

# **MARKSCHEME**

**November 2000**

**CHEMISTRY**

**Higher Level**

**Paper 2**

SECTION A

1. (a) (i) A, C, D [1]

(Must have all three for mark.)

- (ii) A [1]

- (iii) van der Waal's forces (or dispersion or London forces or induced dipole induced dipole (but **not** dipole–dipole) interaction). [1]

- (iv) Nitrogen or oxygen or fluorine. [1]

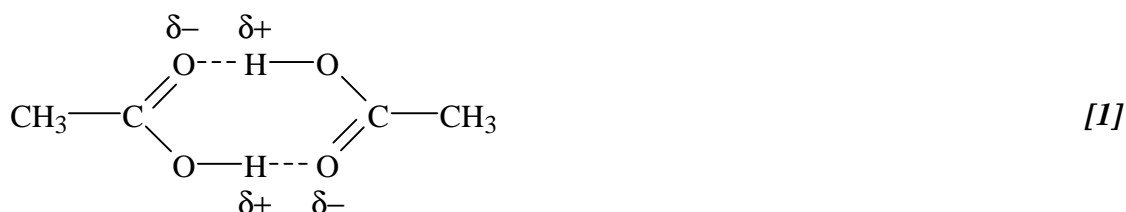
- (v) F because it has the highest melting/boiling point. [1]

(Need explanation for mark.)

- (vi) E: a metal; [1]

F: a metalloid (accept semi-conductor). [1]

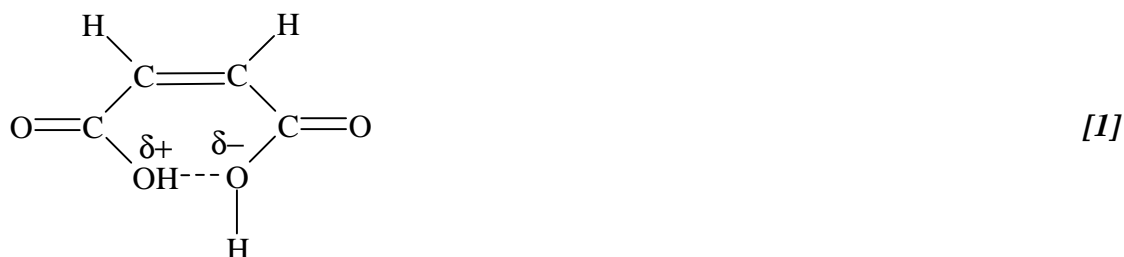
- (b) (i)



Exists as a dimer in non-polar solvents (because of strong inter-molecular H-bonding) but exists as a monomer in aqueous solution (because of H-bonding with water). [1]

(No mark without mention of non-polar solvent.)

- (ii)



(Award [1] for diagram showing intra-molecular H-bonding)

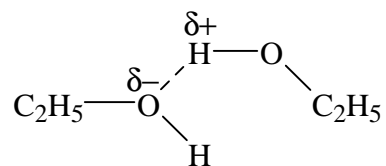
The cis-isomer experiences **intra**-molecular H-bonding that reduces the chances of H-bonding between molecules; [1]

**OR** the trans-isomer experiences (more) **inter**-molecular H-bonding that increases the chances of H-bonding between molecules.

continued...

Question 1 (b) continued

(iii)



[1]

Only ethanol experiences H-bonding because H is bonded to O, whereas in the ether, all H atoms are bonded to C

**OR** ether does not exhibit H-bonding as H is not bonded to O.

[1]

2. (a) (i)

|                    | 4s | 3d |   |   |   |   |
|--------------------|----|----|---|---|---|---|
| Fe <sup>0</sup> :  | ↑↓ | ↑↓ | ↑ | ↑ | ↑ | ↑ |
| Fe <sup>2+</sup> : |    | ↑↓ | ↑ | ↑ | ↑ | ↑ |
| Fe <sup>3+</sup> : |    | ↑  | ↑ | ↑ | ↑ | ↑ |

(Award [1] for each correct electronic configuration.)

[3]

(ii) +2

[1]

(iii) FeO<sub>4</sub><sup>2-</sup>, **OR** FeO<sub>3</sub> **OR** Fe<sub>2</sub>O<sub>7</sub><sup>2-</sup> **OR** Fe<sub>2</sub>O<sub>6</sub>

[1]

(b) (i) A ligand is an anion or a molecule (having lone electron pairs) that can form a (co-ordinate) bond to a (central) atom or cation.

[1]

(ii) A Lewis acid–base reaction

[1]

The ligand is a Lewis base (or an electron pair donor) **and** the metal ion a Lewis acid (or an electron pair acceptor).

[1]

**OR** because H<sub>2</sub>O donates an e<sup>-</sup> pair to form a covalent bond with Fe<sup>2+</sup>

(Need both comments for mark.)

(iii) Because the d orbitals are split into two sets of different energy levels **and** electron transitions between them are responsible for their colours.

[1]

(Need both statements for mark.)

Different ligands split to different extent giving different colours.

[1]

**OR** They contain different ligands, so the energy difference between the split 3d orbitals is not the same in each case.

The e<sup>-</sup> transitions between the two absorb different amounts of energy, corresponding to different wavelength of light in the visible spectrum.

3. (a) (i)  $t_{\frac{1}{2}} = \frac{0.693}{k}$ ;

$$k = \frac{0.693}{1.62 \times 10^4 \text{ s}}$$

$$= 4.28 \times 10^{-5} \text{ s}^{-1}$$

[1]

(No mark without units.)

(ii)  $\ln k = \frac{-E_a}{RT} + \ln A$

Therefore  $E_a = (\ln A - \ln k) RT$

$$= [3.219 - (-10.059)] \times 8.314 \text{ J K}^{-1} \times 1107 \text{ K}$$

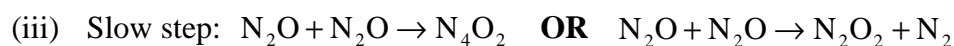
[1]

(Award [1] for correct temperature.)

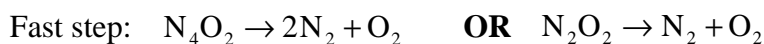
$$= 122 \text{ kJ}$$

[1]

(No mark without unit. If  $T$  taken as  $834^\circ \text{C}$ , then  $E_a = 92.1 \text{ kJ}$ )

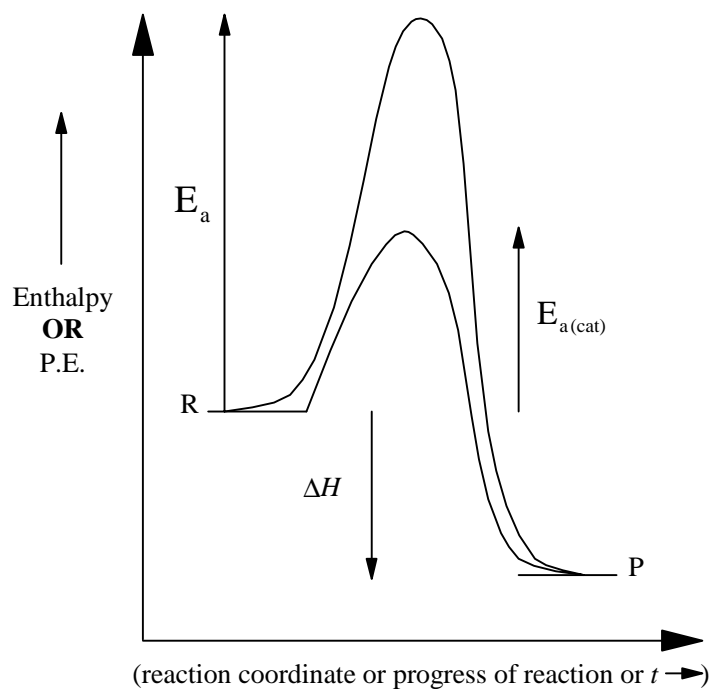


[1]



[1]

(b)



(Award [1] for exothermic reaction and [1] for  $E_a$  and  $E_{a(\text{cat})}$ . Allow [1] for showing  $E_a$  lower for catalysed reaction.)

[2]

4. (a) (i) There will be no change in pressure. [1]
- (ii) The pressure will decrease. [1]
- (b) (i) The temperature will increase. [1]
- (ii) The methanol concentration will increase. [1]
- (c) (i)  $K_c = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2} \text{ mol}^{-2} \text{ dm}^6$  [1]

(Need units to score mark.)

- (ii)  $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$   $\Delta H = -91 \text{ kJ mol}^{-1}$
- |       |  |                     |   |     |
|-------|--|---------------------|---|-----|
| n:    | 1.00                                   | 2.00                | –   |     |
| neq:  | 1.00 – 0.85                            | 2.00 – 1.70         | 0.85  | [1] |
| [eq:  | $\frac{0.15}{0.45}$                    | $\frac{0.30}{0.45}$ | $\frac{0.85}{0.45}$                         | [1] |
|       | = 0.333                                | = 0.667             | = 1.889                                     |     |
| $K_c$ | $= \frac{1.889}{0.333 \times 0.667^2}$ |                     | = 12.8 (mol <sup>-2</sup> dm <sup>6</sup> ) | [1] |
- (iii) Side reactions **OR** leaks in the system **OR** not operating under equilibrium conditions **OR** operating at a **higher** temperature **OR** the product might be collected before equilibrium is reached. [1]
- (iv) No effect on  $K_c$  (it just speeds up the reaction). [1]

### SECTION B

5. (a) (i) Electrons go into **same** main shell/energy level. [1]  
**Increase** in nuclear charge **OR** number of protons in the nucleus across period  
 (pulls valence electrons closer together). [1]
- (ii) Mg is  $3s^2$ , Al is  $3s^2 3p^1$ . [1]  
 The  $3p^1$  electron is in a higher energy level and easier to remove. [1]
- (iii) P is  $3p^3$  where the electrons are arranged singly; S is  $3p^4$  [1]  
 Repulsion of the paired electron in S causes lower I.E. [1]
- (b) NaCl,  $MgCl_2$ ,  $AlCl_3$  ( $Al_2Cl_6$ ),  $SiCl_4$ ,  $PCl_5$  or  $PCl_3$ . [2]  
*(Award [2] for all correct and [1] for one error.)*
- Argon is a noble (unreactive) gas with full outer shell of electrons. [1]
- $SiCl_4$ : covalent bonding between atoms (within the molecules). [1]  
 Weak van der Waal's or London or dispersion forces between molecules. [1]
- (c) Oxides of Na and Mg: basic; [1]  
 oxide of Al: amphoteric; [1]  
 oxide of Si, P and S: acidic. [1]  
*(Award no marks for any one missing; formulas of oxides not asked for.)*
- $MgO + H_2O \rightarrow Mg(OH)_2$  [1]  
 $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$  (accept  $P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$ ) [1]  
*(Accept appropriate acid–base reactions; equations must be balanced to score marks.)*
- Slightly acidic from dissolved  $CO_2$  in water forming carbonic acid **OR**  
 $CO_2 + H_2O \rightarrow H_2CO_3$  (weak acid) *(No mark if  $SO_x$  or  $NO_x$  mentioned)* [1]
- (d) (i)  $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$  [1]  
 $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$  (accept  $2Na^+ AlO_2^- + H_2O$ ) [1]  
**OR**  $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$  (accept  $2Na^+ Al(OH)_4^-$ )  
*(Accept net ionic equations; equations must be balanced for marks.)*
- (ii)  $[Fe(H_2O)_6]^{3+} \rightleftharpoons [Fe(H_2O)_5OH]^{3+} + H^+$  [1]  
**OR**  $FeCl_3 + 6H_2O \rightarrow [Fe(H_2O)_6]^{3+} + 3Cl^-$
- (e)  $Cl_2$  reacts with (oxidises)  $Br^-$  and  $I^-$  to the corresponding halogens [1]  
 as it is a better oxidising agent than  $Br_2$  and  $I_2$ . *(Accept balanced equations)* [1]  
 $Br_2$  reacts with  $I^-$  but not  $Cl^-$  (to form  $I_2$ ) *(accept balanced equation)* [1]  
 as it is a better oxidising agent than  $I_2$ . [1]  
 $I_2$  will not react with  $Cl^-$  or  $Br^-$  (as it is the weakest oxidising agent of the three). [1]

6. (a) (i)  $\Delta H_f^\circ$  = standard enthalpy change of formation of a substance. [1]  
 It is the heat **change** (absorbed or released under constant pressure) when a mole of a compound is formed from its elements in their standard states. [1]
- $S^\circ$  = standard entropy. [1]  
 It is related to (is a measure of) the disorder or randomness of particles. [1]  
**OR** It is the quantity of energy owned by a mole of an element or a compound in its standard state at 298 K.
- A: related to standard conditions or 298 K (25 °C) **and** one atmosphere pressure. (Need both for mark.) [1]
- (ii)  $\Delta$ : not included because  $S$  has absolute values, **OR**  $S$  values can be measured. [1]
- (iii)  $\Delta H_f^\circ(\text{Cu}) = 0$  [1]
- (b) (i)  $\Delta H_f^\circ \text{ reaction} = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$  [1]  
 (Can be implicit in the calculation)
- $\Delta H_f^\circ \text{ reaction} = \{[4 \times (-242) + (-1084)] - [-2278]\} \text{ kJ mol}^{-1}$  [1]  
 $= +226 \text{ kJ mol}^{-1}$  (accept kJ) [1]  
 (Must include unit to score mark.)
- An endothermic process **OR** reaction needs energy/heat [1]
- (ii)  $\Delta S^\circ \text{ reaction} = \sum \Delta S^\circ \text{ products} - \sum \Delta S^\circ \text{ reactants}$   
 $= [4 \times (189) + (150)] - [305] \text{ J K}^{-1}$  [1]
- $\Delta S^\circ \text{ reaction} = 601 \text{ J K}^{-1}$  **OR**  $0.601 \text{ kJ K}^{-1}$  (correct value) [1]  
 (correct units) [1]
- (+) sign/value, thus products are more disordered than reactants. [1]
- (iii) Gibbs free energy, **OR**  $G$  (accept  $\Delta G$ ). [1]  
 Units: J or kJ **OR**  $\text{kJ mol}^{-1}$ . [1]

continued...



*Question 6 continued*

$$\begin{aligned} \text{(c) (i)} \quad \Delta G^{\ominus} &= \Delta H^{\ominus} - T\Delta S^{\ominus} \\ &= 226 \text{ kJ} - 298 \text{ K} (0.601 \text{ kJ K}^{-1}) \end{aligned}$$

*(Award [1] for temperature and [1] for  $\Delta H^{\ominus}$  and  $\Delta S^{\ominus}$  values.)* [2]

$$= +47 \text{ kJ (accept } 47 \text{ kJ mol}^{-1}\text{; no marks without units)} \quad [1]$$

$\Delta G^{\ominus} > 0$ , therefore reverse action is spontaneous. [1]

**OR** forward reaction is non-spontaneous

thus  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  is more stable at  $25^{\circ}\text{C}$ . [1]

*(No double jeopardy if wrong answers are used from (b) above.)*

$$\text{(ii)} \quad \Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$$

$$\text{Therefore } 0 = 226 \text{ kJ} - TK (0.601 \text{ kJ K}^{-1}) \quad [1]$$

$$\text{Therefore } T = \frac{226}{0.601} = 376 \text{ K}. \quad [1]$$

Thus forward reaction is spontaneous above  $103^{\circ}\text{C}$  [1]

(i.e.  $\text{CuSO}_4 \cdot \text{H}_2\text{O}$  is more stable above  $103^{\circ}\text{C}$ ).

7. (a) (i) Weak acid [1]  
 for a strong  $0.100 \text{ mol dm}^{-3}$ , pH would be 1.0  
 (thus acid is partially dissociated and weak). [1]  
 pH of final solution closer to 13 means  $\text{pOH} = 1$  **OR** there is a substantial [1]  
 vertical portion of the pH curve near the end point  
 thus a strong base. [1]
- (ii)  $V_b = 0.100 \text{ mol dm}^{-3} \times \frac{25.0}{22.2}$ . [1]  
 $= 0.113 \text{ mol dm}^{-3}$  (accept M as unit). [1]
- (iii)  $\text{HIn} \rightleftharpoons \text{H}^+ + \text{In}^-$  (generally weak acids) [1]  
 In acid solution,  $[\text{H}^+]$  will shift equilibrium to the left, indicator is  
 predominantly present as HIn which is one colour [1]  
 and in basic solution,  $\text{H}^+$  ions are removed by  $\text{OH}^-$ , shifting equilibrium to the  
 right;  $\text{In}^-$  predominantly present which is another colour. [1]
- (iv)  $K_a = \frac{[\text{H}^+][\text{In}^-]}{[\text{HIn}]}$  [1]  
 At end point intensity of HIn and  $\text{In}^-$  is about the same (where colour change  
 takes place), **OR**  $[\text{HIn}] = [\text{In}^-]$  [1]  
 therefore  $K_a = [\text{H}^+]$ , and  $\text{p}K_a = \text{pH}$ . [1]
- (v) At equivalence point  $\text{pH} \approx 8$  / between 8 and 9, so use indicator of  $\text{p}K_a \approx 8$ .  
 (Accept 9.) [1]

continued...

Question 7 continued

- (b)  $\text{Na}^+$  ions are neutral cations from a strong base. [1]  
 ethanoate ions are basic (from a weak acid)  
**OR**  $\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{OH}^-$  **OR** hydrolyses to produce weak acid + strong base, therefore basic. [1]  
 Since ammonium ion is a weak acid **OR**  $\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$  [1]  
 then the presence of a weak acid and a weak base produces (an approximately) neutral solution. [1]

*Alternate answer:*

The ions in sodium ethanoate solution are

- $\text{CH}_3\text{COO}^-$  and  $\text{Na}^+$ ,
- $\text{H}^+$  and  $\text{OH}^-$ .

$\text{Na}^+$  and  $\text{OH}^-$  do not combine because NaOH is a strong base.  $\text{CH}_3\text{COO}^-$  and  $\text{H}^+$  do combine because  $\text{CH}_3\text{COOH}$  is a weak acid. The solution contains more  $\text{OH}^-$  than  $\text{H}^+$  ions, so is alkaline. The ions in ammonium ethanoate solution are

- $\text{CH}_3\text{COO}^-$  and  $\text{NH}_4^+$ ,
- $\text{H}^+$  and  $\text{OH}^-$ .

$\text{NH}_4\text{OH}$  is a weak base, so the  $\text{NH}_4^+$  and  $\text{OH}^-$  ions combine. As this happens to about the same extent as the combination of  $\text{CH}_3\text{COO}^-$  and  $\text{H}^+$ , the numbers of  $\text{H}^+$  and  $\text{OH}^-$  ions are about equal, so the solution is approximately neutral.

- (c)  $\text{SO}_4^{2-}$ : neutral anions (from a strong acid). [1]  
 $\text{Al}^{3+}$ : weakly acidic **OR**  $\text{Al}(\text{H}_2\text{O})_6^{3+} \rightleftharpoons [\text{Al}(\text{H}_2\text{O})_5(\text{OH})]^{2+} + \text{H}^+$  [1]  
 The  $\text{H}^+$  reacts with the basic solution, reducing its pH [1]  
**OR**  $[\text{Al}(\text{H}_2\text{O})_6]^{3+} + \text{OH}^- \rightarrow [\text{Al}(\text{H}_2\text{O})_5(\text{OH})]^{2+} + \text{H}_2\text{O}$
- (d) (i)  $2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$  [1]

(accept  $\text{NH}_4\text{OH} + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4 + \text{H}_2\text{O}$ )

- (ii)  $n = cV = 0.4040 \text{ mol dm}^{-3} \times 0.02851 \text{ dm}^3 = 0.01152 \text{ mol}$  [1]

$\text{mol NH}_3 = 2 \text{ mol acid} = 0.02304 \text{ mol}$  [1]

$M_r = 17.04$ ;  $\text{mass} = 17.04 \text{ g mol}^{-1} \times 0.02304 = 0.3926 \text{ g}$  [1]

(if  $M_r = 17.0$ , accept 0.392 g).

$\% = \frac{0.3919}{2.447} \times 100 = 16.04 \%$  [1]

(Accept answers within + or – one s.f.; maximum penalty of [1] in question for serious errors in use of significant figures.)

8. (a)  $C=C$ : add bromine (or bromine water) [1]  
 its colour is discharged **OR** changes from orange to clear. [1]  
 $COOH$ : add sodium carbonate solution **OR** Na **OR** acid/base indicator. [1]  
 It would effervesce/gas bubbles produced. [1]

- (b) (i)  $C=C$  at  $1610-1680\text{ cm}^{-1}$   
 $C=O$  at  $1680-1750\text{ cm}^{-1}$   
 $C-H$  at  $2840-3095\text{ cm}^{-1}$  [2]  
 $O-H$  at  $2500-3300\text{ cm}^{-1}$   
 (Award [2] for three correct and [1] for any two.)

- (ii)  $CH_3$  at 0.9 ppm  
 $C=C-H$  at 4.9–5.9 ppm  
 $COOH$  at 11.5 ppm [2]  
 (Award [2] for all three and [1] for any two.)

Ratio of areas of peaks: 6:1:1 [1]

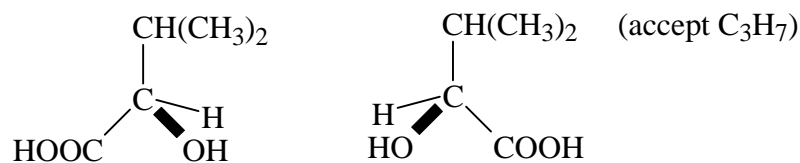
- (c) (i) NMR [1]  
 because B would give 5 peaks [1]  
 whereas C would give only 4 peaks [1]  
 (Accept: because the chemical environments of the H atoms are different and the number of peaks would be different.)

- (ii) Test based on fact that secondary alkanols (alcohols)  
 are easily oxidised, whereas tertiary alkanols are not [1]  
 Warm (or reflux) with acidified dichromate or manganate(VII) [1]  
 With B orange dichromate would change to green (**OR** purple manganate(VII)  
 would turn (almost) clear) [1]  
 With C it would remain orange (or purple) [1]

- (d) (i) Optical activity is the ability to rotate the plane of polarised light (accept rotate plane polarised light). [1]

It has an asymmetric carbon atom **OR** a carbon bonded to four different groups  
**OR** the molecule is asymmetric **OR** chiral centre. [1]

- (ii) Compound B can exhibit optical activity. [1]



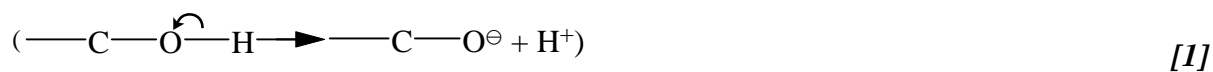
(Award only [1] if relationship is not clear.)

One enantiomer rotates plane of polarised light clockwise (or +), the other anticlockwise (or –); accept dextrorotatory and levorotatory. [1]

continued...

*Question 8 continued*

- (e) For OH to be acidic, the O—H bond has to break/ $H^+$  or protons form



In COOH the O—H bond breaks/ $H^+$  forms because the second O on carbon attracts  $e^-$  density from the O—H bond. [1]

Delocalisation stabilises the  $\text{COO}^-$  anion. [1]

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