

# **MARKSCHEME**

**November 2001**

**CHEMISTRY**

**Higher Level**

**Paper 2**

SECTION A

1. (a) (i)  $M_r = 88/88.17$  [1]  
 $\Delta H_c^\ominus = -3325 \pm 25 \text{ kJ mol}^{-1}$  (allow for ECF) [1]  
 (no mark if minus sign missing; no penalty if units not given)
- (ii) The value should be (about) the same. [1]  
 Same (number and type of) bonds are being broken and made. [1]  
 (Do **not** accept “the compounds have the same relative molecular masses or same formula”.)
- (b) The reaction of methanol and oxygen has a high activation energy / OWTTE. [1]  
 When  $E \geq E_a$  / OWTTE is provided, a (highly exothermic) reaction takes place. [1]
- (c) (i)  $\text{heat evolved} = 110 \text{ g} \times 4.20 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1} \times 21.4 \text{ }^\circ\text{C}$  (accept  $(44.6 - 23.2)$ )  
 (Award [1] for correct  $\Delta T$ ; [1] for 110 g, **not** 100 g.) [2]  
 $= 9887 \text{ J}$  (accept 9890 J, allow ECF) [1]  
 (No double jeopardy if 100 g or 10 g used; no mark without unit.)
- (ii)  $M_r = 40.0$ ;  $\Delta H \text{ per mol} = -9887 \text{ J} \times \frac{40.0}{10.0} = -39.5 \text{ kJ mol}^{-1}$  (accept  $-39.6$ ) [1]  
 (need minus sign for mark; no penalty if units not given)
- (iii) Heat loss to the surrounding (thus less  $\Delta H$ ) [1]  
 Use a styrofoam/plastic cup **OR** insulate (and cover) beaker [1]  
 (Accept answer that says “calculate heat gained by glass calorimeter”.)

2. (a) (i)  $M_r = 44.01$ ;  $m_C$  in  $\text{CO}_2$  produced  $= \frac{12.01}{44.01} \times 5.470 = 1.493 \text{ g}$  [1]

Percentage C  $= \frac{1.493}{2.036} \times 100 = 73.32 \%$  [1]

(ii)  $m_H = \frac{2.02}{18.02} \times 0.697 = 0.0781 \text{ g}$  [1]

Percentage H  $= \frac{0.0781}{2.036} \times 100 = 3.84 \%$  [1]

(b) Percentage O  $= 100 - 73.32 - 3.84 - 10.75 = 12.09 \%$  [1]

	C	H	N	O	
amount, $n$	$\frac{73.32}{12.01}$	$\frac{3.84}{1.01}$	$\frac{10.75}{14.01}$	$\frac{12.09}{16.00}$	(ECF if % oxygen not worked out)
	$= 6.1$	$3.8$	$0.77$	$0.76$	(divide by 0.76)
	$= 8:5:1:1$	thus $\text{C}_8\text{H}_5\text{NO}$			

(c) Empirical mass  $= (8 \times 12) + (5 \times 1) + 14 + 16 = 131 \text{ g mol}^{-1}$  (allow for ECF) [1]

This is half the  $M_r$  **OR**  $M_r = 2 \times M_{\text{emp}}$ ; thus molecular formula is  $\text{C}_{16}\text{H}_{10}\text{N}_2\text{O}_2$ . [1]

3. (a) Pressure, volume and temperature of the gas. (*Need all three for mark.*) [1]

$$PV = nRT \text{ OR } n = \frac{PV}{RT} \text{ [1]}; \quad n = \frac{m}{M} \text{ OR } M = \frac{m}{n} \text{ [1]} \quad [2]$$

$$\text{OR } M = \frac{m}{V} \frac{RT}{P} \text{ (for [2])}$$

Where R is the Ideal Gas Constant (*accept gas constant, but not just constant*)  
(= 8.314 J mol<sup>-1</sup> K<sup>-1</sup>) [1]

**OR** calculations as appropriate using molar volume = 22.4 dm<sup>3</sup>

- (b) More energetic molecules escape / *owtte*. [1]

Remaining molecules are less energetic (lower T) [1]

**OR** Thus its average energy drops (so does its temperature)

**OR** Bonds are broken as molecules escape

Energy to break these bonds comes from the remaining molecules which are less energetic (thus lower T)

- (c) Vapour pressures are all the same. [1]

Vapour pressure does not depend on the:

- volume of the liquid [1]
- volume of the container [1]

**OR** As long as there is vapour-liquid equilibrium present, and the temperature remains the same, then the vapour pressure will be the same.

*correct explanations in terms of dynamic equilibrium involved should be awarded marks*

4. (a) Anode: Cu(s) → Cu<sup>2+</sup>(aq) + 2e<sup>-</sup> (*state symbols needed*) [1]

Cathode: Cu<sup>2+</sup>(aq) + 2e<sup>-</sup> → Cu(s) (*state symbols needed*) [1]

- (b) Remains the same as [Cu<sup>2+</sup>] does not change (*reasoning needed*) [1]  
(*ECF if reaction in 4 (a) is incorrect*)

- (c) 2H<sub>2</sub>O(l) → O<sub>2</sub>(g) + 4H<sup>+</sup>(aq) + 4e<sup>-</sup> (*states not required*) [2]  
(*Award [1] for balanced half equation and [1] for O<sub>2</sub> and H<sup>+</sup> as products.*)

- (d) The colour intensity decreases / changes [1]  
The pH decreases / changes [1]

- (e) C = At = 0.180 A × 1210 s = 218 C [1]

$$\text{Number of Faradays, } F = \frac{218 \text{ C}}{96480 \text{ C}} (\text{mole}^-) = 2.26 \times 10^{-3} \text{ mole}^- \quad [1]$$

2 mole<sup>-</sup> produce 1 mol Cu = 63.35 g Cu

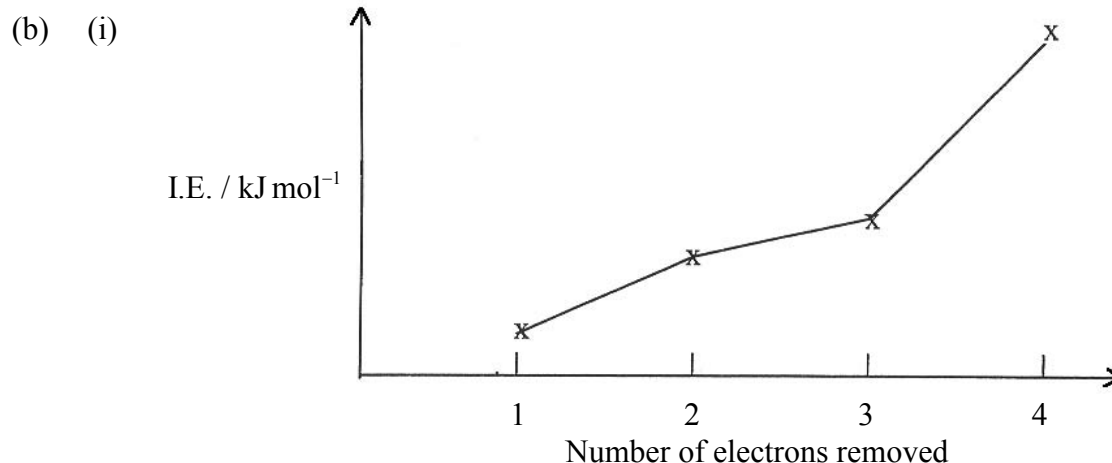
thus 2.26 × 10<sup>-3</sup> mole<sup>-</sup> gives 0.50 × 63.35 × 2.26 × 10<sup>-3</sup> g = 0.0715 g Cu [1]

**SECTION B**

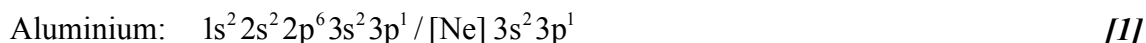
5. (a) (i) Average  $A_r = \frac{(32.00 \times 95.00) + (33.00 \times 0.76) + (34.00 \times 4.20) + (36.00 \times 0.020)}{100}$  [1]

$= 32.1$  [1]

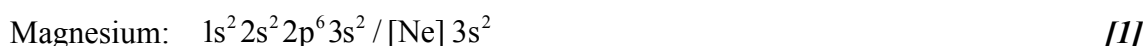
(ii) Number of neutrons in  $^{36}\text{S} = 36 - 16 = 20$  [1]



(Award [1] for increase from first to third I.E. and [1] for larger increase from third to fourth I.E.; for “I.E. keeps increasing” award only [1]) [2]



Al has an  $e^-$  in a higher / third energy level further away from the nucleus that is easier to remove. [1]



$3p^1$  is easier to remove than  $3s^2$  as it is higher in energy. [1]

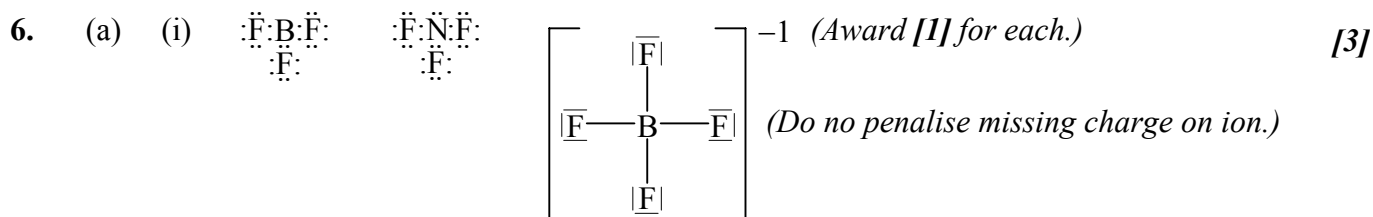
- (c) Spectrum showing discrete lines [1]  
 converging at higher energy [1]  
 transition of (excited) electrons from higher energy levels to lower one(s). [1]

(Only one series need be shown to score mark.)

continued...

*Question 5 continued*

- (d) (i) One valence electron / one electron in outer shell [1]  
 Melting point low (compared to other metals) [1]  
 First I.E.: low; second I.E.: **very** high (*need both for mark*) [1]  
 For at least two full electron arrangements given. [1]
- (ii) Reactivity increases down the group [1]  
 as outer electrons are further from the nucleus so easier to remove. [1]
- Description of reaction with water:  
*e.g.* vigorous / highly exothermic. [1]  
 Gas produced / alkaline solution. [1]  
 Balanced equation, *e.g.*  $2\text{Na(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2\text{(g)}$  [1]  
 (*must be balanced; state symbols **not** required.*)
- Description of reaction with chlorine:  
*e.g.* vigorous / highly exothermic [1]  
 white solid formed [1]  
 Balanced equation, *e.g.*  $2\text{Na(s)} + \text{Cl}_2\text{(g)} \rightarrow 2\text{NaCl(s)}$  [1]  
 (*must be balanced, state symbols **not** required.*)



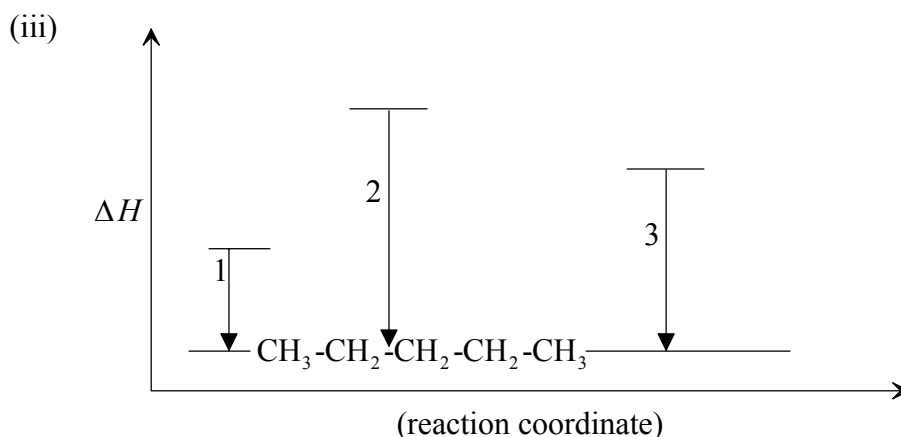
(Need lone pair on N for mark; must show valence electrons on F in each case. Accept dashes in place of pairs of dots, penalise only once if lone e<sup>-</sup> pairs missing on F.)

- (ii) BF<sub>3</sub> planar triangular [1]  
 NF<sub>3</sub> triangular pyramidal [1]  
 BF<sub>4</sub><sup>-</sup> tetrahedral [1]  
 109½° compared to 107° / bond angle in BF<sub>4</sub><sup>-</sup> > bond angle in NF<sub>3</sub> [1]  
 Explanation: Lone electron pair on N produces extra repulsion that (slightly) pushes the bonding electrons closer together. [1]
- (iii) Hybridisation: mixing / merging (*but not joining*) of atomic orbitals (to form same number of new ones of lower energy) [1]  
 BF<sub>3</sub> sp<sup>2</sup> [1]  
 NF<sub>3</sub> sp<sup>3</sup> (hybridised orbitals) [1]
- (iv) ‘Polar bond’ indicates that bonding electrons are **not equally distributed** between the atoms in the bond [1]  
 the more electronegative atom will have the greater electron density. [1]  
 B—F is a polar bond, because F is more electronegative than B  
 N—F is a polar bond, because F is more electronegative than N [1]  
**OR** both bonds are polar because F is the most electronegative element.  
 BF<sub>3</sub> is a **non-polar** molecule due to its **planar triangular shape / polarity** of bonds is **cancelled** / because of symmetrical distribution of electron cloud. [1]  
 NF<sub>3</sub> is a **polar** molecule due to its (trigonal) pyramidal shape and polarity of bonds does not cancel / non-symmetrical distribution of electron cloud. [1]

*continued...*

*Question 6 continued*

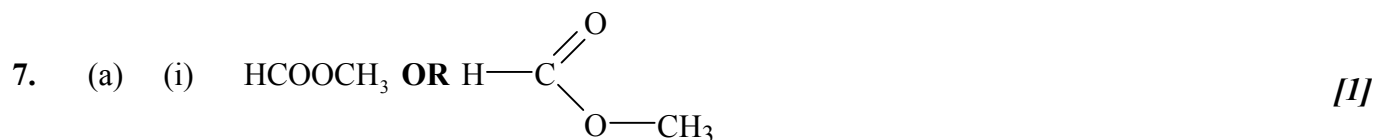
- (b) (i)  $\sigma$  bonds involve overlap of orbitals end-on / along the molecular axis (it has axial symmetry around axis joining the two nuclei) / overlap of s orbitals. [1]  
 $\pi$  bonds result from overlapping of parallel p orbitals / sideways overlap. [1]  
 Double bond: a  $\sigma$  bond and a  $\pi$  bond. [1]  
 Triple bond: a  $\sigma$  bond plus **two**  $\pi$  bonds. [1]
- (ii) Delocalisation: when electron pairs are not confined to two adjacent bonding atoms but extend over **three or more** atoms. [1]



*(Award [1] for enthalpy diagram.)*

- Twice the number of bonds made and broken in 2 compared to 1, thus twice the energy given out. [1]  
 Delocalisation present (only) in 3. [1]  
 Thus 3 is more stable / less energy is given out. [1]



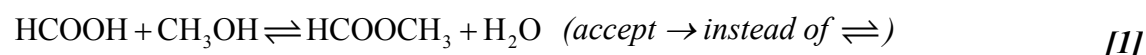


Heat [1]

Acid catalyst /  $\text{H}^+$  [1]

$\text{HCOOH}$  / methanoic acid [1]

$\text{CH}_3\text{OH}$  / methanol [1]



(ii)  $\text{CH}_3\text{COOH}$  (but not  $\text{C}_2\text{H}_4\text{O}_2$ ) [1]

Physical:

Boiling point: acid is higher (due to greater H-bonding) / ester is lower

pH: acid  $< 7$ ; ester = 7 (need both for mark).

**OR** Smell: acid: vinegar/pungent smell; ester: sweet smell. [1]

Chemical: [1]

acid reacts with  $\text{OH}^-$  to form salt and water. [1]

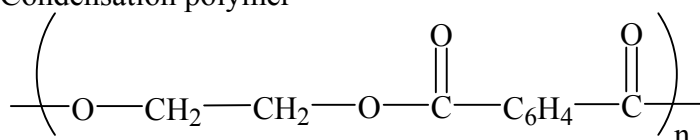
Ester reacts with  $\text{OH}^-$  to form salt plus methanol / acid can be esterified; ester cannot [1]

(b) (i) When two (small) molecules combine to form a larger one **with** the elimination of a smaller molecule (such as water). [1]

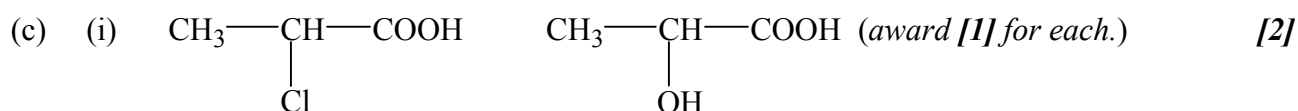
The need for two functional groups on each of the two monomers. [1]

Addition polymerisation: process in which unsaturated monomers combine to form a polymer **without** the elimination of any atoms/molecules. [1]

(ii) Condensation polymer [1]



(Award [1] for ester group and [1] for  $\text{CH}_2\text{CH}_2$  and  $\text{C}_6\text{H}_4$  groups.) [2]



(ii) Negatively charged or neutral species containing electron pairs / electron pair donors / Lewis bases [1]

$\text{OH}^-$  (no mark for  $\text{H}_2\text{O}$  – water does not react) [1]

(iii) Each compound contains a C with four different groups on it / contains a chiral centre / molecules are asymmetric / contains asymmetric C / optically active starting materials. [1]

Reaction must involve  $\text{S}_{\text{N}}1$  mechanism. [1]

Forming a planar carbocation. [1]

The nucleophile can attach from either side producing an equal mixture of enantiomers / racemic mixture (thus optically inactive). [1]

8. (a)  $\frac{[\text{H}_2(\text{g})][\text{CO}(\text{g})]}{[\text{H}_2\text{O}(\text{g})]}$  (state symbols not needed) [1]
- mol dm<sup>-3</sup> (ECF if  $K_c$  expression incorrect) [1]
- Endothermic. [1]
- The value of  $K_c$  increases with temperature (forward reaction is favoured). [1]
- (b) (i) The rate of the forward reaction:
- Increase in temperature:  
increases rate of the forward reaction [1]  
since it increases the number of collisions with  $E \geq E_a$  [1]  
(thus rate of forward and reverse reaction increases).
- (Award [0] for “more frequent collisions” as this is not the main reason.)
- Increase in pressure:  
Increases the rate of the forward reaction. [1]  
An increase in pressure increases the concentration / the same amount of molecules in a smaller volume (thus rate increases) / more frequent collisions. [1]
- Increase in surface area of C(s):  
Increases rate of forward reaction. [1]  
The reactive surface area of C(s) increases / concentration of H<sub>2</sub>O(g) in contact with C(s) increases (thus rate increases) / more frequent collisions. [1]
- (ii) [H<sub>2</sub>O]:[H<sub>2</sub>] ratio:
- Increase in T: decreases ratio / more [H<sub>2</sub>] compared to [H<sub>2</sub>O]. [1]  
Favours forward / endothermic reaction by using up (some of the) heat supplied (no mark for saying “because of Le Chatelier’s principle”). [1]
- Increase in P:  
Increases the ratio / more [H<sub>2</sub>O] compared to [H<sub>2</sub>]. [1]  
1 mol / volume of gas in the reactants, 2 mol / volume of gases in the products / increasing pressure will move position of equilibrium to the left to relieve pressure due to more volumes of gas (in the products). [1]
- Increase in surface area of C(s):  
No effect. [1]  
Because [C(s)] is constant / position of equilibrium is unchanged. [1]
- (iii) The value of the equilibrium constant:
- Increase in T: increases value of  $K_c$ . [1]  
Increase in P: no effect on  $K_c$  (because  $K_c$  is only temperature dependent). [1]  
Increase in surface area: no effect ( $K_c$  is only temperature dependent). [1]

continued...

*Question 8 continued*

- (c) Correct diagram (reactants level, products level and activation energy) *[1]*  
 for an endothermic change (*no double jeopardy*) *[1]*  
 showing a lower  $E_a$  for the catalysed reaction. *[1]*
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- |                           |           |            |
|---------------------------|-----------|------------|
| Rate of forward reaction: | increases | <i>[1]</i> |
| Rate of reverse reaction: | increases | <i>[1]</i> |
| Equilibrium position:     | unchanged | <i>[1]</i> |
-