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MARKSCHEME

November 2001

CHEMISTRY

Higher Level

Paper 2

15 pages

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)*

(no mark if minus sign missing; no penalty if units not given) ***[1]***

(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) *heat evolved* $= 110 \text{ g} \times 4.20 \text{ J g}^{-1} \, ^{\circ}\text{C}^{-1} \times 21.4 \, ^{\circ}\text{C}$ *(accept (44.6 – 23.2))*

*(Award **[1]** for correct ΔT; **[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) $M_r = 40.0$; ΔH per mol $= -9887 \text{ J} \times \dfrac{40.0}{10.0} = -39.5 \text{ kJ mol}^{-1}$ (*accept –39.6*) ***[1]***

(need minus sign for mark; no penalty if units not given)

(iii) Heat loss to the surrounding (thus less ΔH) ***[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 CO_2 produced $= \frac{12.01}{44.01} \times 5.470 = 1.493$ g *[1]*

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

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

$= 8:5:1:1$, thus C_8H_5NO *[1]*

(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** $M_r = 2 \times M_{emp}$; thus molecular formula is $C_{16}H_{10}N_2O_2$. *[1]*

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

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

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

Where R is the Ideal Gas Constant *(accept gas constant, but not just constant)*
$(= 8.314\ \mathrm{J\,mol^{-1}\,K^{-1}})$ ***[1]***

OR calculations as appropriate using molar volume $= 22.4\ \mathrm{dm^3}$

(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: $\mathrm{Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-}$ (*state symbols needed*) ***[1]***

Cathode: $\mathrm{Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)}$ (*state symbols needed*) ***[1]***

(b) Remains the same as $[\mathrm{Cu^{2+}}]$ does not change *(reasoning needed)*
(ECF if reaction in 4 (a) is incorrect) ***[1]***

(c) $\mathrm{2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-}$ (*states **not** required*)
*(Award **[1]** for balanced half equation and **[1]** for O_2 and H^+ as products.)* ***[2]***

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

(e) $C = At = 0.180\ \mathrm{A} \times 1210\ \mathrm{s} = 218\ \mathrm{C}$ ***[1]***

Number of Faradays, $F = \frac{218\ \mathrm{C}}{96\,480\ \mathrm{C}}(\mathrm{mol\,e^-}) = 2.26 \times 10^{-3}\ \mathrm{mol\,e^-}$ ***[1]***

$2\ \mathrm{mol\,e^-}$ produce $1\ \mathrm{mol\,Cu} = 63.35\ \mathrm{g\,Cu}$

thus $2.26 \times 10^{-3}\ \mathrm{mol\,e^-}$ gives $0.50 \times 63.35 \times 2.26 \times 10^{-3}\ \mathrm{g} = 0.0715\ \mathrm{g\,Cu}$ ***[1]***

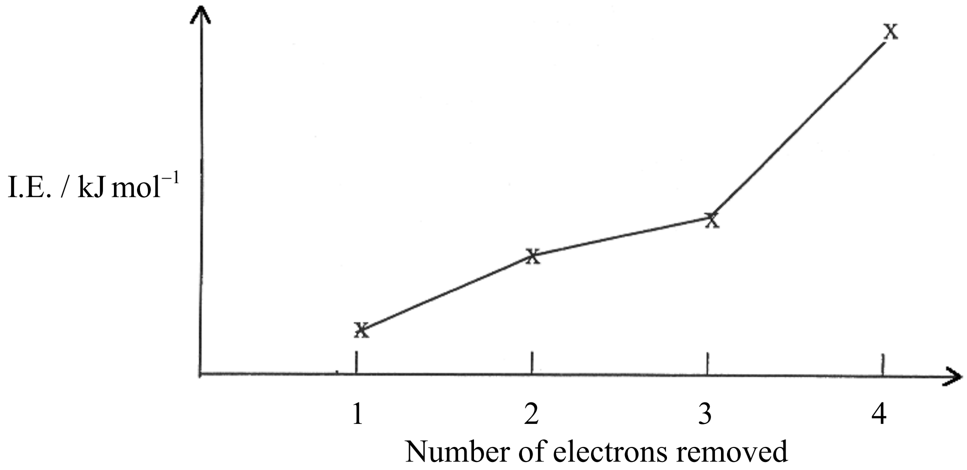
SECTION B

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 $^{36}S = 36 - 16 = 20$ ***[1]***

(b) (i)



*(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]***

(ii) Boron: $1s^2 2s^2 2p^1$ / [He] $2s^2 2p^1$ ***[1]***
Aluminium: $1s^2 2s^2 2p^6 3s^2 3p^1$ / [Ne] $3s^2 3p^1$ ***[1]***

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

Magnesium: $1s^2 2s^2 2p^6 3s^2$ / [Ne] $3s^2$ ***[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

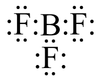
(d) (i) One valence electron / one electron in outer shell ***[1]***
Melting point low (compared to other metals) ***[1]***
First I.E.: low; second I.E.: **very** high (*need both for mark*) ***[1]***
For at least two full electron arrangements given. ***[1]***

(ii) Reactivity increases down the group ***[1]***
as outer electrons are further from the nucleus so easier to remove. ***[1]***

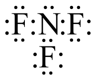
Description of reaction with water:
e.g. vigorous / highly exothermic. ***[1]***
Gas produced / alkaline solution. ***[1]***
Balanced equation, *e.g.* $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ ***[1]***
(*must be balanced; state symbols **not** required.*)

Description of reaction with chlorine:
e.g. vigorous / highly exothermic ***[1]***
white solid formed ***[1]***
Balanced equation, *e.g.* $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$ ***[1]***
(*must be balanced, state symbols **not** required.*)

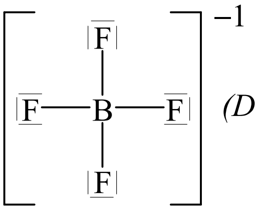
6. (a) (i)



$:\overset{\cdot\cdot}{\underset{\cdot\cdot}{F}}:\underset{:\underset{\cdot\cdot}{F}:}{B}:\overset{\cdot\cdot}{\underset{\cdot\cdot}{F}}:$



$:\overset{\cdot\cdot}{\underset{\cdot\cdot}{F}}:\overset{\cdot\cdot}{\underset{:\underset{\cdot\cdot}{F}:}{N}}:\overset{\cdot\cdot}{\underset{\cdot\cdot}{F}}:$



*(Award **[1]** for each.)* ***[3]***

(Do no penalise missing charge on ion.)

(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^- *pairs missing on F.)*

(ii) BF_3 planar triangular ***[1]***

NF_3 triangular pyramidal ***[1]***

BF_4^- tetrahedral ***[1]***

$109\frac{1}{2}^\circ$ compared to 107° / bond angle in BF_4^- > bond angle in NF_3 ***[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_3 sp^2 ***[1]***

NF_3 sp^3 (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_3 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_3 is a **polar** molecule due to its (trigonal) pyramidal shape and polarity of bonds does not cancel / non-symmetrical distribution of electron cloud. ***[1]***

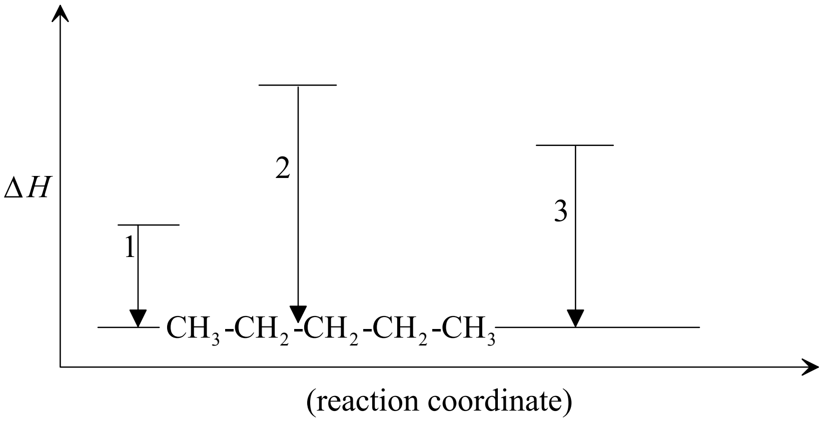
continued...

Question 6 continued

(b) (i) σ 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]***
π bonds result from overlapping of parallel p orbitals / sideways overlap. ***[1]***
Double bond: a σ bond and a π bond. ***[1]***
Triple bond: a σ bond plus **two** π bonds. ***[1]***

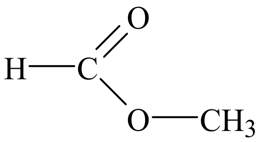
(ii) Delocalisation: when electron pairs are not confined to two adjacent bonding atoms but extend over **three or more** atoms. ***[1]***

(iii)



*(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]***

7. (a) (i) $HCOOCH_3$ **OR** 
$H-C(=O)-O-CH_3$ *[1]*

Heat *[1]*
Acid catalyst / H^+ *[1]*
HCOOH / methanoic acid *[1]*
CH_3OH / methanol *[1]*
$HCOOH + CH_3OH \rightleftharpoons HCOOCH_3 + H_2O$ *(accept → instead of ⇌)* *[1]*

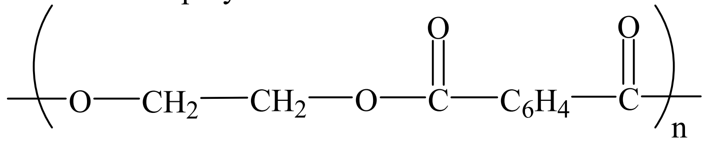
(ii) CH_3COOH (*but not* $C_2H_4O_2$) *[1]*
Physical:
Boiling point: acid is higher (due to greater H-bonding) / ester is lower
pH: acid < 7; ester = 7 (*need both for mark*). *[1]*
OR Smell: acid: vinegar/pungent smell; ester: sweet smell. *[1]*

Chemical:
acid reacts with OH^- to form salt and water. *[1]*

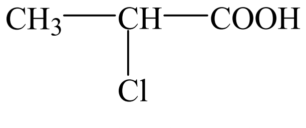
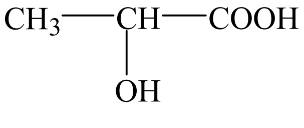
Ester reacts with OH^- to form salt plus methanol / acid can be esterified; ester cannot *[1]*

(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]*


$$\left(-O-CH_2-CH_2-O-\overset{\overset{\displaystyle O}{\|}}{C}-C_6H_4-\overset{\overset{\displaystyle O}{\|}}{C}-\right)_n$$

(Award ***[1]*** *for ester group and* ***[1]*** *for* CH_2CH_2 *and* C_6H_4 *groups.)* *[2]*

(c) (i) 
$$CH_3-\underset{\underset{\displaystyle Cl}{|}}{CH}-COOH$$

$$CH_3-\underset{\underset{\displaystyle OH}{|}}{CH}-COOH$$
(*award* ***[1]*** *for each.*) *[2]*

(ii) Negatively charged or neutral species containing electron pairs / electron pair donors / Lewis bases *[1]*
OH^- (*no mark for* H_2O *– 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 S_N1 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) $\dfrac{[H_2(g)][CO(g)]}{[H_2O(g)]}$ *(state symbols not needed)* *[1]*

$mol\,dm^{-3}$ *(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 $H_2O(g)$ in contact with C(s) increases (thus rate increases) / more frequent collisions. *[1]*

(ii) $[H_2O]:[H_2]$ ratio:

Increase in T: decreases ratio / more $[H_2]$ compared to $[H_2O]$. *[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 $[H_2O]$ compared to $[H_2]$. *[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]***

Rate of forward reaction: increases ***[1]***
Rate of reverse reaction: increases ***[1]***
Equilibrium position: unchanged ***[1]***