International Baccalaureate®
Baccalauréat International
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MARKSCHEME

May 2011

CHEMISTRY

Higher Level

Paper 2

General Marking Instructions

Subject Details: Chemistry HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[40 marks]** and **TWO** questions in Section B **[2 × 25 marks]**. Maximum total = **[90 marks]**.

1.   A markscheme often has more marking points than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

2.   Each marking point has a separate line and the end is signified by means of a semicolon (;).

3.   An alternative answer or wording is indicated in the markscheme by a slash (/) – either wording can be accepted.

4.   Words in brackets (   ) in the markscheme are not necessary to gain the mark.

5.   Words that are underlined are essential for the mark.

6.   The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7.   If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8.   Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized.

9.   Only consider units at the end of a calculation.

10.   Significant digits should only be considered in the final answer. Penalize an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:
      2   *reject*
      1.6   accept
      1.63   accept
      1.631   accept
      1.6314   *reject*

11.   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.

12.   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 directed otherwise in the markscheme.

13.   Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

SECTION A

1.   (a)   (i)   amount $= \dfrac{3.99}{159.61} = 0.0250$ (mol);   *[1]*

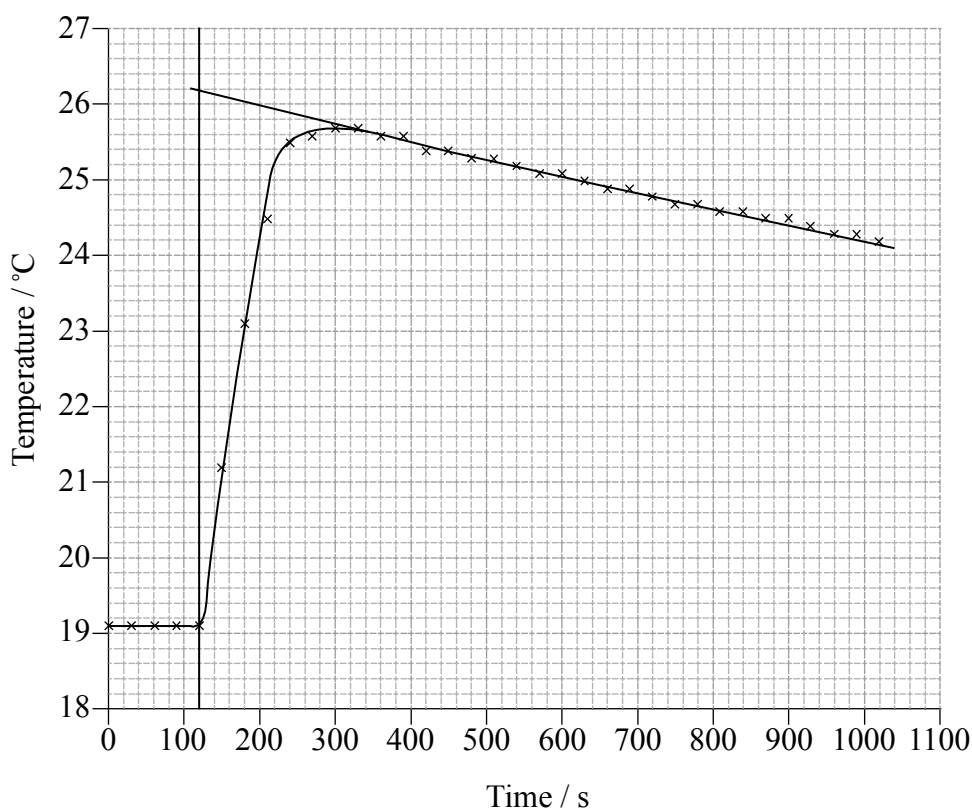(ii)   26.1 (°C);
Accept answers between 26.0 and 26.2 (°C).

temperature rise $= 26.1 - 19.1 = 7.0$ (°C);   *[2]*
Accept answers between 6.9 °C and 7.1 (°C).
Award [2] for the correct final answer.
No ECF if both initial and final temperatures incorrect.

(iii)   heat change $= \dfrac{50.0}{1000} \times 4.18 \times 7.0$ (kJ) / $50.0 \times 4.18 \times 7.0$ (J);
Accept 53.99 instead of 50.0 for mass.

$= 1.5$ (kJ);   *[2]*
Allow 1.6 (kJ) if mass of 53.99 is used.
Ignore sign.

(iv) $\Delta H_1 = -\dfrac{1.5}{0.0250} = -60$ (kJ mol^{-1});   *[1]*
Value must be negative to award mark.
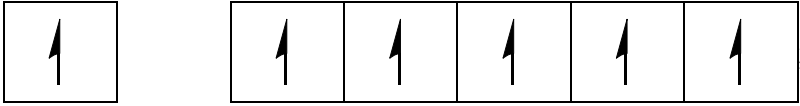*Accept answers in range –58.0 to –60.0.*
Allow –63 (kJ mol^{-1}) if 53.99 g is used in (iii).

(b) (i) (amount of $CuSO_4 \cdot 5H_2O = \dfrac{6.24}{249.71} =$) 0.0250 (mol);

(amount of H_2O in 0.0250 mol of $CuSO_4 \cdot 5H_2O = 5 \times 0.0250 =$) 0.125 (mol);   *[2]*

(ii) ($50.0 \times 4.18 \times 1.10 =$) 230 (J);

$\left(\dfrac{229.9}{(1000 \times 0.0250)} = \right) + 9.20$ (kJ);   *[2]*

Accept mass of 47.75 or 53.99 instead of 50.00 giving answers of +.8.78 or +9.9.
Do not penalize missing + sign but penalize – sign unless charge already penalized in (a) (iv).

(iii) ($\Delta H_x = \Delta H_1 - \Delta H_2 = -58.4 - (+9.20) =$) -67.6 (kJ mol^{-1});   *[1]*

(c) (i) $\dfrac{[-78.0 - (-67.6)]}{-78.0} \times 100 = 13.3\%$;   *[1]*

If 70.0 kJ mol^{-1} is used accept 10.3%.

(ii) the anhydrous copper(II) sulfate had already absorbed some water from the air / *OWTTE*;
the value would be less exothermic/less negative than expected as the temperature increase would be lower / less heat will be evolved when the anhydrous salt is dissolved in water / *OWTTE*;   *[2]*
Do not accept less without a reason.

2. (a) (i) M_r for $Sb_2S_3 = (2 \times 121.75) + (3 \times 32.06) = 339.68$;

% of Sb in $Sb_2S_3 = \dfrac{(2 \times 121.75)}{339.68} \times 100 = 71.69\%$; **[2]**

Accept 71.68%.
Award [2] for correct final answer.

(ii) +3; **[1]**
Do not accept 3, 3+ or the use of Roman numerals.

(iii) +5 / –3; **[1]**
*Penalize incorrect format **only** if not penalized in (a)(ii).*

(b) (i) $Sb_2S_3 + 4\tfrac{1}{2}O_2 \rightarrow Sb_2O_3 + 3SO_2$ / $2Sb_2S_3 + 9O_2 \rightarrow 2Sb_2O_3 + 6SO_2$;
$2Sb_2O_3 + 3C \rightarrow 4Sb + 3CO_2$ / $Sb_2O_3 + 3C \rightarrow 2Sb + 3CO$; **[2]**
Ignore state symbols.

(ii) the SO_2 causes acid rain / *OWTTE*;
the CO_2 is a greenhouse gas/causes global warming / *OWTTE*;
CO is a poisonous gas / *OWTTE*; **[2 max]**

(c) (i) (let $x = $ fraction of ^{121}Sb)
$\dfrac{(x \times 121) + [(100 - x) \times 123]}{100} = 121.75$;
$^{121}Sb = 62.5\%$ **and** $^{123}Sb = 37.5\%$; **[2]**
Award [2] for correct final answer.

(ii) the (vaporized) ions are deflected by the (external) magnetic field;
the ^{121}Sb /lighter ions are deflected more than the ^{123}Sb /heavier ions / *OWTTE*;
Allow deflection depends on mass to charge ratio or momentum of ions.

the ions are detected by conversion into an electrical current / *OWTTE*;
the ratio of the intensity of the peaks in the spectrum is equal to the ratio of the ions in the sample / the ratio of the height of the peaks due to ^{121}Sb and ^{123}Sb will be 62.5:37.5 / *OWTTE*; **[3 max]**
If atoms/elements used instead of ions, penalize only once.
Allow the use of sample or isotopes instead of ions.

(iii) 70; **[1]**

3. (a) (i) the electron configuration (of argon) / $1s^2 2s^2 2p^6 3s^2 3p^6$; **[1]**

(ii) $x = 1$ **and** $y = 5$; **[1]**

(iii)

4s   3d   **[1]**

Accept all six arrows pointing down rather than up.

(b) (i) the concentration (of nitrogen(II) oxide); **[1]**
Award [0] if reference made to equilibrium.

(ii) $mol^{-2} \, dm^6 \, s^{-1}$ / $dm^6 \, mol^{-2} \, s^{-1}$; **[1]**
Accept $(mol^{-1} \, dm^3)^2 s^{-1}$.

(c) (i) complex (ion) / the charge is delocalized over all that is contained in the brackets; **[1]**

(ii) colour is due to energy being absorbed when electrons are promoted within the split d orbitals;
the colour observed is the complementary colour to the energy absorbed / *OWTTE*;
Accept either answer for first mark.

changing the ligand / coordination number / geometry changes the amount the d orbitals are split/energy difference between the d orbitals / *OWTTE*; **[2 max]**

(d) the reaction gives out (Gibbs Free) energy that can do work;
ΔG for the reaction has a negative value;
a reaction that occurs without adding energy (beyond that required to overcome energy barrier); **[1 max]**

4. methoxymethane is very weakly polar / weak van der Waals'/dipole-dipole forces exist between methoxymethane molecules;
Accept alternatives to van der Waals' such as London and dispersion forces.

ethanol contains a hydrogen atom bonded directly to an electronegative oxygen atom / hydrogen bonding can occur between two ethanol molecules / intermolecular hydrogen bonding in ethanol;
the forces of attraction between molecules are stronger in ethanol than in methoxymethane / hydrogen bonding stronger than van der Waals'/dipole-dipole attractions; **[3 max]**
Award [2 max] if covalent bonds breaking during boiling is mentioned in the answer.
Penalize only once if no reference given to intermolecular nature of hydrogen bonding or van der Waal is missing.

SECTION B

5. (a) (i)
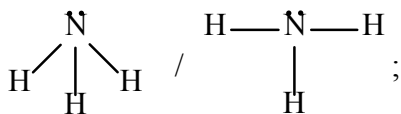
Accept any combination of dots/crosses and lines to represent electron pairs.

trigonal/triangular pyramid;
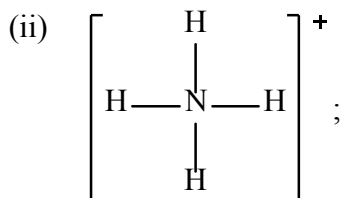*Allow 3D representation using wedges and dotted bonds of trigonal pyramidal molecule.*
$107°$;   **[3]**

Accept any angle between $105°$ and $108.5°$.
No ECF for shape based on incorrect Lewis structure.

(ii)

Charge needed for mark.

tetrahedral;
Allow a 3D representation using wedges and dotted bonds of tetrahedral molecule.

$109.5° / 109° / 109° \ 28'$;   **[3]**
No ECF for shape based on incorrect Lewis structure.

(iii) it can donate the lone/non-bonding <u>pair</u> of electrons (on the N atom);   **[1]**

(iv) $K_b = \dfrac{[OH^-]^2}{[NH_3]} = 10^{-4.75} \ / \ 1.78 \times 10^{-5}$;

$[OH^-] = \sqrt{(1.00 \times 10^{-2} \times 10^{-4.75})} = 4.22 \times 10^{-4} \ (\text{mol dm}^{-3})$;

$pOH = -\log_{10}(4.22 \times 10^{-4}) = 3.37 \ / \ [H^+] = \dfrac{1.00 \times 10^{-14}}{4.22 \times 10^{-4}} = 2.37 \times 10^{-11}$;

$pH = 14 - 3.37 = 10.6$;   **[4]**
*Award **[2 max]** for correct final answer if no working shown.*

(v)   initial amount of HCl $= \dfrac{25.0}{1000} \times 1.00 \times 10^{-2} = 2.50 \times 10^{-4}$ mol **and** initial amount

of $NH_3 = \dfrac{50.0}{1000} \times 1.00 \times 10^{-2} = 5.00 \times 10^{-4}$ mol;

final amount of NH_4^+ and NH_3 both $= 2.50 \times 10^{-4}$ mol;

final $[NH_4^+]$ and $[NH_3]$ both $= \dfrac{2.50 \times 10^{-4}}{75.0 \times 10^{-3}} = 3.33 \times 10^{-3}$ mol dm^{-3};

$[OH^-] = K_b \times \dfrac{[NH_3]}{[NH_4^+]} = K_b = 10^{-4.75}/1.78 \times 10^{-5}$;

pOH $= 4.75$ hence pH $= 9.25$;   *[5]*
Award final two marking points if half-equivalence method used.

(vi) a buffer solution resists a change in pH when <u>small amounts</u> of acid or base are
added to it;
Do not accept description in terms of composition of buffer.

when H^+ is added it reacts with NH_3 to form NH_4^+;

when OH^- is added it reacts with NH_4^+ to form NH_3 and H_2O;   *[3]*
Accept equations for last two marking points.

(b)   (i)   NaCl is the salt of a strong acid and a strong base / no hydrolysis with (Na^+ and
Cl^- ion);
the CO_3^{2-} ions combine with H^+ from water to form a weak acid leaving
OH^- ions / $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$ / *OWTTE*;   *[2]*

(ii) Fe^{3+} has a small radius and a high charge / Fe^{3+} has a high charge density;
it forms bonds with the OH^- ions from water leaving H^+ ions / it increases the
polarity of the O–H bond (in the water ligands) /
$[Fe(H_2O)_6]^{3+} \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H^+$ *etc*;   *[2]*

(iii) $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ / $Na_2O + H_2O \rightarrow 2NaOH$;
$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$;   *[2]*
Ignore state symbols.

6. (a) (i) reactants and products in same phase/state;
rate of forward reaction = rate of reverse reaction;
concentrations of reactants and products remain constant / macroscopic properties remain constant; *[2 max]*
Do not accept concentrations are equal.

(ii) $(K_c) = \dfrac{[HI]^2}{[H_2][I_2]}$; *[1]*

(iii) no change to position of equilibrium; *[1]*

(iv) the reaction is exothermic/heat is given out/ ΔH is negative; *[1]*

(v) amount of H_2 remaining at equilibrium $= 1.60 - \dfrac{1.80}{2} = 0.70$ mol;

amount of I_2 remaining at equilibrium $= 1.0 - \dfrac{1.80}{2} = 0.10$ mol;

$K_c = \dfrac{(1.80/4.0)^2}{(0.70/4.00) \times (0.10/4.00)} \ / \ \dfrac{1.80^2}{0.70 \times 0.10}$;

$K_c = \dfrac{(1.80)^2}{0.70 \times 0.10} = 46.3$; *[4]*

Award [4] for correct final answer.

(vi) no effect (on the value of the equilibrium constant);
as it speeds up forward and reverse reaction / concentrations of reactants and products do not change / position of equilibrium does not change / no change in yield; *[2]*

(b) (i) by definition $\Delta H^{\ominus}_f$ of elements (in their standard states) is zero / no reaction involved / *OWTTE*; *[1]*

(ii) $\Delta H = -104 - (+20.4)$;
$= -124.4$ (kJ mol^{-1}); *[2]*
Award [1 max] for 124.4 (kJ mol^{-1}).
Award [2] for correct final answer.

(iii) $\Delta S = 270 - (267 + 131)$;
$= -128$ (J K^{-1} mol^{-1}); *[2]*
Award [1 max] for +128 (J K^{-1} mol^{-1}).
Award [2] for correct final answer.

(iv) $\Delta G = \Delta H - T\Delta S = -124.4 - \dfrac{(-128 \times 298)}{1000}$;
$= -86.3$ kJ mol^{-1}; *[2]*
Units needed for the mark.
Award [2] for correct final answer.
Allow ECF if only one error in first marking point.

(v) $\Delta G = \Delta H - T\Delta S = 0 \,/\, \Delta H = T\Delta S$;

$T = \dfrac{-124.4}{-128/1000} = 972 \text{ K} \,/\, 699\,^{\circ}\text{C}$; **[2]**

Only penalize incorrect units for T and inconsistent ΔS value once in (iv) and (v).

(c) (i) addition of bromine/bromine water;
the bromine colour remains with propane **and** propene decolourizes the bromine / solution changes from brown to colourless; **[2]**
Do not accept "clear" instead of "colourless".

(ii) addition (polymerization);
$-\!\!\left(\!\text{CH(CH}_3)\text{–CH}_2\right)\!\!-$ / $-\text{CH(CH}_3)\text{CH}_2-$; **[2]**
Continuation bonds necessary for mark, displayed formula or condensed structural formula can be given.
Accept if more than one repeating unit is shown.

(iii) hydrogenation (of vegetable oils) / manufacture of margarine / manufacture of ethanol / addition of water; **[1]**
Accept manufacture of alcohol.
Do not accept hydrogenation of alkenes.

7. (a) (i) the potential difference/voltage obtained when a half-cell is connected to a standard hydrogen electrode;
under standard conditions / 1.00 mol dm^{-3} solutions, 298 K; *[2]*

(ii) the electrons flow from the half-cell to the standard hydrogen electrode / the half-cell forms the negative electrode when connected to the standard half-cell / Fe is a better reducing agent than H_2 / Fe is above H_2 in electrochemical series; *[1]*
Accept "the half reaction is not spontaneous".

(b) (i) bromine/ Br_2; *[1]*

(ii) hydrogen/ H_2; *[1]*

(iii) iron/Fe; *[1]*

Ignore coefficients for Br₂, H₂ or Fe.

(c) (i)
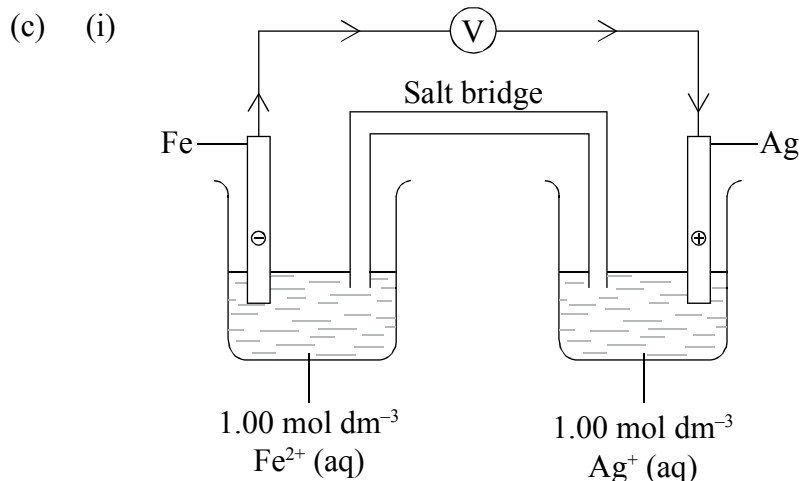
correct diagram including voltmeter;
No credit if wires to electrodes immersed in the solutions.

labelled salt bridge;
Do not accept name of salt (e.g. potassium nitrate) in place of salt bridge.

correctly labelled (+) and (−) electrodes / cathode and anode;
1 or 1.00 mol dm^{-3} concentrations/298 K;
flow of electrons from Fe to Ag in external circuit; *[5]*
Award [2 max] if battery shown instead of voltmeter.

(ii) $Fe + 2Ag^+ \rightarrow Fe^{2+} + 2Ag$;
$E^{\ominus}_{cell} (= 0.80 - (-0.45) =) 1.25$ V; *[2]*
Ignore state symbols.

(d) (i)   (the solution changes) from orange to green;   *[1]*

(ii)   +6;   *[1]*
Do not accept 6, 6+ or the use of Roman numerals unless they have already been penalized in (2)(a).

(iii) $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$;   *[1]*

(iv) $CH_3CH_2OH \rightarrow CH_3CHO + 2H^+ + 2e^-$;
$Cr_2O_7^{2-} + 3CH_3CH_2OH + 8H^+ \rightarrow 2Cr^{3+} + 3CH_3CHO + 7H_2O$ *[3]*
For second equation award [1] for correct reactants and products and [1] for correct balancing.

(v) H^+ is a reactant / *OWTTE*;   *[1]*

(vi) ethanoic acid / CH_3COOH / acid;   *[1]*
Accept acetic acid.

(e) (i)   sodium is a very powerful reducing agent/high in electrochemical series;
any chemical reducing agent would need to be even higher in ECS to reduce Na^+ / *OWTTE*;   *[2 max]*

(ii) H^+ ions gain electrons more readily than Na^+ / hydrogen is evolved instead;
hydrogen is below Na in ECS;

if sodium were to be formed it would react with the water in the solution / *OWTTE*;   *[2 max]*
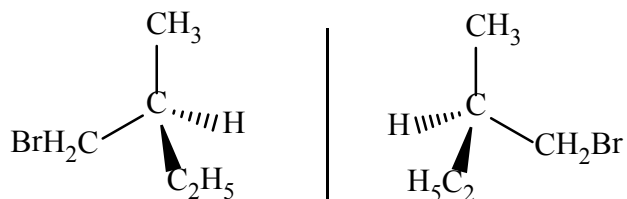
8. (a)

2-bromopentane
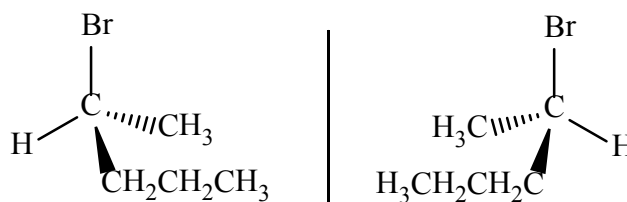
OR

1-bromo-2-methylbutane

OR

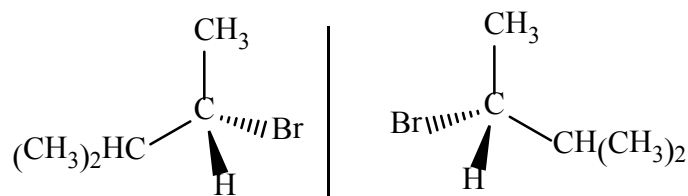2-bromo-3-methylbutane

correct isomer 3D structure;   *[3]*
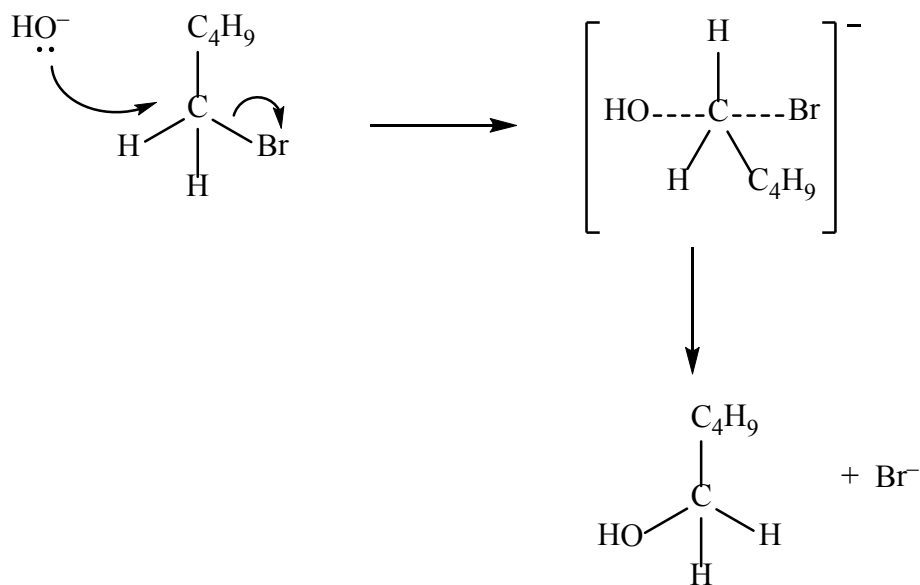correct name;
correct enantiomer 3D structure;
*If compound incorrectly named award **[2 max]** for two correct 3D enantiomers,*
*and **[1 max]** for a correct structure of an enantiomer not shown in 3D.*
*If non-optically active isomers given (e.g. 2-bromo-2-methyl-butane) award **[1 max]***
if name and 3D structure are correct.
*Accept condensed form for alkyl chain throughout.*

(b) (i)

curly arrow going from lone pair/negative charge on O in HO^- to C bonded to Br;
Do not allow curly arrow originating on H in HO^- (e.g. originating on negative charge on H i.e. lone pair/negative charge must be on O).

curly arrow from C–Br bond to form Br^- (this can also be shown in transition state);
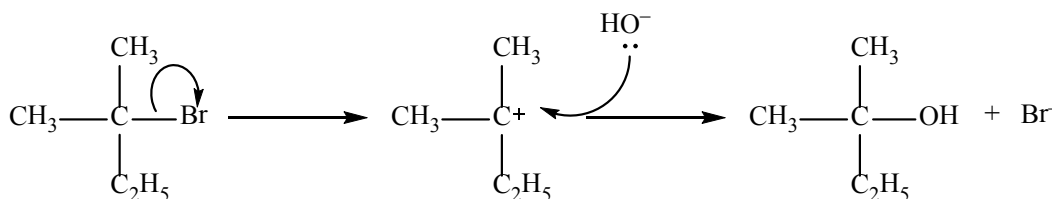transition state showing overall negative charge;   *[3]*
Accept condensed formulas as long as curly arrows can still be shown e.g.

Accept
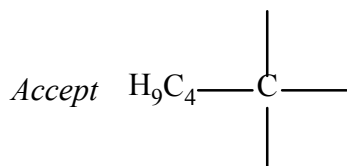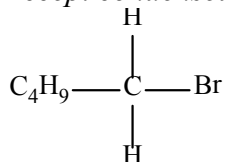
If wrong formula used for halogenoalkane, e.g. 1-bromobutane award [2 max].

(ii)

curly arrow from C–Br bond to form Br^- ;
correct structure of tertiary carbocation;
curly arrow going from lone pair/negative charge on O in HO^- to C^+ ;   **[3]**
If non-bonding pair not shown then arrow must originate from negative sign on O or the minus sign .
Only penalize arrow from H once in (b).
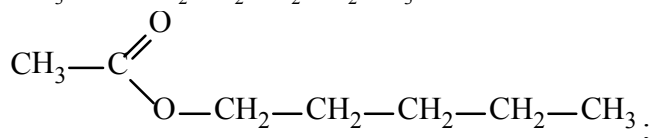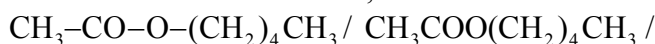*If wrong formula is used for 2-bromo-2-methylbutane award* **[2 max]**.

(iii)   the C bonded to the Br in 1-bromopentane is also bonded to two H atoms so can accommodate five groups around it in the transition state / *OWTTE*;
the C bonded to the Br in 2-bromo-2-methylbutane has three other (bulky) groups bonded to it so cannot accommodate five groups around it in the transition state / *OWTTE*;
2-bromo-2-methylbutane forms a tertiary carbocation which is stabilized by the positive inductive effect of the three alkyl groups / *OWTTE*;
1-bromopentane would form a primary carbocation (if it went by $S_N 2$) which is much less stable as there is only one alkyl group exerting a positive inductive effect / *OWTTE*;   **[3 max]**

(iv)   the boiling point of 1-bromopentane is higher than the boiling point of 2-bromo-2-methylbutane;
2-bromo-2-methylbutane is more spherical in shape / less surface area in contact between molecules of 2-bromo-2-methylbutane than between molecules of 1-bromopentane / *OWTTE*;
hence weaker intermolecular forces of attraction/van der Waals' forces of attraction between molecules of 2-bromo-2-methylbutane / *OWTTE*;   **[3]**
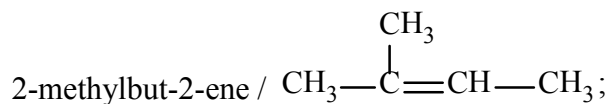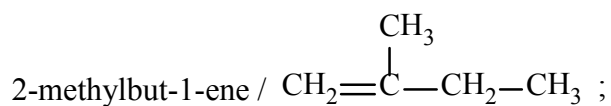
(v)   esterification / condensation;
$CH_3–CO–O–(CH_2)_4CH_3$ / $CH_3COO(CH_2)_4CH_3$ /
$CH_3COOCH_2CH_2CH_2CH_2CH_3$ /

;   **[2]**
Accept $CH_3–CO–O–C_5H_{11}$

(c)   elimination;

2-methylbut-1-ene / $CH_2\!=\!\underset{\underset{\displaystyle CH_3}{|}}{C}\!-\!CH_2\!-\!CH_3$;

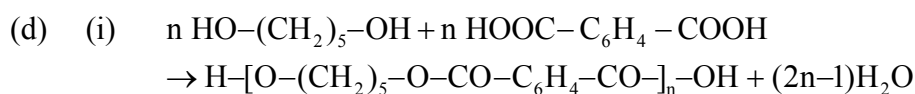2-methylbut-2-ene / $CH_3\!-\!\underset{\underset{\displaystyle CH_3}{|}}{C}\!=\!CH\!-\!CH_3$;

neither can exist as geometrical isomers as they contain the same two groups/atoms on one of the double bonded carbon atoms / *OWTTE*;   *[4]*

(d)   (i) $n\ HO\!-\!(CH_2)_5\!-\!OH + n\ HOOC\!-\!C_6H_4\!-\!COOH$
$\rightarrow H\!-\![O\!-\!(CH_2)_5\!-\!O\!-\!CO\!-\!C_6H_4\!-\!CO\!-\!]_n\!-\!OH + (2n\!-\!1)H_2O$ *[3]*
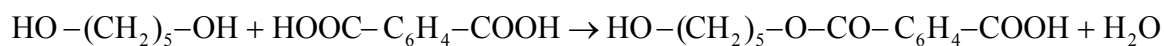*Award [1] for correct reactants, [1] for correct polyester and [1] for balanced water.*
Award [3] if correct equation given for one molecule of diol reacting with one molecule of dicarboxylic acid.
i.e.
$HO\!-\!(CH_2)_5\!-\!OH + HOOC\!-\!C_6H_4\!-\!COOH \rightarrow HO\!-\!(CH_2)_5\!-\!O\!-\!CO\!-\!C_6H_4\!-\!COOH + H_2O$

        (ii)   formation of polyesters/condensation polymers/synthetic fabrics;   *[1]*