04 Chemical Formulae, Equations, the Mole and Gases

Set A **Answer key**

A From the lesson

30 MARKS

1 **C** $2Mg + O_2 \rightarrow 2MgO$ [1]

There are 2 Mg atoms and 2 O atoms on each side.

A has 2 Cl on the left and 1 on the right, B has 2 O on the left and 1 on the right, and D has 3 O on the left and 5 on the right.

2 **A** 2.0 g of H_2 [1]

2.0 g of H_2 is 1.0 mol of molecules, which is 2.0 mol of atoms.

4.0 g of He is 1.0 mol of atoms. 16.0 g of O_2 and 14.0 g of N_2 are 0.50 mol of molecules, which is 1.0 mol of atoms each.

3 **B** 2.0 mol [1]

2.0 mol of N_2 would need 6.0 mol of H_2, but only 3.0 mol is present, so H_2 is the limiting reagent.

3.0 mol of H_2 gives $2/3 \times 3.0 = 2.0$ mol of NH_3. Option A works from the N_2, which is in excess.

4 **C** $7.2\ dm^3$ [1]

Each C_3H_8 gives $3CO_2$, so 0.10 mol gives 0.30 mol of CO_2.

$0.30 \times 24 = 7.2\ dm^3$. Option D counts the water as a gas, but it is a liquid at room temperature.

5 **B** low pressure, high temperature [1]

At low pressure the particles are far apart, so their own volume and the attractions between them hardly matter.

At high temperature the particles move fast enough to overcome the attractions.

6 $4Al + 3O_2 \rightarrow 2Al_2O_3$ [1]

7 $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$. Na^+ and Cl^- are spectator ions. [1]

8 $2(14.0 + 4 \times 1.0) + 32.1 + 4 \times 16.0 = 132.1$ [1]

9 $(69 \times 63 + 31 \times 65) \div 100 = 63.6$ [1]

10 **(a)** M = 40.0, mass = $0.250 \times 40.0 = 10.0$ g [1]

(b) $0.10 \times 2 = 0.20$ mol of Cl^-, which is $0.20 \times 6.02 \times 10^{23} = 1.2 \times 10^{23}$ ions [1]

11 C: $85.7 \div 12.0 = 7.14$, H: $14.3 \div 1.0 = 14.3$, ratio 1 : 2, so the empirical formula is CH_2 (mass 14).
$56 \div 14 = 4$, so the molecular formula is C_4H_8. [2]

12 $n_{CaCO_3} = 25.0 \div 100.1 = 0.2498$ mol $= n_{CaO}$
mass = $0.2498 \times 56.1 = 14.0$ g [2]

13 $n_{CO_2} = 1.76 \div 44.0 = 0.0400$ mol $= n_{CaCO_3}$, mass = $0.0400 \times 100.1 = 4.004$ g
purity = $4.004 \div 5.00 \times 100\% = 80.1\%$ [2]

14 **(a)** $0.200 \times 0.0250 = 0.00500$ mol [1]

(b) $0.500 \times 58.5 = 29.3$ g dm^{-3} [1]

15 **(a)** n = $8.0 \div 32.0 = 0.25$ mol, V = $0.25 \times 24 = 6.0$ dm^3 [1]

(b) 40 cm^3: the volume ratio $CH_4 : O_2$ is 1 : 2. [1]

16 **(a)** 298 K [1]

(b) 2.50×10^{-4} m^3 [1]

(c) 2.03×10^5 Pa [1]

17 $V = nRT \div p = 1.00 \times 8.31 \times 273 \div 1.00 \times 10^5 = 0.0227$ m^3
$= 22.7$ dm^3 [2]

18

mole fraction of He = 0.5 ÷ 2.0 = 0.25

p(He) = 0.25 × 200 = 50 kPa **[2]**

19

Helium atoms have only very weak instantaneous dipole–induced dipole forces and a small volume.

Ammonia molecules attract one another by hydrogen bonds, so ammonia deviates more. **[2]**

B Practice

17 MARKS

20 **A** Chlorine atoms can have different numbers of neutrons. [1]

Chlorine is a mixture of isotopes, chlorine-35 and chlorine-37, which differ in their numbers of neutrons.

A_r is the average mass of the atoms, weighted by abundance, so it is not a whole number. The other statements do not explain it.

21 **C** 204.4 [1]

Tl-205 makes up 100 – 30 = 70% of the atoms.

$A_r = (30 \times 203 + 70 \times 205) \div 100 = 204.4$

22 **D** 80% [1]

Let carbon-12 be x%: $12x + 13(100 - x) = 100 \times 12.2$, so $1300 - x = 1220$.

x = 80%. The average lies nearer 12, so carbon-12 is the more common isotope.

23 **A** 84 g/mol [1]

V has 13 protons and nucleon number 27: aluminium, which forms Al^{3+}. W has 9 protons and nucleon number 19: fluorine, which forms F^-.

The compound is VW_3 (AlF_3): $27 + 3 \times 19 = 84$ g/mol.

24 **C** methane, because it has a lower molecular mass [1]

Methane, CH_4 ($M_r = 16$), is lighter than propene, C_3H_6 ($M_r = 42$), so its molecules move faster at the same temperature and it diffuses faster.

The rate of diffusion depends on the mass of the particles, not on how reactive the gas is or on its boiling point.

25 **B** 0.3 mol of ammonia gas [1]

Each NH_3 has 4 atoms: $0.3 \times 4 = 1.2$ mol of atoms, and $1.2 \times 6.02 \times 10^{23} = 7.2 \times 10^{23}$.

A is 0.2 mol of atoms, C is 0.8 mol and D is 3.6 mol.

26 **B** $\frac{2L}{x}$ [1]

1.0 g of Q is 1/x mol of molecules, which is L/x molecules.

Each molecule has 2 atoms, so there are 2L/x atoms.

27 **B** RuO_2 [1]

Mass of Ru = 5.79 − 1.39 = 4.40 g. n_{Ru} = 4.40 ÷ 101.1 = 0.0435 mol and n_O = 1.39 ÷ 16.0 = 0.0869 mol.

Ru : O = 1 : 2, so the empirical formula is RuO_2.

28 **B** $CaFe_2O_4$ [1]

Oxygen is 100 − 18.5 − 51.9 = 29.6%. In 100 g: Ca 18.5 ÷ 40.1 = 0.461 mol, Fe 51.9 ÷ 55.8 = 0.930 mol, O 29.6 ÷ 16.0 = 1.85 mol.

Dividing by 0.461 gives 1 : 2 : 4, so $CaFe_2O_4$.

29 **B** row B [1]

In 100 g: C 40.0 ÷ 12.0 = 3.33 mol, H 6.70 ÷ 1.0 = 6.70 mol, O 53.3 ÷ 16.0 = 3.33 mol. The ratio 1 : 2 : 1 gives CH_2O, mass 30.

60 ÷ 30 = 2, so the molecular formula is $C_2H_4O_2$.

30 **A** CH_4 [1]

n_{CO_2} = 11.0 ÷ 44.0 = 0.250 mol, so 0.250 mol of C. n_{H_2O} = 9.0 ÷ 18.0 = 0.50 mol, so 1.0 mol of H.

C : H = 0.250 : 1.0 = 1 : 4, so the hydrocarbon is CH_4.

31 **B** 74% [1]

$2Mg + O_2 \rightarrow 2MgO$, so $n_{MgO} = n_{Mg}$ = 4.8 ÷ 24.3 = 0.198 mol, a theoretical yield of 0.198 × 40.3 = 7.96 g.

Percentage yield = 5.9 ÷ 7.96 × 100% = 74%.

32 **D** 42.5 g [1]

60.0 g of urea is 1.00 mol. At 80% yield, the ammonia must be enough to make 1.00 ÷ 0.80 = 1.25 mol in theory.

2 mol of NH_3 gives 1 mol of urea, so n_{NH_3} = 2.50 mol and its mass is 2.50 × 17 = 42.5 g.

33 **B** 50% [1]

n_{NaHCO_3} = 42.0 ÷ 84 = 0.500 mol, so in theory 0.250 mol of CO_2 forms, which is 0.250 × 24 = 6.00 dm^3.

Percentage yield = 3.00 ÷ 6.00 × 100% = 50%.

34 **C** 1.12 g/dm^3 [1]

Iron(III) sulfate is $Fe_2(SO_4)_3$, so each unit gives 2 Fe^{3+}: $[Fe^{3+}] = 0.02$ mol/dm^3.

In g/dm^3: 0.02 × 55.8 = 1.12 g/dm^3.

35 **C** C_4H_8 **[1]**

n = 12 ÷ 24 = 0.50 mol, so M_r = 28 ÷ 0.50 = 56.

C_4H_8: 4 × 12 + 8 × 1 = 56.

36 **B** 1.5 mol of C_4H_8 **[1]**

144 dm^3 of CO_2 is 144 ÷ 24 = 6.0 mol. Each C atom in the fuel ends up in one CO_2.

1.5 mol of C_4H_8 has 1.5 × 4 = 6.0 mol of C. A gives 3.0 mol, C gives 9.0 mol and D gives 12 mol.