

A competition to select the team to represent the

UNITED KINGDOM

at the

**XXXVIth INTERNATIONAL CHEMISTRY
OLYMPIAD**

ANSWER BOOKLET FOR MARKERS

Round I - 2004

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Olympiad Round 1 2004 – Mark Scheme

1. This question is about redox reactions

- (a) $\text{Fe}^{3+} + \text{e}^{-} \rightarrow \text{Fe}^{2+}$ reduction
- (b) $2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{H}_2$ reduction
- (c) $\text{MnO}_4^{2-} \rightarrow \text{MnO}_4^{-} + \text{e}^{-}$ oxidation
- (d) $2\text{SO}_4^{2-} \rightarrow \text{S}_2\text{O}_8^{2-} + 2\text{e}^{-}$ oxidation
- (e) $\text{NO}_3^{-} + 2\text{H}^{+} + \text{e}^{-} \rightarrow \text{NO}_2 + \text{H}_2\text{O}$ reduction
- (f) $\text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}^{+} + 2\text{e}^{-}$ oxidation
- (g) $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^{+} + 6\text{e}^{-} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ reduction

1 mark for each correct reaction (=7)
2 marks if all oxidation and reduction correct
Take off 1 mark for a single mistake.

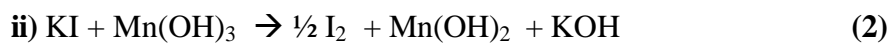
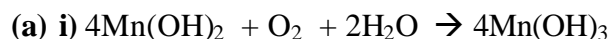
Total 9

2. This question is about pollution and the Taj Mahal

- (a) $\text{CaCO}_3 + \text{H}_2\text{CO}_3 \rightarrow \text{Ca}(\text{HCO}_3)_2$
- (b) i) $\text{CaCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{CaSO}_4 + \text{H}_2\text{CO}_3$
ii) CaSO_4 is more soluble than CaCO_3 .
- (c) $\text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 2\text{NH}_3$
- (d) i) $\text{CO}_2 + \text{Ba}(\text{OH})_2 \rightarrow \text{BaCO}_3 + \text{H}_2\text{O}$
ii) BaCO_3 is even less soluble than CaCO_3 .
- (e) i) $2\text{BaCO}_3 + 2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{BaSO}_4 + 2\text{CO}_2$
ii) Slow down, because BaSO_4 is least soluble of all/ The reaction consumes SO_2 , thus less H_2SO_4 is formed.

Total 8

3. This question is about oxygen dissolved in water



(b) Starch (1)

(c) 25.0 cm^3 of $0.00100 \text{ mol dm}^{-3} \text{ Na}_2\text{S}_2\text{O}_3$ contains 2.50×10^{-5} moles

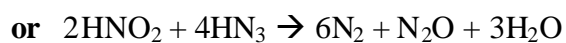
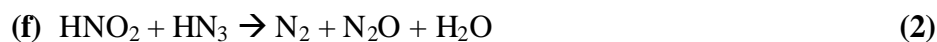
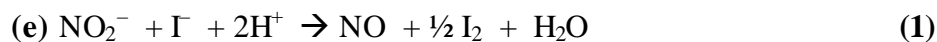
This reacts with $1.25 \times 10^{-5} \text{ mol I}_2$, which is formed from $2.50 \times 10^{-5} \text{ mol}$

$\text{Mn}(\text{OH})_3$. $2.50 \times 10^{-5} \text{ mol Mn}(\text{OH})_3$ is formed from $6.25 \times 10^{-6} \text{ mol O}_2$. Mass

$\text{O}_2 = 6.25 \times 10^{-6} \times 32 = 0.200 \text{ mg}$ in 25.0 cm^3 . Therefore concentration of $\text{O}_2 =$

8.00 mg dm^{-3} (2)

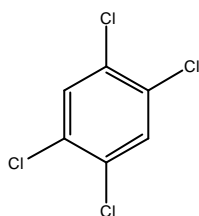
(d) The colourless gas is NO.



Total 9

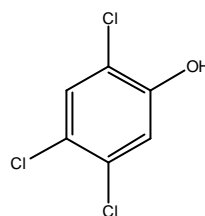
4. This question is about Agent Orange

(a)



(1)

(b)

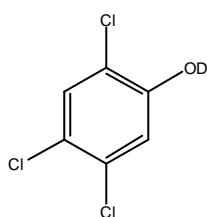


(1)

(c) 2,4,5-trichlorophenol

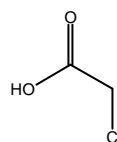
(1)

(d)



(1)

(e)

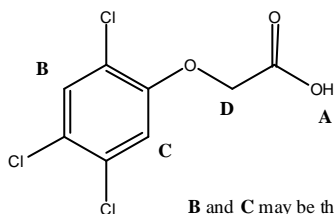


(1)

(f), (g)

2 for structure, 2 for assignment

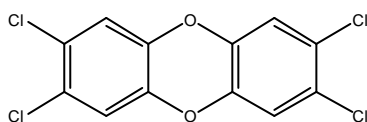
(4)



B and C may be the other way round

h)

(2)



5. This question is about tin pest

(a) $\Delta H = -2.09 \text{ kJ mol}^{-1}$ 1 for value, 1 for units (2)

(b) $\Delta S = 44.1 - 51.4$
 $= -7.30 \text{ J K}^{-1} \text{ mol}^{-1}$ 1 for value, 1 for units (2)

(c) $25^\circ\text{C} = 298 \text{ K}$
 $\Delta G = \Delta H - T\Delta S$
 $= -2090 - (298 \times -7.3)$
 $= 85.4 \text{ J mol}^{-1}$ (2)

1 mark for using 25 instead of 298 = -1.91 kJ mol⁻¹
 1 mark for using 2.09 instead of 2090 = 2.17 kJ mol⁻¹

(d) White because $\Delta G > 0$ at room temperature (1)

(e) $T = (\Delta H - \Delta G) / \Delta S$
 $= (-2090 - 0) / -7.3$
 $= 286 \text{ K} (13^\circ\text{C})$ (1)

(f) Volume of 1 g white tin = $1/7.31 = 0.137 \text{ cm}^3$
 Volume of 1 g grey tin = $1/5.75 = 0.174 \text{ cm}^3$
 Percentage volume increase
 $= [(0.174 - 0.137) / 0.137] \times 100 = 27.1 \%$ (1)

(g) White tin will have a great coordination number because it is denser so the atoms are more tightly packed/ there is a larger distance to its nearer neighbours which implies it has more neighbours (1)

6. This question is about a supernova

$$\begin{aligned}
 \text{(a) } E &= -R_H Z^2 / n^2 \\
 &= -2.179 \times 10^{-18} \times 1/4 \\
 &= -5.45 \times 10^{-19} \text{ J} \qquad (1)
 \end{aligned}$$

$$\begin{aligned}
 \text{(b) } E &= -5.45 \times 10^{-19} - (-2.179 \times 10^{-18}) \\
 &= 1.63 \times 10^{-18} \text{ J} \qquad (1)
 \end{aligned}$$

$$\begin{aligned}
 \text{(c) I.E.} &= 0 - (-2.179 \times 10^{-18} \times 4/1) \\
 &= 8.72 \times 10^{-18} \text{ J} \qquad (1)
 \end{aligned}$$

$$\begin{aligned}
 \text{(d) } f &= 1.63 \times 10^{-18} / 6.626 \times 10^{-34} \\
 &= 2.47 \times 10^{15} \text{ Hz} \qquad (1)
 \end{aligned}$$

$$\begin{aligned}
 \text{(e) } ?E &= -R_H Z^2 (1/n_2^2 - 1/n_1^2) \\
 &= -2.179 \times 10^{-18} \times 64 \times (1/4 - 1) \\
 &= 1.05 \times 10^{-16} \text{ J} \\
 f = ?E/h &= 1.05 \times 10^{-16} / 6.626 \times 10^{-34} \\
 &= 1.58 \times 10^{17} \text{ Hz} \qquad (3)
 \end{aligned}$$

lose 1 mark for using $Z=7$

(gives $?E = 8.01 \times 10^{-17} \text{ J}$, $f = 1.58 \times 10^{17} \text{ Hz}$)

$$\begin{aligned}
 \text{(f) } ?E &= hf = 6.626 \times 10^{-34} \times 2.471 \times 10^{17} \\
 &= 1.64 \times 10^{-16} \text{ J} \qquad (1)
 \end{aligned}$$

$$\begin{aligned}
 ?E &= -R_H Z^2 (1/n_2^2 - 1/n_1^2) \\
 &= -R_H Z^2 (-3/4)
 \end{aligned}$$

$$\begin{aligned}
 Z &= \sqrt{(4/3 \times ?E / R_H)} \\
 &= \sqrt{(4/3 \times 1.63 \times 10^{-16} / 2.179 \times 10^{-18})} \\
 &= 10 \text{ The element is Neon} \qquad (1)
 \end{aligned}$$

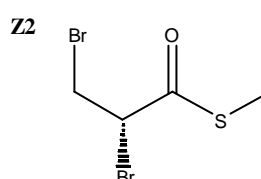
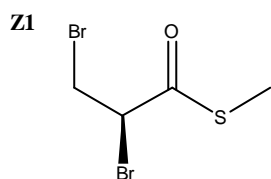
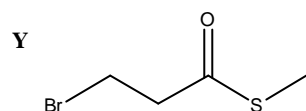
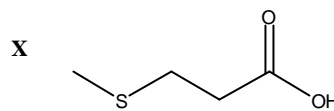
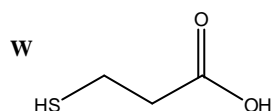
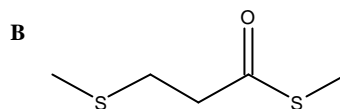
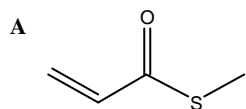
Total 9

7. This question is about 'asparagus-pee'

(a) (iii) dehydrating agent

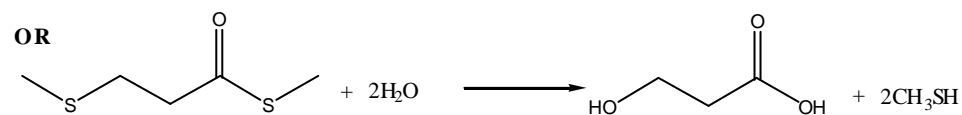
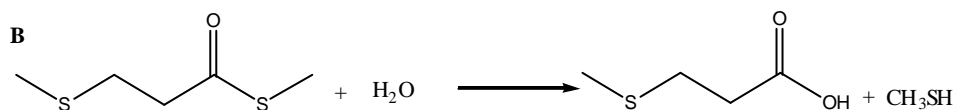
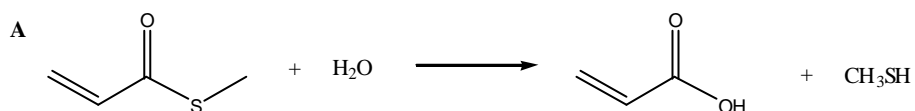
(1)

(b)



(7)

(c)



(2)

Total 10

Total for paper 66