06 The Mole Concept and Stoichiometry

Set A **Answer key**

A From the lesson

23 MARKS

1

Let the abundance of ^{79}Br be x%.

$79.90 = \frac{79x + 81(100 - x)}{100}$ [1]

$7990 = 8100 - 2x$

x = **55.0**, so 55.0% ^{79}Br (and 45.0% ^{81}Br) [1]

2

	C	H
mass in 100 g / g	85.7	14.3
amount / mol	85.7 ÷ 12.0 = 7.142	14.3 ÷ 1.0 = 14.30
ratio	1	2

Empirical formula CH_2 (M_r = 14.0) [1]

$n = \frac{56.0}{14.0} = 4$, so the molecular formula is **C_4H_8** [1]

3

$mass_C = \frac{12.0}{44.0} \times 0.880 = 0.2400$ g, $mass_H = \frac{2.0}{18.0} \times 0.360 = 0.04000$ g [1]

$mass_O = 0.600 - 0.2400 - 0.04000 = 0.3200$ g [1]

$n_C : n_H : n_O = 0.02000 : 0.04000 : 0.02000 = 1 : 2 : 1$, so the empirical formula is **CH_2O** [1]

4

$n_{CaCO_3} = \frac{5.00}{100.1} = 0.04995$ mol, $n_{HCl} = \frac{50.0}{1000} \times 1.00 = 0.05000$ mol [1]

0.04995 mol of $CaCO_3$ needs 0.09990 mol of HCl, but only 0.05000 mol is present, so **HCl is limiting**. [1]

$n_{CO_2} = ½ \times 0.05000 = 0.02500$ mol

$V_{CO_2} = 0.02500 \times 24.0 =$ **0.600 dm^3** [1]

5

$$C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

$V_{CO_2} = 110 - 50 = 60\ cm^3 = 20x$, so $x = 3$ [1]

V_{O_2} used $= 150 - 50 = 100\ cm^3 = 20(x + \frac{y}{4})$, so $y = 8$ [1]

The hydrocarbon is **C_3H_8** (propane). [1]

NOTE The gas left after NaOH(aq) is the unreacted O_2. Water is a liquid at room temperature and pressure, so it takes no part in the gas volume.

6

n_{HCl} added $= 0.05000$ mol, n_{HCl} left over $= n_{NaOH} = \frac{20.0}{1000} \times 0.500 = 0.01000$ mol [1]

n_{HCl} reacted $= 0.04000$ mol, so $n_{CaCO_3} = ½ \times 0.04000 = 0.02000$ mol [1]

$mass_{CaCO_3} = 0.02000 \times 100.1 = 2.002$ g

% purity $= \frac{2.002}{2.50} \times 100\% =$ **80.1%** [1]

7

(a) $2x + 7(-2) = -2$, so $x =$ **+6** [1]

(b) $2x + 3(-2) = -2$, so $x =$ **+2** [1]

(c) $x + 4(+1) = +1$, so $x =$ **−3** [1]

8

Reduction: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

Oxidation (× 6): $Fe^{2+} \rightarrow Fe^{3+} + e^-$ [1]

Overall: **$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$** [1]

EXAM TIP Check that both atoms and total charge balance: left $-2 + 14 + 12 = +24$, right $6 + 18 = +24$.

9

$n_{SO_3^{2-}} = \frac{25.0}{1000} \times 0.100 = 2.500 \times 10^{-3}$ mol. Each SO_3^{2-} loses 2 electrons as the oxidation number of S increases from +4 to +6, so 5.000×10^{-3} mol of electrons are lost. [1]

$n_{oxidant} = \frac{20.0}{1000} \times 0.0500 = 1.000 \times 10^{-3}$ mol, so each M gains 5 electrons. Final oxidation number of M $= +5 - 5 =$ **0** [1]

B Practice

15 MARKS

10 **C** Relative atomic mass of oxygen = average mass of one atom of oxygen ÷ ($^1/_{12}$ × mass of one atom of carbon-12) [1]

A By definition, one mole of a substance contains exactly 6.02×10^{23} elementary entities. A is incorrect because of the phrase "same number of atoms as there are in 12.000 g of carbon-12".

B Relative isotopic mass is the mass of one mole of atoms of an isotope relative to $^1/_{12}$ the mass of one mole of ^{12}C atoms. B is incorrect because the numerator used is "average mass of all isotopes of lithium".

C Relative atomic mass is the average mass of one mole of atoms of an element relative to $^1/_{12}$ the mass of one mole of ^{12}C atoms *or* the average mass of one atom of an element relative to $^1/_{12}$ the mass of one ^{12}C atom. C is correct.

D Relative molecular mass is the average mass of one mole of molecules relative to $^1/_{12}$ the mass of one mole of ^{12}C atoms. D is incorrect because the numerator used is "average mass of one atom of E".

11 **B** $37.5\ cm^3$ [1]

Dilution does not change the amount: $c_iV_i = c_fV_f$

$(0.280)(50) = (0.160)V_f$, so $V_f = 87.5\ cm^3$

Volume of water added = $87.5 - 50.0 = 37.5\ cm^3$

12 **(a)**

Reduction: $PbO_2 + 2e^- \rightarrow PbO_2^{2-}$

Oxidation: $Cr(OH)_3 + 5OH^- \rightarrow CrO_4^{2-} + 4H_2O + 3e^-$ [1]

Overall: $2Cr(OH)_3 + 10OH^- + 3PbO_2 \rightarrow 2CrO_4^{2-} + 8H_2O + 3PbO_2^{2-}$ [1]

(b)

Volumes used: 25.55, 25.40, 25.30 cm^3 (2 d.p.) [1]

Average volume of Fe^{2+} used = ½(25.40 + 25.30) = 25.35 cm^3 (the two concordant titres)

Amount of Fe^{2+} reacted = $\frac{25.35}{1000} \times 0.150 =$ **3.80×10^{-3} mol** [1]

(c)

% uncertainty = $\frac{0.05 + 0.05}{25.35} \times 100\% =$ **0.394%** [1]

(d)

$6Fe^{2+} \equiv Cr_2O_7^{2-} \equiv 2CrO_4^{2-}$

Amount of $Cr_2O_7^{2-}$ in 25.0 cm^3 = $\frac{3.803 \times 10^{-3}}{6} = 6.338 \times 10^{-4}$ mol

Amount of CrO_4^{2-} in 250 cm^3 = $6.338 \times 10^{-4} \times 2 \times \frac{250}{25.0} = 0.01268$ mol [1]

$2CrO_4^{2-} \equiv 3PbO_2$, so amount of $PbO_2 = 0.01268 \times \frac{3}{2} = 0.01901$ mol

Mass of $PbO_2 = 0.01901 \times (207.2 + 32.0) = 4.548$ g

% by mass of PbO_2 = $\frac{4.548}{5.00} \times 100\% =$ **91.0%** [1]

13 **(a)**

Oxidation: $Mn^{2+} + 3OH^- \rightarrow Mn(OH)_3 + e^-$ [1]

Overall: $4Mn^{2+} + 8OH^- + 2H_2O + O_2 \rightarrow 4Mn(OH)_3$ [1]

(b)

(i) $1O_2 \equiv 4Mn(OH)_3 \equiv 2I_2 \equiv 4Na_2S_2O_3$ [1]

(ii) Amount of $Na_2S_2O_3 = \frac{25.00}{1000} \times 0.00100 = 2.50 \times 10^{-5}$ mol

Amount of dissolved $O_2 = \frac{2.50 \times 10^{-5}}{4} =$ **6.25×10^{-6} mol** [1]

(iii) Mass of $O_2 = 6.25 \times 10^{-6} \times 32.0 = 2.00 \times 10^{-4}$ g = 0.200 mg

DOC $= 0.200 \times \frac{1000}{25.0} =$ **8.00 mg dm^{-3}** [1]

8.00 mg dm^{-3} is more than 5 mg dm^{-3}, so fish can survive in the river. [1]