06 The Mole Concept and Stoichiometry

Set B **Answer key**

A Multiple choice

3 MARKS

1 **B** +1, +2, +3 [1]

Let the sum of the oxidation numbers of the three Cu atoms be x.

$2(+3) + 2(+2) + 2(+2) + x + 10(-2) = 0$

x = +6. Only B adds up to +6 (A +4, C +4, D +5).

2 **B** 64.9 [1]

Relative atomic mass of Zn = $\frac{100 \times 64 + 80 \times 65 + 20 \times 67 + 10 \times 68}{210}$ = 64.9 (3 s.f.)

3 **A** $3ClO^- \rightarrow ClO_3^- + 2Cl^-$ [1]

A Cl is oxidised from +1 in ClO^- to +5 in ClO_3^-, and reduced from +1 to −1 in Cl^-.

B C is only reduced: +3 in $H_2C_2O_4$ to 0 in C and +2 in CO.

C S is reduced from +6 to +4 in SO_2, and unchanged in SO_3.

D Mn is only reduced: +7 to +4 in MnO_2 and +2 in MnO.

B Structured questions

32 MARKS

4 **(a)** $2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(l)$ [1]

(b) Volume of FA 2 = $\frac{82}{10} \times 25.0 = 205\ cm^3$ [1]

205.00 cm^3 of FA 2 would be needed from the burette, so the titration would be very tedious, as the burette would have to be refilled carefully several times. [1]

(c) Amount of H_2O_2 in 25.0 cm^3 of FA 3 = $\frac{5}{2} \times \frac{y}{1000} \times 0.0200 = 5.00 \times 10^{-5}y$ mol [1]

Amount of H_2O_2 in v cm^3 of FA 1 = amount in w cm^3 of FA 3 = $\frac{w}{25.0} \times 5.00 \times 10^{-5}y = 2.00 \times 10^{-6}wy$ mol

$[H_2O_2]$ in FA 1 = $2.00 \times 10^{-6}wy \div \frac{v}{1000}$ = **0.00200** $\frac{\mathbf{wy}}{\mathbf{v}}$ **mol dm^{-3}** [1]

(d)

Amount of O_2 from 1 dm^3 = $\frac{13.4}{22.7}$ = 0.5903 mol

Amount of H_2O_2 = 2 × 0.5903 = 1.181 mol, so $[H_2O_2]$ = **1.18 mol dm^{-3}** [1]

NOTE The volume is at s.t.p., so use 22.7 dm^3 mol^{-1}, not 24.0. The mole ratio comes from the decomposition $2H_2O_2 \rightarrow 2H_2O + O_2$, not from the equation in (a).

5 **(a)**

Reduction: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ Oxidation: $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$

Overall: $5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$ [1]

(b)

Amount of $S_2O_3^{2-}$ = $\frac{24.50}{1000}$ × 0.20 = 4.90 × 10^{-3} mol

Amount of I_2 = ½ × 4.90 × 10^{-3} = 2.45 × 10^{-3} mol

Amount of remaining MnO_4^- in 25.0 cm^3 = $\frac{2}{5}$ × 2.45 × 10^{-3} = 9.80 × 10^{-4} mol [1]

Remaining MnO_4^- in 100 cm^3 = 9.80 × 10^{-4} × $\frac{100}{25.0}$ = 0.00392 mol

Initial MnO_4^- = $\frac{100.0}{1000}$ × 0.10 = 0.0100 mol, so MnO_4^- reacted with $C_2O_4^{2-}$ = 0.0100 − 0.00392 = 0.00608 mol [1]

Amount of CaC_2O_4 = $\frac{5}{2}$ × 0.00608 = 0.0152 mol

Mass of pure CaC_2O_4 = 0.0152 × [40.1 + 2(12.0) + 4(16.0)] = 1.95 g

% purity = $\frac{1.95}{3.20}$ × 100% = **60.9%** [1]

6 **(a)**

No. of moles of $EDTA^{4-}$ = 0.0200 × $\frac{35.45}{1000}$ = **7.09 × 10^{-4} mol** [1]

(b)

No. of moles of Al^{3+} in 25.0 cm^3 = 7.09 × 10^{-4} mol

No. of moles of Al^{3+} in 250 cm^3 (the whole water sample) = 7.09 × 10^{-4} × $\frac{250}{25}$ = **7.09 × 10^{-3} mol** [1]

7 **(a)**

$HClO + 2I^- + H^+ \rightarrow Cl^- + I_2 + H_2O$ [1]

(b)

Amount of $S_2O_3^{2-}$ = $\frac{6.0}{1000}$ × 0.0050 = 3.0 × 10^{-5} mol

Amount of I_2 = amount of HClO = amount of N-chlorosuccinimide = 1.5 × 10^{-5} mol [1]

$M_r(C_4H_4O_2NCl)$ = 133.5, so mass = 1.5 × 10^{-5} × 133.5 = **2.0 × 10^{-3} g** [1]

8 **(a)**

[R]: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ (× 1) [O]: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (× 6)

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

(b)

Amount of $Cr_2O_7^{2-}$ reacted = $\frac{21.45}{1000} \times 0.100 = 2.145 \times 10^{-3}$ mol

Since $6Fe^{2+} \equiv Cr_2O_7^{2-}$, amount of Fe^{2+} in 25.0 cm^3 of solution = $6 \times 2.145 \times 10^{-3}$ = 0.01287 mol [1]

Amount of Fe^{2+} in 250 cm^3 of solution = $0.01287 \times \frac{250}{25.0}$ = **0.129 mol** [1]

(c)

By the law of conservation of mass, amount of Fe in the iron ore = amount of Fe^{2+} in 250 cm^3 of solution.

Mass of Fe in the iron ore sample = $0.1287 \times 55.8 = 7.181$ g [1]

% by mass of Fe in the sample = $\frac{7.181}{11.15} \times 100\%$ = **64.4%** [1]

9 **(a)**

Let the mass of a sample of R be 100 g.

Amount of Cs = 58.1 ÷ 132.9 = 0.437 mol

Amount of P = 6.78 ÷ 31.0 = 0.219 mol

Amount of S = 35.1 ÷ 32.1 = 1.09 mol

Simplest ratio Cs : P : S = 2 : 1 : 5, so the empirical formula is **Cs_2PS_5** [1]

Let the chemical formula be $(Cs_2PS_5)_n$.

$(2(132.9) + 31.0 + 5(32.1))n = 914.6$

$457.3n = 914.6$, so $n = 2$

The chemical formula of R is **$Cs_4P_2S_{10}$** [1]

(b)

$P_2S_{10}^{4-}$ [1]

10 **(a)**

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$ [1]

(b)(i)

Amount of Fe_2O_3 used = 150 ÷ 159.6 = 0.940 mol

Amount of CO used = 60 ÷ 24.0 = 2.50 mol

Since 1 mol of Fe_2O_3 reacts with 3 mol of CO, 0.940 mol of Fe_2O_3 requires 2.82 mol of CO for complete reaction. Hence, CO is the limiting reagent. [1]

Since 3 mol of CO form 2 mol of Fe, the maximum amount of Fe formed = $2.50 \times \frac{2}{3}$ = 1.667 mol

Maximum mass of Fe = 1.667×55.8 = **93.0 g** [1]

(ii)

Amount of CO_2 formed = amount of CO used = 2.50 mol

Number of CO_2 molecules = $2.50 \times 6.02 \times 10^{23}$ = **1.51×10^{24}** [1]

(iii)

Percentage yield = $\frac{70}{93.0} \times 100\%$ = **75.3%** [1]

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Only ethanedioic acid reacts with NaOH, and it is dibasic. $n_{NaOH} = \frac{14.75}{1000} \times 0.100 = 1.475 \times 10^{-3}$ mol

$n_{H_2C_2O_4} = ½ \times 1.475 \times 10^{-3} = 7.375 \times 10^{-4}$ mol **[1]**

$[H_2C_2O_4] = 7.375 \times 10^{-4} \times \frac{1000}{25.0} =$ **0.0295 mol dm^{-3}** **[1]**

Both the acid and its salt are oxidised by MnO_4^-: $2MnO_4^- \equiv 5C_2O_4^{2-}$. $n_{MnO_4^-} = \frac{32.00}{1000} \times 0.0205 = 6.560 \times 10^{-4}$ mol

Total ethanedioate $= \frac{5}{2} \times 6.560 \times 10^{-4} = 1.640 \times 10^{-3}$ mol **[1]**

$n_{Na_2C_2O_4} = 1.640 \times 10^{-3} - 7.375 \times 10^{-4} = 9.025 \times 10^{-4}$ mol, so $[Na_2C_2O_4] =$ **0.0361 mol dm^{-3}** **[1]**