Olympiad Round 1 2003 – Mark Scheme

1. Heating a cup of coffee

(a) $CaO + H_2O \rightarrow Ca(OH)_2$ **(1)**

(b) acidic, neutral, basic **(1)**

(c) $?_rH = -\ 1003 + 635 + 286 =$ **$-$ 82 kJ mol^{-1}** **(1) fig + sign**

(d) To warm 1g by 1°C requires 4.18 J
210g by 40°C requires 4.18 x 210 x 40 J = **35.1 kJ** **(1)**

(e) 1 mol CaO provides 82 kJ
We need 35.1 kJ = 35.1 / 82 mol = 0.428 mol
Taking RMM for CaO as 56, minimum mass required = 56 x 0.428 = **24.0 g** **(1)**
(Actual mass used in cans = 70g)

Total 5

2. Reinecke's Salt

(a) Cr (Ar = 52.0) is 15.5% of total
Therefore total = $\frac{100}{15.5}$ X 52.0 = 335.5

For 5 $\frac{38.15}{100}$ x 335.5 = 128

$\frac{128}{32} = 4 = x$

Therefore $NH_4[Cr(SCN)_4(NH3)_y] = 335.5$
Therefore 18 + 52 + 4 x 58.1 + 17y = 335.5
Therefore 17y = 33.5
X = 4 **y = 2** **(1, 1)**

(b) +1 + Cr + 4 x -1 + 2 x 0 = 0 **(1)**
Therefore Cr = **+ 3**

(c) Octahedral **(1)**

(d) Two octahedral structures, one with $2NH_3$ groups adjacent, one with them opposite

Geometrical **(1) for 2 shapes**
(1) for geometric or cis/trans

Total 6

3. Green Chemistry

(a) (i) $C_2H_4 + Cl_2 + Ca(OH)_2 \rightarrow C_2H_4O + CaCl_2 + H_2O$ extra H_2O ok **(1)**

(ii) % atom economy $= \frac{44}{44 + 111 + 18} \times 10$ (not 23.6)

$= 25.4$ **(1)**

(b) 100% **(1)**

(c)(i) Mr ibuprofen = 206

% atom economy $= \frac{206}{206 + 60} \times 100 = 77.4$ **(1)**

(ii) Catalyst **(1)**

(iii) goes up to <u>100%</u> (needed) **(1)**

Total 6

4. Redox Equations Any suitable equation

(a) $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$ **(1)**

(b) $Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$ **(1)**

(c) $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ **(1)**

(d) $MnO_2(s) + 4H^+(aq) + 2Cl^- \rightarrow Mn^{2+}(aq) + 2H_2O(l) + Cl_2(g)$ **(1)**

(e) $5SO_3^{2-}(aq) + 6H^+(aq) + 2MnO^-_4(aq) \rightarrow 5SO_4^{2-}(aq) + 2Mn^{2+}(aq) + 3H_2O(l)$ **(1)**

(f) $3Sn^{2+}(aq) + 14H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow 2Cr^{3+}(aq) + 3Sn^{4+}(aq) + 7H_2O(l)$ **(1)**

(g) $3MnO^-_4(aq) + 24H^+(aq) + 5Fe^{2+}(aq) + 5C_2O_4^{2-}(aq) \rightarrow 3Mn^{2+}(aq)$
$+12H_2O(l) + 5Fe^{3+}(aq) + 10\ CO_2(g)$ **(2)**

Do <u>not</u> penalise
State symbols

Total 8

5. Combining Proportions

(a) 12 grains of Sb give 14.4 grains of oxide
12 grains Sb combine with 2.4 grains of oxygen
suppose conversion factor for grains to grams = k

moles of Sb = 12*k* / 121.8
moles of O = 2.4*k* / 16.0 — if used **(1)**

molar ration Sb : O = (12/121.8) : (2.4/16.0) = 0.9852 : 0.15 = 1:1.5 = 2:3

Formula = $\mathbf{Sb_2O_3}$ **(2 marks if answer alone given)** **(1)**

(b) 1 mol Zn forms 1 mol ZnO
65.4g Zn forms (65.4 + 16.0) g ZnO = 81.4g
increase in mass by 81.4 / 65.4
so 60 grains should produce (60 x 81.4) / 65.4 grains = **74.5(8) grains** **(2)**

(c) Total mass at end = unreacted Zn + ZnO
60 grains Zn should give 74.58 grains ZnO

If fraction of Zn reacting is a, amount of Zn used is 60 a grains which forms 74.58 a grains of ZnO.
Amount of Zn left = 60 – 60 a
Total mass at end = 60 – 60 a + 74.58 a = 65 grains = 60 + 14.58 a

a = (66 – 60) / 14.58 = **0.41(15)** **(2)**

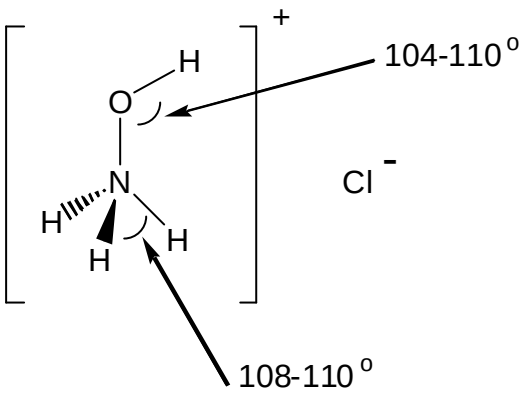
Mass of unreacted Zn = 60 - 60 a = **35(.31) grains** **(1)**

Mass of ZnO = 74.58 a = **30(.69) grains** **(1)**

Total 8

6. Hydroxylamine and its reaction with iron (III) ions

(a)



(1)

no marks for structure except if no angles - then 1 mark.

(1)

(b) Original $NH_3OH^+Cl^-$ solution 1g in $250cm^3$ = $4gdm^{-3}$

= $\frac{4.00}{69.5}$ = 0.0576 mol dm^{-3}

$25cm^3$ aliquot contains $\frac{25}{1000}$ x 0.0576 = 0.00144 moles

$28.9cm^3$ of 0.0200 mol dm^{-3} MnO^-_4 contains $\frac{28.9}{1000}$ x 0.0200 = 0.000578 moles **(1)**

1 mole MnO_4^- = 5 moles Fe^{2+}

Therefore No. of moles Fe^{2+} = 5 x 0.000578 = 0.00289 moles

Ratio $NH_3OH^+Cl^-$: Fe^{2+} = **1:2** **(1)**

(c) x + 3 – 2 + 1 = +1 Therefore x = -1

oxidation state of N = -1

As $Fe^{3+} \rightarrow Fe^{2+}$, and ratio is 2:1

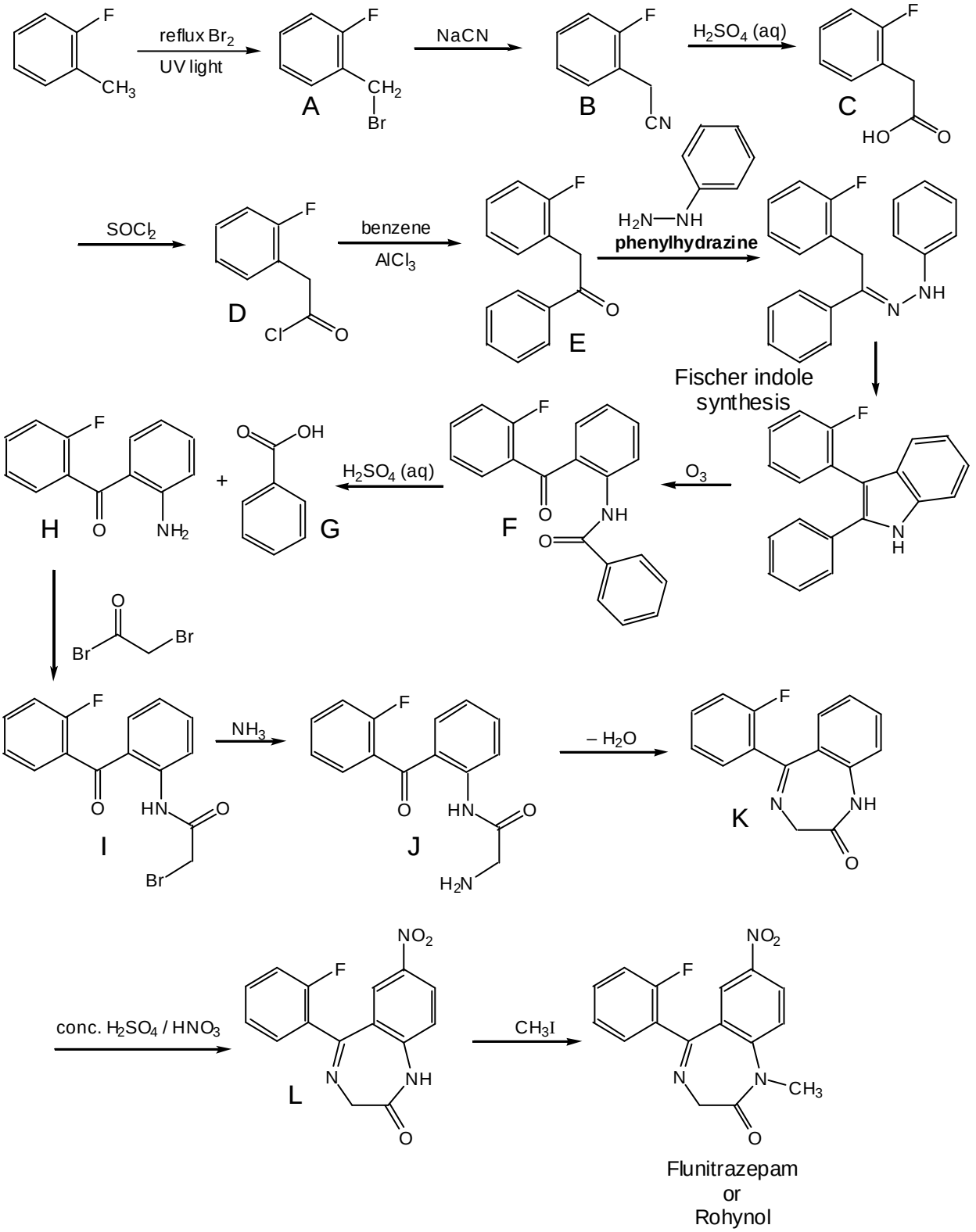
then oxidation state of product goes up by **2 to +1** **(1)**

(d) Product must be N_2O **(1)**

(e) $2NH_3OH^+Cl^- + 4Fe^{3+} \rightarrow N_2O + H_2O + 2Cl^- + 4Fe^{2+} + 6H^+$ **(2)**

Total 8

7. Rohypnol



1 mark for each of A → L + phenylhydrazline **Total 13**

8. Polonium

(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 4f^{14}\ 5s^2\ 5p^6\ 5d^{10}\ 6s^2\ 6p^4$ **(1)**

exact ordering is irrelevant $[Xe]\ 4f^{14}\ 5d^{10}\ 6s^2\ 6p^4$ is also acceptable

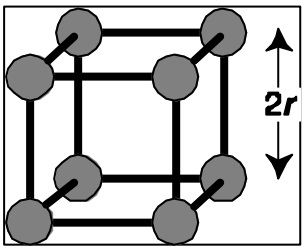
(b) $^{206}_{82}Pb$

(1)

(c) half life = 138 days. 1 year = 365 / 138 half lives = 2.645 half lives. Power output after one year = 141 x $(0.5^{2.645})$ = 22.5(4) W g^{-1} **(2)**

(d) after x half lives, power drops to 0.96 of initial, so $[0.5^x]$ = 0.96 taking logs: x(ln0.5) = ln(0.96), x = 0.05889 half lives in 5 years so time for one half life = 5 / x = 84.899 years = 85 years **(2)**

(e)



1 unit cell contains 8 x 1/8 atoms = 1 **(1)**
volume of unit cell = $(2r)^3$ where r = radius
9.142 g = 1 cm^3 = 1 x $10^{-6}m^3$ **(1)**
mass of 1 atom = 210 g / 6.022 x 10^{23} = 3.487 x 10^{-22}
volume occupied by 1 atom
= $(2r)^3$ = (1 x 10^{-6} / 9.142) x 3.487 x $10^{-22}m^3$ **(1)**
= 3.814 x $10^{-29}m^3$

so $r = \frac{1}{2}\sqrt[3]{3.8143\times10^{-29}}$ = 1.68(3) x 10^{-10}m = 168pm

(168pm x 2 = 2 unless they can say diameter) **(3 for ans)**

336 **Total 9**