**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) \( \Delta H = -1003 + 635 + 286 = -82 \text{ kJ mol}^{-1} \)  
   
   (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 mol = 0.428 mol  
   
   Taking RMM for CaO as 56, minimum mass required = 56 × 0.428 = 24.0 g  
   
   (Actual mass used in cans = 70g)  
   
   Total 5

2. **Reinecke’s Salt**

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

   For 5  
   
   \( \frac{38.15 \times 335.5}{100} = 128 \)

   128 = 4 = x  
   
   \( \frac{32}{128} \)

   Therefore \( \text{NH}_4[\text{Cr (SCN)}_4(\text{NH}_3)_y] \) = 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 \( \text{Cr} = +3 \)

   (c) Octahedral  
   
   (1)

   (d) Two octahedral structures, one with 2NH₃ groups adjacent, one with them opposite  

   Geometrical  
   
   (1) for 2 shapes  
   
   (1) for geometric or cis/trans  
   
   Total 6
3. Green Chemistry

(a) (i) \( \text{C}_2\text{H}_4 + \text{Cl}_2 + \text{Ca(OH)}_2 \rightarrow \text{C}_2\text{H}_4\text{O} + \text{CaCl}_2 + \text{H}_2\text{O} \) extra \( \text{H}_2\text{O} \) ok (1)

(ii) \% atom economy \( = \frac{44}{44 + 111 + 18} \times 10 \) (not 23.6) (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 100\% (needed) (1)

4. Redox Equations

Any suitable equation

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

(b) \( \text{Cl}_2(\text{aq}) + 2\text{Br}^{-}(\text{aq}) \rightarrow 2\text{Cl}^{-}(\text{aq}) + \text{Br}_2(\text{aq}) \) (1)

(c) \( \text{Mg(s)} + 2\text{H}^{+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2(\text{g}) \) (1)

(d) \( \text{MnO}_2(\text{s}) + 4\text{H}^{+}(\text{aq}) + 2\text{Cl}^{-} \rightarrow \text{Mn}^{2+}(\text{aq}) + 2\text{H}_2\text{O(l)} + \text{Cl}_2(\text{g}) \) (1)

(e) \( 5\text{SO}_3^{2-}(\text{aq}) + 6\text{H}^{+}(\text{aq}) + 2\text{MnO}_4^{-}(\text{aq}) \rightarrow 5\text{SO}_4^{2-}(\text{aq}) + 2\text{Mn}^{2+}(\text{aq}) + 3\text{H}_2\text{O(l)} \) (1)

(f) \( 3\text{Sn}^{2+}(\text{aq}) + 14\text{H}^{+}(\text{aq}) + 2\text{Cr}_2\text{O}_7^{2-}(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 3\text{Sn}^{4+}(\text{aq}) + 7\text{H}_2\text{O(l)} \) (1)

(g) \( 3\text{MnO}_4^{-}(\text{aq}) + 24\text{H}^{+}(\text{aq}) + 5\text{Fe}^{2+}(\text{aq}) + 5\text{C}_2\text{O}_4^{2-}(\text{aq}) \rightarrow 3\text{Mn}^{2+}(\text{aq}) + 12\text{H}_2\text{O(l)} + 5\text{Fe}^{3+}(\text{aq}) + 10\text{CO}_2(\text{g}) \) (2)

Do not penalise
State symbols

Total 6

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 = \( \frac{12k}{121.8} \) if used
moles of O = \( \frac{2.4k}{16.0} \)
molar ration Sb : O = \( \frac{12/121.8}{2.4/16.0} = 0.9852 : 0.15 = 1:1.5 = 2:3 \)

Formula = \( \text{Sb}_2\text{O}_3 \) (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 \( \frac{60 \times 81.4}{65.4} \) 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

\[ a = \frac{66 - 60}{14.58} = 0.41(15) \] (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) 

(b) Original NH$_3$OH$^+$Cl$^-$ solution 1g in 250cm$^3$ = 4gdm$^{-3}$
\[ = 4.00 = 0.0576 \text{ mol dm}^{-3} \]

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

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

1 mole MnO$_4^-$ = 5 moles Fe$^{2+}$
Therefore No. of moles Fe$^{2+}$ = 5 x 0.000578 = 0.00289 moles

Ratio NH$_3$OH$^+$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$_2$O (1)

(e) \[ 2\text{NH}_3\text{OH}^+\text{Cl}^- + 4\text{Fe}^{3+} \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O} + 2\text{Cl}^- + 4\text{Fe}^{2+} + 6\text{H}^+ \] (2)

Total 8
7. Rohypnol

![Chemical Reaction Diagram]

1 mark for each of A → L + phenylhydrazline

Total 13
8. Polonium

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

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

(b) \[ ^{206}_{82}\text{Pb} \]

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

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

(e) 

1 unit cell contains 8 x 1/8 atoms = 1  

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

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

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

volume occupied by 1 atom  

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

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

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

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

Total 9