INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
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MARKSCHEME

November 2003

CHEMISTRY

Higher Level

Paper 2

16 pages

1. Follow the markscheme provided, do **not** use decimals or fractions and mark only in **RED**.

2. Where a mark is awarded, a tick ($\checkmark$) should be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark.

3. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases write a brief annotation in the **left hand margin** to explain your decision. You are encouraged to write comments where it helps clarity, especially for moderation and re-marking.

4. Unexplained symbols or personal codes/notations on their own are unacceptable.

5. Record subtotals (where applicable) in the right-hand margin against the part of the answer to which they refer (next to the mark allocation for Section A). Do **not** circle sub-totals. **Circle the total mark for the question in the right-hand margin opposite the last line of the answer.**

6. For Section B, show a mark for each part question (a), (b), *etc.*

7. Where an answer to a part question is worth no marks, put a zero in the right-hand margin.

8. Section A: Add together the total for each question and write it in the Examiner column on the cover sheet.
Section B: Insert the total for each question in the Examiner column on the cover sheet.
Total: Add up the marks awarded and enter this in the box marked TOTAL in the Examiner column.

9. After entering the marks on the cover sheet, check your addition to ensure that you have not made an error. Check also that you have transferred the marks correctly to the cover sheet. **We have script checking and a note of all clerical errors may be given in feedback to examiners.**

10. Every page and every question must have an indication that you have marked it. Do this by **writing your initials** on each page where you have made no other mark.

11. If a candidate has attempted more than the prescribed number of questions, mark only the required number of answers in the order in which they are presented in the script, **unless the candidate has indicated the questions to be marked on the cover sheet**. Make a comment to this effect in the left hand margin.

12. A candidate can be penalized if he/she clearly contradicts him/herself within an answer. Make a comment to this effect in the left hand margin.

Subject Details: Chemistry HL Paper 2 Markscheme

General

- Each marking point is usually shown on a separate line or lines.
- Alternative answers are separated by a slash (/) – this means that either answer is acceptable.
- Words underlined are essential for the mark.
- Material in brackets (…) is not needed for the mark.
- The order in which candidates score marks does not matter (unless stated otherwise).
- The use of **OWTTE** in a markscheme (the abbreviation for "or words to that effect") means that if a candidate's answer contains words different to those in the markscheme, but which can be interpreted as having the same meaning, then the mark should be awarded.
- Please remember that many candidates are writing in a second language, and that effective communication is more important than grammatical accuracy.
- In some cases there may be more acceptable ways of scoring marks than the total mark for the question part. In these cases, tick each correct point, and if the total number of ticks is greater than the maximum possible total then write the maximum total followed by **MAX**.
- In some questions an answer to a question part has to be used in later parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in later parts then "follow through" marks can be scored. Show this by writing **ECF** (error carried forward). This situation often occurs in calculations but may do so in other questions.
- Units for quantities should always be given where appropriate. In some cases a mark is available in the markscheme for writing the correct unit. In other cases the markscheme may state that units are to be ignored. Where this is not the case, penalize the omission of units, or the use of incorrect units, once only in the paper, and show this by writing **−1(U)** at the first point at which it occurs.
- Do not penalize candidates for using too many significant figures in answers to calculations, unless the question specifically states the number of significant figures required. If a candidate gives an answer to fewer significant figures than the answer shown in the markscheme, penalize this once only in the paper, and show this by writing **−1(SF)** at the first point at which this occurs.
- If a question specifically asks for the name of a substance, do not award a mark for a correct formula; similarly, if the formula is specifically asked for, do not award a mark for a correct name.
- If a question asks for an equation for a reaction, a balanced symbol equation is usually expected. Do not award a mark for a word equation or an unbalanced equation unless the question specifically asks for this. In some cases, where more complicated equations are to be written, more than one mark may be available for an equation – in these cases follow the instructions in the mark scheme.
- Ignore missing or incorrect state symbols in an equation unless these are specifically asked for in the question.
- Mark positively. Give candidates credit for what they have got correct, rather than penalizing them for what they have got wrong.
- If candidates answer a question correctly, but by using a method different from that shown in the markscheme, then award marks; if in doubt consult your Team Leader

SECTION A

1. (a)
$$C(s) + 2F_2(g) \rightarrow CF_4(g) \quad \Delta H_1 = -680 \text{ kJ};$$
$$4F(g) \rightarrow 2F_2(g) \quad \Delta H_2 = 2(-158) \text{ kJ};$$
$$(C(g) \rightarrow C(s) \quad \Delta H_3 = -715 \text{ kJ})$$

Accept reverse equations with $+\Delta H$ values.
$$C(g) + 4F(g) \rightarrow CF_4(g) \quad \Delta H = -1711 \text{ kJ} ;$$

average bond enthalpy $= \dfrac{-1711}{4} = -428 \text{ kJ mol}^{-1}$;   **[4]**

Accept + or – sign.
Units not needed for mark, but deduct [1] if incorrect units.
No significant figures penalty.

For a correct enthalpy cycle with symbols, award [2].
For correct numerical value (1711), award [1].
For incorrect value, award [0].
For correct average bond enthalpy, award [1] (ECF).
It is possible to score [3] for an incorrect answer.

(b) (i) $(\Delta G^{\ominus} = \Delta H^{\ominus} - T \Delta S^{\ominus})$

as T increases, $-T\Delta S^{\ominus}$ becomes larger / more positive;
ΔG increases / becomes more positive / less negative;   **[3]**
process becomes less spontaneous / reverse reaction favoured;

(ii) $(\Delta G^{\ominus} = \Delta H^{\ominus} - T \Delta S^{\ominus} = 0)$

therefore, $T = \dfrac{\Delta H}{\Delta S} = \dfrac{-9830 \text{ J mol}^{-1}}{-35.2 \text{ J K}^{-1} \text{ mol}^{-1}}$;

$= 279 \text{ K} = 6 \text{ }^{\circ}\text{C}$;
(no SF penalty) ECF
(ECF if kJ used above)

temperature at which solid and liquid are in equilibrium with each other /   **[3]**
melting point / freezing point / T at which it changes from spontaneous to
non-spontaneous or vice-versa / T at which no (useful) work is done;

2.   (a) $3Ag^+(aq) + XO_4^{3-}(aq) \rightarrow Ag_3XO_4(s)$;   *[2]*

[1] for balanced equation and [1] for states.

(b)   (i) $n_{Ag+} = cV = 0.2040 \text{ mol dm}^{-3} \times 0.04118 \text{ dm}^3$

$= 0.008401 / 8.401 \times 10^{-3} \text{ mol}$ *(−1 SF)*

Unit not needed for mark.   *[1]*

(ii) $n_{Ag_3XO_4} = \frac{1}{3} n_{Ag+} = \frac{1}{3} \times 0.008401 \text{ mol}$

$= 0.002800 / 2.800 \times 10^{-3} \text{ mol}$ *[1]*

ECF from (a) / (b) (i).

(iii) $0.002800 \text{ mol weighs } 1.172 \text{ g}$

$1 \text{ mol weighs } \dfrac{1.172 \text{ g}}{0.002800 \text{ mol}} = 418.6 \text{ g mol}^{-1}$ *[2]*

Accept answer in range 418 to 419.
No penalty for too many sig figs.
ECF from (b)(ii) (g mol⁻¹);
Do not accept g.

(iv) $(3 \times 107.87) + x + 4 (16.0) = 418.6$ *(ECF)*

therefore, $x = 30.99$ *(accept 31.0 / 31)*;   *[2]*
P / phosphorus;

3. (a) mass / density / for gases: rate of effusion or diffusion / melting point / boiling *[1]* point
Do not accept mass number.

(b) if $^{35}Cl = x$, then $(x \times 35.00) + (1 - x) 37.00 = 35.45$;
Award [1] for set up.

therefore, $x = 0.775$ *[2]*
$^{35}Cl = 77.5\%$ and $^{37}Cl = 22.5\%$ *(need both for mark)*;

(c) Br: $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 3d^{10}\, 4s^2\, 4p^5\, /\, 1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^2\, 3d^{10}\, 4p^5$;
For Br, accept only complete configuration (which is asked for).

Fe^{3+}: $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 3d^5$; *[2]*

Accept $[Ar]\, 3d^5$ since [Ar] already listed above.

4. (a) (i) $pK_a = 3.75$, therefore $K_a = 1.78 \times 10^{-4}$ *(accept 1.8×10^{-4})* *[1]*
No units required.

(ii) weak acid;
less $[H^+]$ / partial dissociation / more reactants / less products / *[2]*
$K_a \ll 1$ / small K_a;

(iii) $(HCOOH(aq) \rightleftharpoons H^+(aq) + HCOO^-(aq))$

$$K_a = \frac{[H^+][HCOO^-]}{[HCOOH]} = \frac{x^2}{0.010};$$

$(x^2 = 1.78 \times 10^{-6})$

$x = 1.33 \times 10^{-3}\ mol\ dm^{-3} = [H^+]$ *(no mark without units)*;
ECF from (a) (i). *[4]*
No penalty for incorrect significant figures.
$pH = 2.88 / 2.9$ *(ECF)*;
assume $x \ll 0.010 / 25°C$ / negligible dissociation;

(b) add strong base / sodium hydroxide or other named alkali / salt of methanoic acid / HCOONa to methanoic acid;
in equimolar amounts / quantities / so that $[HCOOH] = [HCOO^-]$;
(from K_a expression) $pH = pK_a$ $(= 3.75)$; *[3]*

5.   (a)   (i)   oxidation half-reaction: $2Cl^- \rightarrow Cl_2 + 2e^-$;

reduction half-reaction: $2H_2O + 2e^- \rightarrow H_2 + 2OH^- / 2H^+ + 2e^- \rightarrow H_2$;

Award [1] only if equations are interchanged.   **[2]**

States not required.

(ii)   Na has high $E_{red}^{\ominus} / Na^+$ not readily reduced (in comparison to H_2O) / if

formed, Na would (immediately) react with water to form Na^+ **[1]**

(b) $H_2(g)$ and $O_2(g)$ / *accept names*;

$2H_2O \rightarrow O_2 + 4H^+ + 4e^- / 4OH^- \rightarrow 2H_2O + O_2 + 4e^-$;

water is oxidized (instead of the halide);

since $E_{ox}^{\ominus}$ for F^- is very negative / $E_{red}^{\ominus}$ for F_2 is very high;   **[4]**

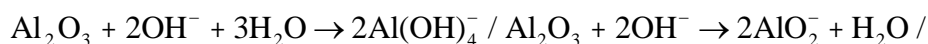*Accept answer based on oxidizing / reducing strengths.*

SECTION B

6. (a) oxides of: Na, Mg: basic;
Al: amphoteric;
Si to Cl: acidic;
Ar: no oxide;
All four correct: [2], two or three correct [1].

basic oxide: $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$ / $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$;
acidic oxide:
$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$ / $Al_2O_3 + 2OH^- \rightarrow 2AlO_2^- + H_2O$ /

$$Al_2O_3 + 3H_2O + 6NaOH \rightarrow 2Na_3Al(OH)_6;$$
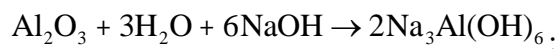
[4]

(b) (i) $Mg: 3s^2$ and $Al: 3s^2 3p^1$ *(need both for mark)*;
3p electron is higher in energy than 3s (and easier to remove);

[2]

(ii) $V^{3+}: [Ar]3d^3$ and $Zn^{2+}: [Ar]3d^{10}$ *(need both for mark)*;
colour due to **splitting** of **partially filled d orbitals** (at different energy levels);
electronic transitions between these are responsible for colour;
V^{3+} has partially filled d orbitals / Zn^{2+} does not;
V^{3+} not in its highest oxidation state (and can be oxidized);
Zn^{2+} in its highest oxidation state (and cannot be further oxidized);

[6]

(c) (i) 1st IE of K < Na as valence electron of K is further away / valence electron of K in n = 4, valence electron of Na in n = 3;
1st IE of K **much less** than that of Ar;
since Ar (also n = 3) has greater nuclear charge (compared to Na);

[3]

(ii) valence electrons in the **same** main energy level;
Mg has greater nuclear charge / Mg: 12 protons, Na: 11 protons;
electrons pulled closer together in Mg / smaller radius;
Mg has higher ionization energy;

[4]

(iii) second electron in Na removed from n = 2, whereas for Mg second electron is removed from n = 3;
therefore, easier to remove in Mg and lower 2nd IE for Mg / harder to remove in Na and higher 2nd IE for Na;

[2]

(d) ligand: a molecule or ion that can bond to a (central) metal ion (to form a complex);
$NH_3:$ Lewis base and $Cu^{2+}:$ Lewis acid *(need both for mark)*;
each NH_3 / ligand donates an electron pair (to Cu^{2+});
forming coordinate covalent / dative covalent bond;

[4]

7. (a) for H_2S, H_2Se and H_2Te, as size / mass / M_r increases, van der Waal's forces increase (and b pt. increases);
H_2O experiences H–bonding ;
H–bonding stronger than van der Waals' / explanation of H–bonding; *[3]*

(b) (i) C_4H_{10} : non-polar, only van der Waal's forces that cannot replace / interact with H–bonding in water;
C_2H_5Cl : only slightly polar / not capable of H–bonding with water; *[2]*

(ii) $(CH_3)_2CO$: highly polar / forms H–bonding with water;
C_3H_7OH : forms H–bonding with water (as H is bonded to O); *[2]*
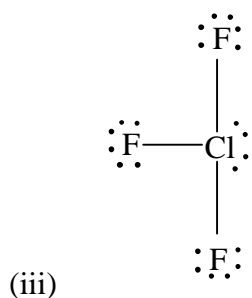
(c) (i)
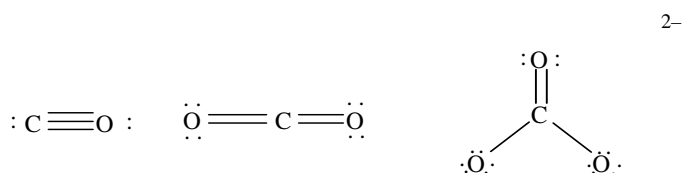
OTTWE

Award [1] each. Need charge on CO_3^{2-} for [1].
Penalize missing lone electron pairs only once. *[3]*

(ii) CO_3^{2-} ;
bond order $1\frac{1}{3} / 1\frac{1}{3}$ bonds each compared to double bonds in CO_2 and triple bond in CO;
the fewer the number of bonding electrons, the less tightly nuclei are held together, the longer the bond; *[3]*

(iii)

No mark if lone e⁻ pairs on F or Cl are missing.
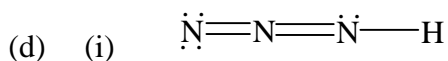*No mark if lone e⁻ pairs on F or Cl are missing.*

        (3 bonded, 2 lone e⁻ pairs) planar / T-shaped; **[2]**
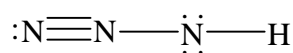*Accept drawing with T-shape.*
Award [1] for correct structure and [1] for the shape.
Accept alternative answer using CIF_3

(d) (i) $\ddot{N}\!=\!N\!=\!\dot{N}\!-\!H$

      I

    $:N\!\equiv\!N\!-\!\ddot{N}\!-\!H$ **[2]**

      II

(ii) $N\!-\!N\!-\!N$ $180°$ in both;
due to two centres of electron charge / density (arranged as far apart as possible);

I: $N\!-\!N\!-\!H \simeq 120° / = 120°$;
due to three centres of electron charge / three electron pairs (one of which is a lone e⁻ pair);

II: $N\!-\!N\!-\!H \simeq 109° / < 109°$ / any angle between $104°$ and $109°$;
four electron pairs / four centres of electron charge, two of which are lone e⁻ pairs /
extra repulsion due to lone electron pairs; **[6]**

(iii) I: sp^2;
     II: sp^3; **[2]**

8. (a) (i) [NO] constant, $[O_2]$ doubles, rate doubles;
rate $\propto [O_2]$ / first order;

[NO] doubles, $[O_2]$ doubles, rate increases 8 times;
rate $\propto [NO]^2$ / second order;

rate = k $[NO]^2 [O_2]$/ rate $\propto [NO_2]^2[O_2]$;   *[5]*

(ii) slow step / rate determining step involves only one NO and one O_2;   *[2]*

not two NO and one O_2 (as required by rate-expression);

(iii) since two NO and one O_2 involved in the (one step) mechanism, correct
rate expression possible;
but unlikely that three particles will collide at the same time;   *[2]*

(iv) from fast step $[NO_3]$ depends on [NO] and $[O_2]$;

rate depends on $[NO_3]$ and [NO];

thus rate must depend on $[NO]^2[O_2]$ (consistent with rate expression);   *[3]*

(v) $NO(g) + NO(g) \rightarrow N_2O_2(g)$ fast;
$N_2O_2(g) + O_2(g) \rightarrow 2NO_2(g)$ slow;

similar reasoning to above / rate depends on $[N_2O_2]$ and $[O_2]$, and   *[3]*
$[N_2O_2]$ depends on [NO] and [NO] (thus consistent with the overall third
order reaction);
Accept ECF from (ii) to (v).
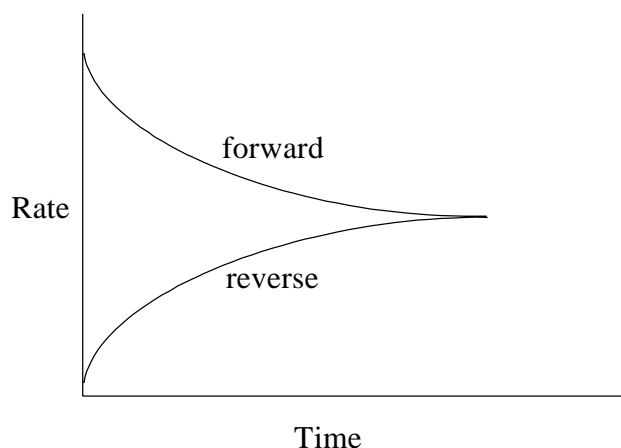
(b)
two curves - one labled "forward" starting up high up y-axis and one labeled "reverse" starting from zero;
curves merge and become horizontal;
No penalty for failing to label axes.

forward reaction:
highest concentration, thus rate high to begin with;
as reaction proceeds, concentrations decrease, so does rate;

reverse reaction:
zero rate initially / at $t = 0$ (since no products present);
rate increases as concentration of products increases;

equilibrium established when rate of forward reaction = rate of reverse reaction;   *[7]*

(c)   (reaction is) endothermic;
K_c increases with (increasing) temperature;
forward reaction favoured / heat used up / OWTTE;   *[3]*

9. (a) (i) one general formula / same general formula;
        differ by CH_2 ;
        similar chemical properties;
        gradual change in physical properties;
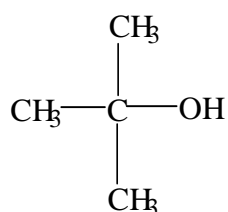   *Award [1] for any two from last three.*

        functional group: atom or group of atoms responsible for the characteristic
        reactions of the molecule / homologous series;   *[3]*

    (ii) ethanol lower / ethanoic acid higher;
        due to larger mass of ethanoic acid / stronger intermolecular forces /
        stronger van der Waals' forces / stronger hydrogen bonding;   *[2]*
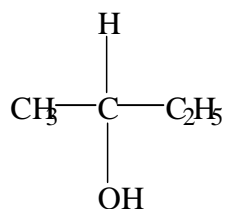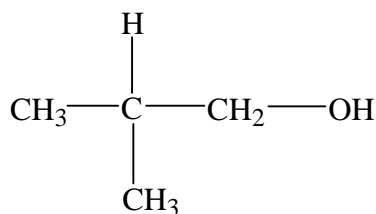   *No mark for H–bonding.*

    (iii)

$$CH_3—CH_2—CH_2—CH_2—OH$$

I

$$CH_3—\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}—OH$$

II

$$CH_3—\underset{\underset{OH}{|}}{\overset{\overset{H}{|}}{C}}—C_2H_5$$

III

$$CH_3—\underset{\underset{CH_3}{|}}{\overset{\overset{H}{|}}{C}}—CH_2—OH$$
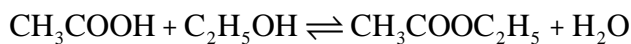
IV

Four correct [2], two or three correct [1].

structure III;
has four different groups around central C / exists as two enantiomers that
can rotate plane of polarized light in (opposite directions) / chiral centre /
asymmetric carbon atom / asymmetric molecule;   *[4]*
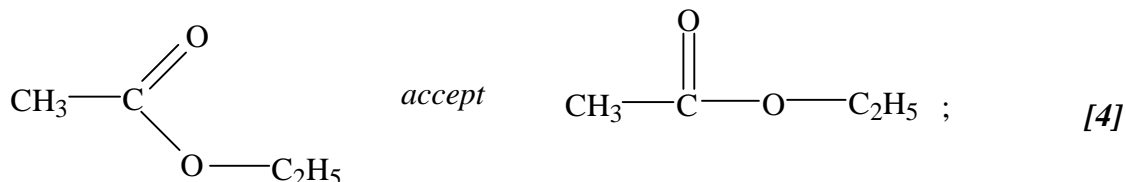
(b) (i) esterification / condensation;

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

(equilibrium sign not necessary);
product: ethyl ethanoate / ethyl acetate;
structure:

accept CH₃—C(=O)—O—C₂H₅ ; **[4]**

(ii) catalyst;

lowers E_a (by providing an alternate pathway); **[2]**

(iii) reverse reaction takes place and the same equilibrium is established; **[1]**

(iv) $CH_3COO\,C_2H_5 + OH^- \rightarrow CH_3COO^- + C_2H_5OH$;

(accept molecular equation)

the acid (CH_3COOH) formed reacts with the base to produce salt; **[2]**

(c) (i) (I no reaction with Br_2 (in the dark)), II reacts with Br_2;

II is an alkene / has unsaturated R group / $C{=}C$ present, I contains only saturated R group; **[2]**

(ii) *infrared:*

II absorption at $1610-1680\,cm^{-1}$ not present in I / different fingerprint region;
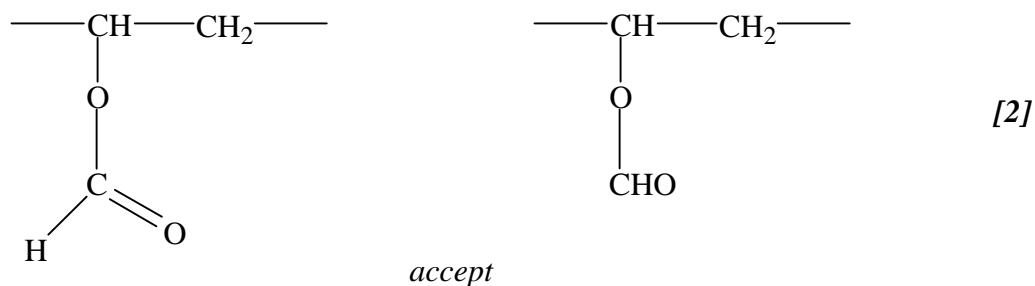
NMR:
I three peaks in ratio 1 : 2 : 3;
II three peaks in ratio 1 : 1 : 2;
Award [1] for "3 peaks at 3 different chemical shift" OWTTE. **[3]**

(iii) addition polymerization;

accept

; **[2]**