

Olympiad Round 1 2003 – Mark Scheme

1. Heating a cup of coffee

- (a) $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$ (1)
- (b) acidic, neutral, basic (1)
- (c) $\Delta_f H = -1003 + 635 + 286 = -82 \text{ kJ mol}^{-1}$ (1) fig + sign
- (d) To warm 1g by 1°C requires 4.18 J
 210g by 40°C requires $4.18 \times 210 \times 40 \text{ J} = 35.1 \text{ kJ}$ (1)
- (e) 1 mol CaO provides 82 kJ
 We need 35.1 kJ = $35.1 / 82 \text{ mol} = 0.428 \text{ mol}$
 Taking RMM for CaO as 56, minimum mass required = $56 \times 0.428 = 24.0 \text{ g}$ (1)
 (Actual mass used in cans = 70g)

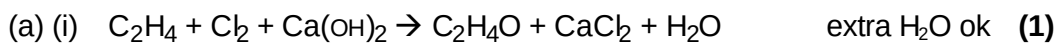
Total 5

2. Reinecke's Salt

- (a) Cr (Ar = 52.0) is 15.5% of total
 Therefore total = $\frac{100}{15.5} \times 52.0 = 335.5$
- For 5 $\frac{38.15}{100} \times 335.5 = 128$
- $\frac{128}{32} = 4 = x$
- Therefore $\text{NH}_4[\text{Cr}(\text{SCN})_4(\text{NH}_3)_y] = 335.5$
 Therefore $18 + 52 + 4 \times 58.1 + 17y = 335.5$
 Therefore $17y = 33.5$
X = 4 y = 2 (1, 1)
- (b) $+1 + \text{Cr} + 4 \times -1 + 2 \times 0 = 0$ (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



(ii) % atom economy = $\frac{44}{44 + 111 + 18} \times 10$ (not 23.6) (1)
 $= 25.4$

(b) 100% (1)

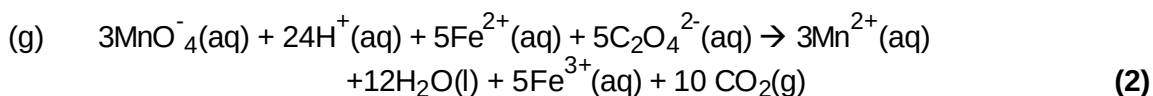
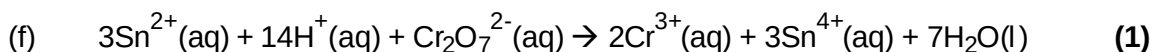
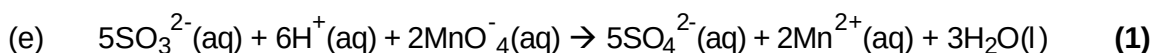
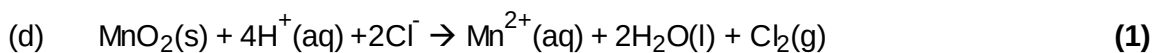
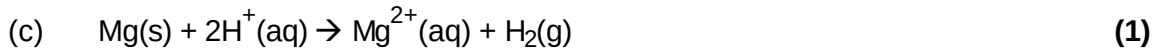
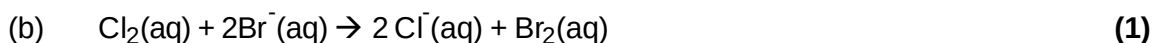
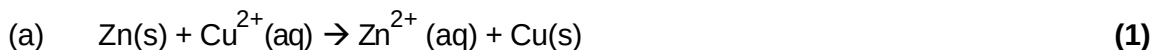
(c)(i) Mr ibuprofen = 206
 % atom economy = $\frac{206}{206 + 60} \times 100 = 77.4$ (1)

(ii) Catalyst (1)

(iii) goes up to 100% (needed) (1)

Total 6

4. Redox Equations Any suitable equation



**Do not 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

$$\begin{array}{l} \text{moles of Sb} = 12k / 121.8 \\ \text{moles of O} = 2.4k / 16.0 \end{array} \quad \begin{array}{l} \text{—————} \\ \text{—————} \end{array} \quad \begin{array}{l} \text{if used} \\ \text{if used} \end{array} \quad (1)$$

$$\text{molar ratio Sb : O} = (12/121.8) : (2.4/16.0) = 0.9852 : 0.15 = 1:1.5 = 2:3$$

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

- (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.

$$\text{Amount of Zn left} = 60 - 60 a$$

$$\text{Total mass at end} = 60 - 60 a + 74.58 a = 65 \text{ grains} = 60 + 14.58 a$$

$$a = (66 - 60) / 14.58 = \mathbf{0.41(15)} \quad (2)$$

$$\text{Mass of unreacted Zn} = 60 - 60 a = \mathbf{35(.31) \text{ grains}} \quad (1)$$

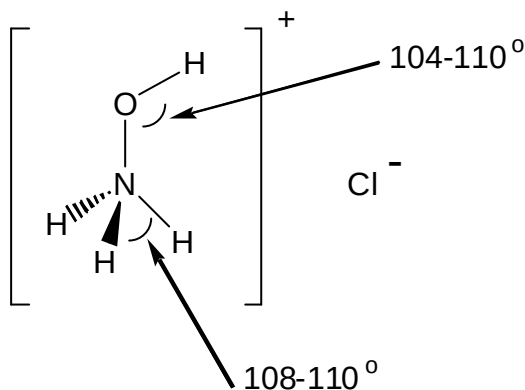
$$\text{Mass of ZnO} = 74.58 a = \mathbf{30(.69) \text{ grains}} \quad (1)$$

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 $\text{NH}_3\text{OH}^+\text{Cl}^-$ solution $1\text{g in } 250\text{cm}^3 = 4\text{gdm}^{-3}$
 $= \frac{4.00}{69.5} = 0.0576 \text{ mol dm}^{-3}$

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

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

1 mole $\text{MnO}_4^- = 5$ moles Fe^{2+}

Therefore No. of moles $\text{Fe}^{2+} = 5 \times 0.000578 = 0.00289$ moles

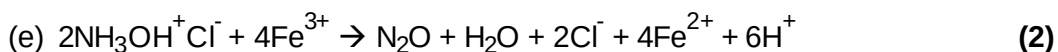
Ratio $\text{NH}_3\text{OH}^+\text{Cl}^- : \text{Fe}^{2+} = \underline{\underline{1:2}}$ (1)

(c) $x + 3 - 2 + 1 = +1$ Therefore $x = -1$
 oxidation state of N = -1

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

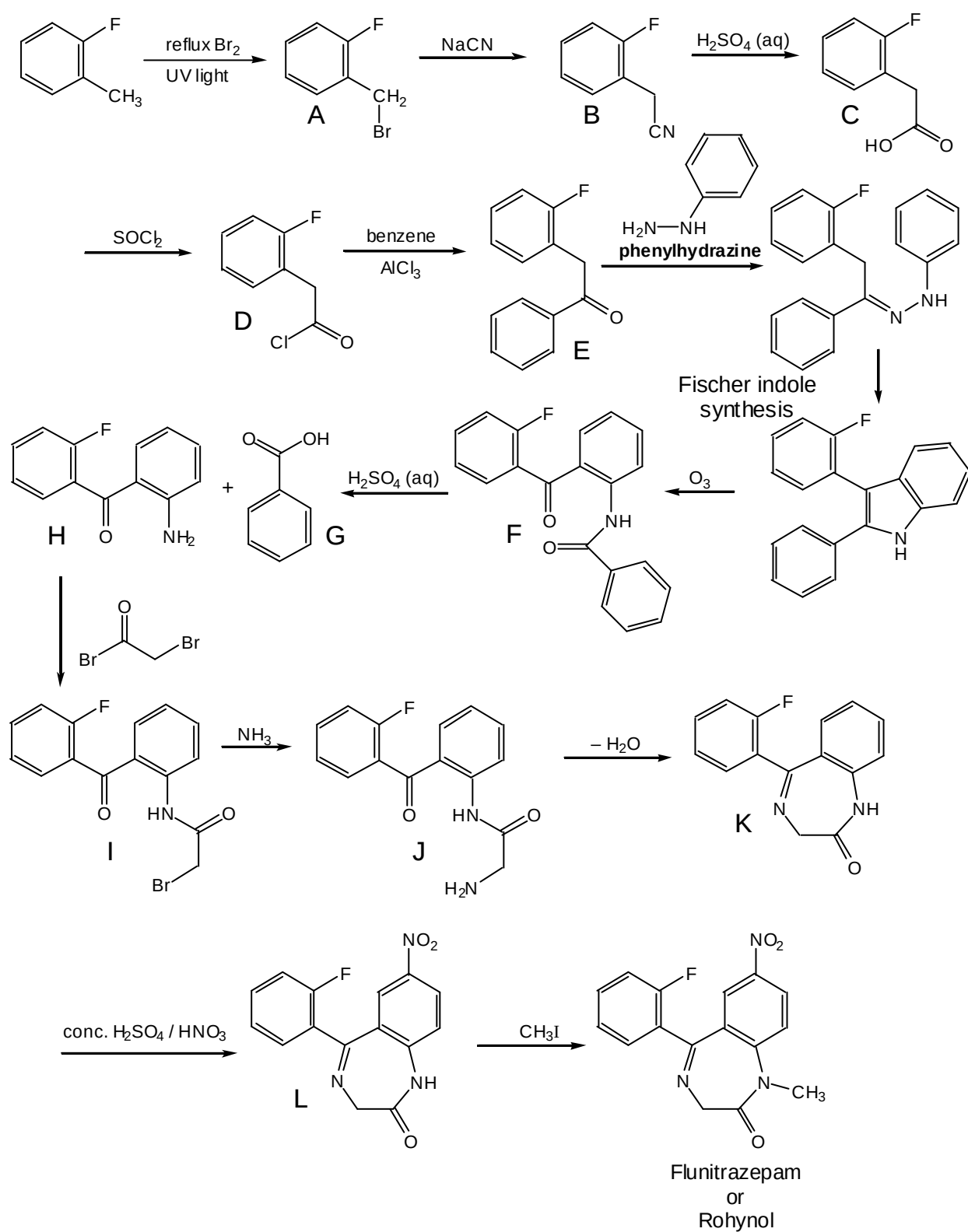
then oxidation state of product goes up by **2 to +1** (1)

(d) Product must be N_2O (1)



Total 8

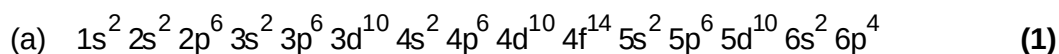
7. Rohypnol



1 mark for each of A $\rightarrow$ L + phenylhydrazine

Total 13

8. Polonium



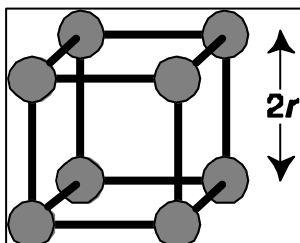
exact ordering is irrelevant $[Xe] 4f^{14} 5d^{10} 6s^2 6p^4$ is also acceptable



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

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

(e)



1 unit cell contains $8 \times 1/8$ atoms = 1 (1)

volume of unit cell = $(2r)^3$ where r = radius

$9.142 \text{ g} = 1 \text{ cm}^3 = 1 \times 10^{-6} \text{ m}^3$ (1)

mass of 1 atom = $210 \text{ g} / 6.022 \times 10^{23} = 3.487 \times 10^{-22}$

volume occupied by 1 atom

$= (2r)^3 = (1 \times 10^{-6} / 9.142) \times 3.487 \times 10^{-22} \text{ m}^3$ (1)

$= 3.814 \times 10^{-29} \text{ m}^3$

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

(168pm x 2 = 2 unless
336 they can say
diameter)

(3 for ans)
Total 9