# Unit 2 · Stoichiometry

**ANSWER KEY · FOR TEACHERS**

Full marks 33

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

## 1 Key words

i. ✓ **True** — K · 4

ii. ✗ **False**: One mole of any gas occupies 22.4 L at STP, 0 °C and 1 atm.

iii. ✗ **False**: The limiting reactant is the reactant used up first; it decides the amount of product.

iv. ✓ **True**

v. ✗ **False**: Gay-Lussac's law says that the volumes of reacting gases (and gaseous products) are in a simple whole-number ratio.

vi. ✓ **True**

vii. ✗ **False**: One mole of water contains $6.022 \times 10^{23}$ molecules (three times as many atoms).

viii. ✓ **True**

Each carries 0.5 mark.

## 2 Label the diagram

K · 2

1. Mass (g)
2. × molar mass
3. ÷ 22.4
4. Number of particles

Each carries 0.5 mark.

## 3 Multiple choice

**i.** **c.** Gay-Lussac's law of gaseous volumes — K · 1

The volumes of the reacting gases and the gaseous product are in the small whole-number ratio 2 : 1 : 2: Gay-Lussac's law of gaseous volumes.

**ii.** **b.** multiple proportions — U · 1

With a fixed mass of sulphur (32 g), $SO_2$ has 32 g of oxygen and $SO_3$ 48 g: 32 : 48 = 2 : 3, a ratio of small whole numbers. That is the law of multiple proportions.

**iii.** **c.** $9.033 \times 10^{23}$ — A · 1

Molecules = $0.5 \times 6.022 \times 10^{23} = 3.011 \times 10^{23}$, and each $O_3$ has 3 atoms: $3 \times 3.011 \times 10^{23} =$ **$9.033 \times 10^{23}$**.

**iv.** **b.** 11.2 L — A · 1

$CH_4 = 12 + 4 = 16$ g/mol, so 8 g is 0.5 mol, and $0.5 \times 22.4 =$ **11.2 L**.

**v.** **a.** hydrogen; 3 mol — A · 1

$H_2$: $3 \div 2 = 1.5$; $O_2$: $2 \div 1 = 2$. Hydrogen's number is smaller, so **hydrogen** is limiting (3 mol of $H_2$ needs only 1.5 mol of $O_2$). 2 mol of $H_2$ give 2 mol of water, so 3 mol give **3 mol**.

## 4 Short answers

**a.** MARKING SCHEME — U · 2

✓ Equal volumes hold equal numbers of molecules (Avogadro's law), so VD = mass of a molecule ÷ mass of an $H_2$ molecule.

✓ The $H_2$ molecule's mass is 2, so $M = 2 \times VD$.

**b.** MARKING SCHEME — A · 2

✓ The same number of molecules (0.25 mol each).

✓ $CO_2$ is heavier: 11 g against 7 g.



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**c.** MARKING SCHEME A · 3

- ✓ Bhumika's ratio 1.5 : 1.
- ✓ Rohan's ratio 1.5 : 1.
- ✓ The same ratio, so the law holds.

## 5 Long answer

ANSWER A · 4

**Law of multiple proportions**: when two elements combine to form more than one compound, the masses of one element that combine with a fixed mass of the other are in a ratio of small whole numbers.

Mass of oxygen combining with 1 g of nitrogen:

- first oxide: 36.4 ÷ 63.6 = 0.572 g
- second oxide: 53.3 ÷ 46.7 = 1.141 g
- third oxide: 69.6 ÷ 30.4 = 2.289 g

Dividing by the smallest: 0.572 : 1.141 : 2.289 = **1 : 2 : 4**, a ratio of small whole numbers, so the law holds.

MARKING SCHEME

- ✓ The law stated.
- ✓ Oxygen per gram of nitrogen found by subtraction (36.4, 53.3, 69.6%).
- ✓ 0.572, 1.141 and 2.289 g.
- ✓ The ratio 1 : 2 : 4, small whole numbers.

## 6 Numerical problems

**a.** ANSWER A · 4

Al: 5.4 ÷ 27 = 0.200 mol. $Cl_2$: 14.2 ÷ 71 = 0.200 mol.

i. Al: 0.200 ÷ 2 = 0.100; $Cl_2$: 0.200 ÷ 3 = 0.067. **Chlorine** is limiting (0.200 mol of Al would need 0.300 mol of $Cl_2$).

ii. 3 mol of $Cl_2$ give 2 mol of $AlCl_3$: 0.200 × 2/3 = 0.1333 mol × 133.5 g/mol = **17.8 g**.

iii. Al used = 0.1333 mol × 27 = 3.6 g, so **1.8 g** of aluminium is left.

iv. Percentage yield = 15.0 ÷ 17.8 × 100% = **84.3%**.

MARKING SCHEME

- ✓ Chlorine is the limiting reactant.
- ✓ Theoretical yield 17.8 g.
- ✓ 1.8 g of aluminium left.
- ✓ Percentage yield 84.3%.

**b.** ANSWER A · 4

Hydrogen = 100 − 82.76 = 17.24%. In 100 g: C 82.76 ÷ 12 = 6.897 mol; H 17.24 ÷ 1 = 17.24 mol.

Dividing by the smaller: C : H = 1 : 2.5 = 2 : 5. Empirical formula $\mathbf{C_2H_5}$, empirical formula mass 2 × 12 + 5 = 29.

Molecular mass = 2 × VD = 58, so n = 58 ÷ 29 = 2: molecular formula $\mathbf{C_4H_{10}}$.

MARKING SCHEME

- ✓ Moles of atoms: C 6.897, H 17.24.
- ✓ Empirical formula $C_2H_5$ (ratio 1 : 2.5 doubled).
- ✓ Molecular mass 58 from 2 × VD.
- ✓ Molecular formula $C_4H_{10}$.



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## 7 Think

**ANSWER** HA · 3

Reactants react in a ratio of **moles**, not of masses. $H_2$: $10 \div 2 = 5$ mol; $O_2$: $10 \div 32 = 0.3125$ mol. $O_2$'s 0.3125 mol needs only 0.625 mol of $H_2$, so **oxygen is limiting**.
Water $= 2 \times 0.3125 = 0.625$ mol $= 0.625 \times 18 =$ **11.25 g**. Hydrogen used $= 0.625 \times 2 = 1.25$ g, so **8.75 g of hydrogen** is left. (Check: $11.25 + 8.75 = 20$ g.)

**MARKING SCHEME**

- ✓ Moles, not masses, decide: oxygen (0.3125 mol) is limiting.
- ✓ 11.25 g of water.
- ✓ 8.75 g of hydrogen left over.

## 8 Activity: Counting by weighing

(not marked)

**WHAT STUDENTS SHOULD FIND**

Each kind of grain has its own mass per grain, so a weighed amount stands for a known number of grains: number = mass ÷ mass of one grain. A mole does the same for atoms and molecules: the number of particles = (mass ÷ molar mass) $\times 6.022 \times 10^{23}$. A heavier grain, like a heavier molecule, gives fewer in the same mass. The grains vary a little in size, so the counted handful comes out near the worked-out number, not exactly on it.

| Marks by level | Knowledge | Understanding | Application | Higher ability | Total |
|---|---|---|---|---|---|
| **Marks** | 7 | 3 | 20 | 3 | **33** |


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