of an atom of an element compared with 1/12 of the mass of a carbon-12 atom
- **Answer: Ar is the average mass of an atom compared with 1/12 the mass of carbon-12**

Question 2

- **B1** Mr is the sum of the relative atomic masses of all atoms in the formula of the compound
- **Answer: Mr is the sum of the Ar values of all atoms in the compound formula**

Question 3

- **B1** 6.02 x 10^{23} particles per mole (or per mol)
- **Answer: 6.02 x 10^{23} particles per mole**

Question 4

- **M1** writes Mr = (2 x Ar of Na) + (1 x Ar of O) as the working equation
- **A1** Mr = 62 cao
- **Answer: Mr Na2O = (2 x 23) + 16 = 62**

Question 5

- **B1** one mole is the amount of substance containing 6.02 x 10^{23} specified particles (atoms, molecules or formula units)
- **Answer: One mole contains 6.02 x 10^{23} specified particles (atoms or molecules)**

Question 6

- **B1** moles = mass / Mr with mass in g, Mr unitless and moles in mol
- **Answer: moles = mass / Mr ; mass in g, Mr unitless, moles in mol**

Question 7

- **M1** writes equation Mr CO2 = 12 + (2 x 16) = 44 and moles = mass / Mr
- **M1** substitutes: moles = 24 / 44
- **A1** gives moles = 0.545 mol cao (to 3 s.f.)
- **Answer: Mr CO2 = 12 + 2(16) = 44; moles = 24 / 44 = 0.545 mol**

Question 8

- **M1** writes equation: number of particles = moles x Avogadro constant
- **M1** substitutes: number = 0.150 x 6.02 x 10^{23}
- **A1** evaluates number = 9.03 x 10^{22} particles cao
- **Answer: Number = 0.150 x 6.02 x 10^{23} = 9.03 x 10^{22} molecules**

Question 9

- **M1** converts masses to moles: moles Mg = 6.12 / 24.3 and moles O = 3.88 / 16
- **M1** divides by smallest to get ratio and simplifies to whole numbers
- **A1** gives empirical formula MgO cao
- **Answer: Moles Mg = 6.12 / 24.3 = 0.252 mol; moles O = 3.88 / 16 = 0.243 mol; ratio approx 0.252:0.243 -> 1.04:1 -> empirical formula MgO**

Question 10

- **M1** assumes 100 g: masses C 40.0 g, H 6.71 g, O 53.29 g and converts to moles using Ar 12.0, 1.01, 16.0
- **M1** calculates moles: C = 40.0/12.0, H = 6.71/1.01, O = 53.29/16.0
- **M1** divides by smallest mole value and finds simplest whole number ratio
- **A1** gives empirical formula CH2O cao
- **Answer: Moles: C = 40.0/12.0 = 3.333; H = 6.71/1.01 = 6.644; O = 53.29/16.0 = 3.330. Ratio C:H:O = 3.333:6.644:3.330 -> divide by 3.330 -> 1.001:1.996:1 -> approx 1:2:1 so empirical formula CH2O**

Question 11

- **M1** calculates Mr of empirical formula CH2 = 12.0 + 2(1.01) = 14.02
- **M1** divides Mr molecular by empirical Mr: 56.0 / 14.02 and finds integer n
- **A1** gives molecular formula C4H8 cao
- **Answer: Mr(empirical) = 12.0 + 2(1.01) = 14.02; n = 56.0 / 14.02 = 4.00; molecular formula = C4H8**

Question 12

- **M1** writes Mr NaCl = 23.0 + 35.5 = 58.5 and equation mass = moles x Mr or moles = mass / Mr rearranged to mass = moles x Mr
- **M1** substitutes: mass = 0.250 x 58.5
- **A1** evaluates mass = 14.625 g
- **A1** gives final answer with correct units, mass = 14.6 g (to 3 s.f.) cao
- **Answer: Mr NaCl = 58.5; mass = 0.250 x 58.5 = 14.6 g**

Question 13

- **M1** finds mass of metal and oxygen combined into moles: moles metal = 0.500 / 27.0, moles O = 0.144 / 16.0
- **M1** calculates numerical mole values correctly
- **M1** divides both mole values by the smallest to get simplest ratio
- **M1** adjusts ratio to whole numbers if necessary and states the simplest whole number ratio
- **A1** gives empirical formula Aligned with calculation, here expected formula is Al2O3? or other, cao
- **A1** final empirical formula stated correctly with correct subscripts
- **Answer: Moles metal = 0.500 / 27.0 = 0.01852 mol; moles O = 0.144 / 16.0 = 0.00900 mol; ratio metal:O = 0.01852:0.00900 = 2.058:1 -> approx 2:1 so empirical formula M2O**

Question 14

- **M1** calculates Mr(empirical) = 12.0 + 1.01 = 13.01
- **M1** divides 78 by 13.01 to find n
- **M1** finds integer n = 6 (or 5.993 awrt) and states this
- **A1** constructs molecular formula by multiplying empirical subscripts by n
- **A1** gives final molecular formula C6H6 cao
- **Answer: Mr(empirical) = 13.01; n = 78 / 13.01 = 6.00; molecular formula = C6H6**

Question 15

- **M1** finds mass of water lost = 2.50 - 1.60 = 0.90 g and converts to moles of water: 0.90 / 18.02
- **M1** calculates Mr CuSO4 = 63.5 + 32.1 + 4(16.0) = 159.6 and converts mass anhydrous to moles: 1.60 / 159.6
- **M1** computes numerical mole values correctly
- **M1** divides moles H2O by moles CuSO4 to find x and rounds to nearest whole number
- **A1** gives integer value x = 5 cao
- **Answer: Mass H2O = 0.90 g -> moles H2O = 0.90 / 18.02 = 0.04995 mol; Mr CuSO4 = 159.6, moles CuSO4 = 1.60 / 159.6 = 0.01003 mol; x = 0.04995 / 0.01003 = 4.98 approx 5 so x = 5**