04 Chemical Formulae, Equations, the Mole and Gases

Set B **Answer key**

A Competition questions

22 MARKS

1 **C** $M + 2Cl_2 \rightarrow MCl_4$ [1]

The big jump is after the 4th ionisation energy (3313 to 7863), so M has 4 valence electrons and is in Group 14.

M bonds to four chlorine atoms, giving MCl_4. One mole of M needs 2 mol of Cl_2.

2 **A** 58.8 [1]

The abundances add up to 69.3 + 26.7 + 1.20 + 3.80 + 1.00 = 102, so divide by 102, not 100.

$A_r = (58 \times 69.3 + 60 \times 26.7 + 61 \times 1.20 + 62 \times 3.80 + 64 \times 1.00) \div 102 = 5994 \div 102 = 58.8$

3 **A** 40% [1]

Let ^{121}Sb be x%: 121x + 123(100 − x) = 12 180, so 12 300 − 2x = 12 180 and x = 60.

^{123}Sb is 100 − 60 = 40%. Option D is the percentage of ^{121}Sb.

4 **B** 2n [1]

10 g of CH_4 (M_r 16) is 0.625 mol, which is n molecules.

55 g of CO_2 (M_r 44) is 1.25 mol, twice as many moles, so it has 2n molecules.

5 **D** It contains 3.01×10^{22} ions. [1]

n = 20.3 ÷ 406 = 0.0500 mol. Each unit has 2 Co^{3+} and 3 SO_4^{2-}, so there are 0.250 mol of ions, 1.51×10^{23}, not 3.01×10^{22}.

A: 0.0500 mol of gas at 293 K and 1 atm is $0.0500 \times 8.31 \times 293 \div 101\,325 = 1.2 \times 10^{-3}$ m^3. B: 12 × 16.0 ÷ 406 = 47.3%. C: 3 × 0.0500 = 0.15 mol.

6 **C** The number of ions in 68.05 g of $CaSO_4$. [1]

$CaSO_4$ has $M_r = 40.1 + 32.1 + 4 \times 16.0 = 136.2$, so 68.05 g is 0.50 mol. Each unit is 2 ions, Ca^{2+} and SO_4^{2-}, so there is 1.0 mol of ions.

A is 1 mol of O_2, which is 2 mol of atoms. B is pV/RT = 0.067 mol. D is 1 mol of C_2H_6, which has 2 mol of C atoms.

7 **D** 1, 2, 3 and 4 [1]

1: $1.20 \times 4 = 4.80$ mol of atoms. 2: $1.445 \times 10^{24} \div 6.02 \times 10^{23} = 2.40$ mol of O_2, which is 4.80 mol of atoms.

3: $36.0 \div 180 = 0.200$ mol, and 0.200×24 atoms = 4.80 mol. 4: $57.6 \div 24 = 2.40$ mol of Cl_2, which is 4.80 mol of atoms. All four are equal.

8 **C** C_3H_8 [1]

$n_C = n_{CO_2} = 0.66 \div 44 = 0.015$ mol. $n_H = 2 \times 0.36 \div 18 = 0.040$ mol.

C : H = 0.015 : 0.040 = 3 : 8, so the empirical formula is C_3H_8.

9 **C** $C_8H_{15}BO_2$ [1]

$n_C = 4.58 \div 44.0 = 0.104$ mol, 8 per molecule ($\div 0.0130$). $n_H = 2 \times 1.76 \div 18.0 = 0.196$ mol, 15 per molecule.

$M_r = 2.0 \div 0.0130 = 154$. $C_8H_{15}B$ accounts for 96 + 15 + 10.8 = 121.8, leaving 32 for 2 O atoms: $C_8H_{15}BO_2$.

10 **A** phosphorus [1]

Mass of X = 106.5 − 60 = 46.5 g. $n_O = 60 \div 16 = 3.75$ mol, so $n_X = 3.75 \times 2/5 = 1.50$ mol.

$A_r(X) = 46.5 \div 1.50 = 31$, which is phosphorus.

11 **B** 43.7% [1]

50 000 g of Na_2S is 640 mol, which could give $2 \times 640 = 1280$ mol of $NaHCO_3$. Only $20\,500 \div 84.0 = 244$ mol formed, an overall yield of 19.1%.

With the same yield y in both steps, $y \times y = 0.191$, so $y = 0.437 = 43.7\%$. Option C forgets that each Na_2CO_3 gives $2NaHCO_3$.

12 **B** 37.5 cm^3 [1]

$c_1V_1 = c_2V_2$: $0.280 \times 50 = 0.160 \times V_2$, so $V_2 = 87.5$ cm^3.

V_2 is the final volume, so the water added is 87.5 − 50 = 37.5 cm^3. Option D is the final volume.

13 **C** The number of molecules in A < the number of molecules in B [1]

The masses are equal but A is denser, so A occupies the smaller volume (D is false).

At the same temperature and pressure a smaller volume holds fewer molecules, so A has fewer molecules than B. With the same mass, its molar mass is larger (A is false). The number of atoms depends on the formulae, which are not given.

14 **A** graph A [1]

Boyle's law: at constant temperature $p \propto 1/V$, so p against 1/V is a straight line through the origin.

p against V is a curve, not a straight line. C is Charles's law, $V \propto T$, and V against 1/T matches neither law.

15 **B** C_2H_4O [1]

$n = pV/RT = (50 \times 10^3 \times 40 \times 10^{-6}) \div (8.31 \times 300) = 8.02 \times 10^{-4}$ mol, so $M_r = 0.0353 \div 8.02 \times 10^{-4} = 44.0$.

Volume ratio = mole ratio: 40 cm^3 gives 80 cm^3 of CO_2 (2 C) and 80 cm^3 of H_2O (4 H). C_2H_4 is 28, so one O makes 44: C_2H_4O.

16 **D** $\frac{0.100 \times 373 \times 22.7}{0.0250 \times 273}$ [1]

At s.t.p. (273 K and 1 bar) the vapour would occupy $0.0250 \times 273/373$ dm^3, since $V \propto T$ at constant pressure.

n = that volume ÷ 22.7, and $M_r = 0.100 \div n = (0.100 \times 373 \times 22.7) \div (0.0250 \times 273)$.

17 **C** 64.1 [1]

$^2H_2$ has $M_r = 4.0$, so $n = 0.6 \div 4.0 = 0.15$ mol. With the same V, $n \propto p/T$: $n_A = 0.15 \times 2 \times 293/313 = 0.281$ mol.

$M_r(A) = 18.0 \div 0.281 = 64.1$

18 **A** 14 127 [1]

NH_3 is limiting: 0.25 mol reacts with 0.25 mol of HCl, leaving 0.42 − 0.25 = 0.17 mol of HCl. NH_4Cl is a solid, so it adds nothing to the pressure.

$p = nRT/V = 0.17 \times 8.31 \times 500 \div (50 \times 10^{-3}) = 14\,127$ Pa.

19 **D** 0.25P [1]

Equal amounts, so each gas starts at 0.5P. $2H_2 + O_2 \rightarrow 2H_2O$: the H_2 (0.5P) uses half as much O_2, 0.25P.

0.5P − 0.25P = 0.25P of O_2 is left. The water is liquid at room temperature, so it adds no pressure.

20 **B** 1 and 2 only [1]

$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$, so 1 is correct. x dm^3 of methanol uses 1.5x of O_2, leaving 2.5x, and makes x of CO_2 and 2x of steam: 5.5x in all.

$p(CO_2) = x \div 5.5x \times P = 0.18P$, so 2 is correct. 3 is wrong: an ideal gas's particles have negligible volume, but the gas itself fills its container.

21 **D** XeF_4 [1]

At constant volume and temperature, partial pressure is proportional to amount. Xe used: 1.6 atm. F_2 used: 7.0 − 3.8 = 3.2 atm.

Xe : F_2 = 1.6 : 3.2 = 1 : 2, so $Xe + 2F_2 \rightarrow XeF_4$.

22 **B** row B [1]

$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$ and $CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$. 2 mol of H_2S and 1 mol of CS_2 give 4 mol of SO_2 and 1 mol of CO_2.

CS_2 has more electrons than CO_2, so its instantaneous dipole–induced dipole forces are stronger and its molecules larger: it deviates more.