N12/4/CHEMI/HP2/ENG/TZ0/XX/M

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MARKSCHEME

November 2012

CHEMISTRY

Higher Level

Paper 2

26 pages

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 x 25 marks]**. Maximum total = **[90 marks]**.

1. A markscheme often has more marking points than the total allows. This is intentional.

2. Each marking point has a separate line and the end is shown 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 ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. 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. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.

10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

11. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the markscheme, similarly, if the formula is specifically asked for, unless directed otherwise in the markscheme 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) *$I_2(s)$*: four/4 **and** *$ICl(l)$*: three/3; ***[1]***

(ii) $n(Cl_2) = \left(\frac{2.24}{2 \times 35.45} =\right) 0.0316 / 3.16 \times 10^{-2}$ (mol);
Allow answers such as 3.2×10^{-2}/0.032/3.15×10^{-2}/0.0315 (mol).

$n(ICl) = 2 \times 0.0316$ / 0.0632/6.32×10^{-2} (mol);
Allow answers such as 6.4×10^{-2}/0.064/6.3×10^{-2}/0.063 (mol).

$m(ICl) = (0.0632 \times 162.35 =) 10.3$ (g); ***[3]***
Allow answers in range 10.2 to 10.4 (g).
*Award **[3]** for correct final answer.*

(iii) $\left(\frac{8.60}{10.3} \times 100 =\right) 83.5\%$; ***[1]***
Allow answers in the range of 82.5 to 84.5%.

(iv) negative/–/minus/ < 0; ***[1]***

(b) Br_2 has London/dispersion/van der Waals' forces/vdW **and** ICl has (London/dispersion/van der Waals' forces/vdW and) dipole–dipole forces;
dipole–dipole forces are stronger than London/dispersion/van der Waals'/vdW forces ; ***[2]***
Allow induced dipole-induced dipole forces for London forces.
Allow interactions instead of forces.
Do not allow ICl polar and Br_2 non-polar for M1.
Name of IMF in both molecules is required for M1 and idea of dipole-dipole stronger than vdW is required for M2.

(c) (i) $\left(\frac{126.90}{330.71} \times 100\right) = 38.4\%$; ***[1]***

(ii) $(25.25 - 1.05) = 24.20$ (cm^3); ***[1]***
Accept 24.2 (cm^3) but not 24 (cm^3).

(iii) $\left(\frac{24.20 \times 5.00 \times 10^{-2}}{1000}\right) = 1.21 \times 10^{-3} / 0.00121$(mol); ***[1]***

(iv) $(0.5 \times 1.21 \times 10^{-3}) = 6.05 \times 10^{-4} / 0.000605$(mol); ***[1]***
Accept alternate method e.g. (0.384/126.9 × 0.2015) = 6.10×10^{-4}/0.000610 (mol).

(v) $(126.90 \times 6.05 \times 10^{-4}) = 7.68 \times 10^{-2} / 0.0768\,(\text{g})$; ***[1]***

Accept alternate method e.g. $(6.10 \times 10^{-4} \times 126.9)$ or $(0.2015 \times 0.384) = 7.74 \times 10^{-2}/0.00774$ (g).

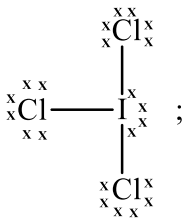
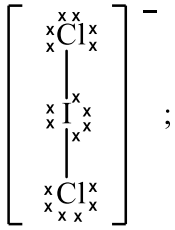
(vi) $\left(\frac{7.68 \times 10^{-2}}{0.2015} \times 100\right) = 38.1\,\%$; ***[1]***

Answer must be given to <u>three</u> significant figures.

(d) ICl / iodine monochloride; ***[1]***

Do not accept iodine or bromine.

(e)

	ICl_3	ICl_2^-
Lewis (electron dot) structure	 ;	 ;
	Do not penalize for an incorrect shape for Lewis structures. *Accept lines, dots or crosses for electron pairs for both Lewis structures.* *Penalize missing lone pairs <u>on Cl</u> once only.* *Square brackets and negative charge must be shown for Lewis structure of $[ICl_2]^-$.*	
Name of shape	T-shaped;	linear;

[4]

No ECF for shape if Lewis structure is incorrect.

(f) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^5$ / $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^5$; ***[1]***

No mark for 2,8,18,18,7 or [Kr] $5s^2 4d^{10} 5p^5$.

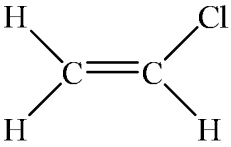
Allow electron configurations with order of sublevels interchanged.

Electrons must be represented as superscript to award mark.

(ii) $Cl_2(aq) + H_2O(l) \rightleftharpoons HCl(aq) + HOCl(aq)$; ***[1]***

Accept $\rightarrow$.
Accept HClO(aq).
Allow $H^+(aq) + Cl^-(aq)$ *for HCl(aq) and* $H^+(aq) + {}^-OCl(aq)/OCl^-(aq)/ClO^-(aq)$ *for HOCl(aq).*
Allow $2Cl_2(g) + 2H_2O(l) \rightarrow 4HCl(aq) + O_2(g)$.
Ignore state symbols.

(iii) *Monomer*:



/ chloroethene /CH_2CHCl;

Accept vinyl chloride or chloroethylene.
Allow C_2H_3Cl.

Use:
raincoats / packaging / window frames / pipes / carpets / gutters / electrical cable sheathing / covers for electrical wires / rope / bottles; ***[2]***
Accept suitable alternatives.
Do not allow glue.
Do not allow just plastic(s) or just windows.
Allow plastic bag.

2. (a) (i) *Group*: (elements in vertical) columns in periodic table **and** *Period*: (elements in horizontal) rows in periodic table; ***[1]***

*Allow elements in same group have similar chemical properties **and** within a period, atoms have same number of shells/energy levels (but number of electrons in valence/outer shell increases).*
*Allow groups distributed vertically **and** periods distributed horizontally / OWTTE.*
*Allow group number gives number of valence/outer shell electrons (for main-group elements) **and** period gives same number of shells/energy levels.*

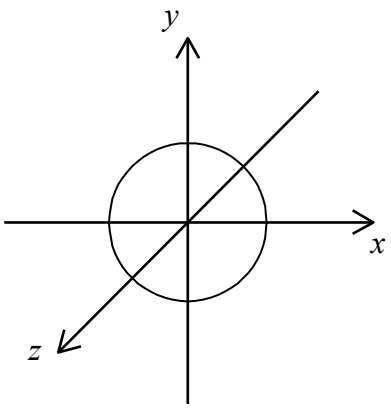
(ii)

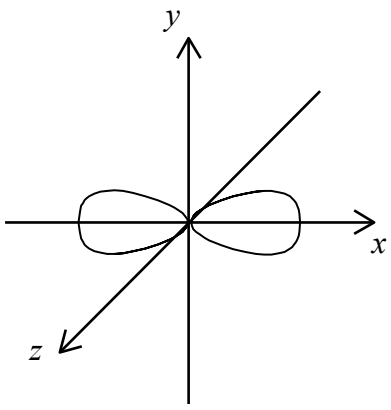
Mass number (*A*)	Number of protons	Number of electrons	Number of neutrons
6	3	3	3 ;
7	3	3	4 ;

[2]

*Award **[1 max]** for correct number of neutrons for both isotopes if numbers of protons or electrons is not given.*
*Award **[1 max]** for correct number of protons and electrons for both isotopes if number of neutrons is not given or if numbers of neutrons are incorrect.*

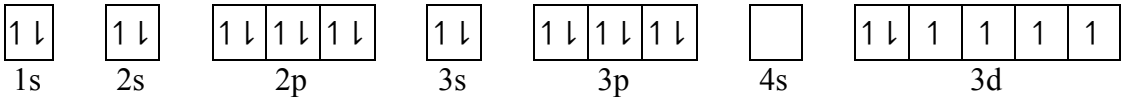
(iii) symmetrical shape of s orbital **and** dumbbell-shaped p orbital with electron density along *x*-axis; ***[1]***





(b) (i) metals have delocalized electrons / sea of electrons which are mobile/can move / *OWTTE*;
layers/positive ions/cations/atoms slide past/over each other / *OWTTE*; ***[2]***
Do not accept nuclei for M2.

(ii)



[1]

Allow full arrows instead of half-arrows for example ↑↓.
Do not allow arrows with the same spin for example ↑↑ or ↓↓ in the same orbital.
Do not allow an orbital diagram with a $4s^1 3d^5$ configuration.

(iii) Co^{2+} ; ***[1]***
Accept +2, 2+, cobalt(II), II.

(iv) partially filled/incomplete d subshell/sub-level/orbitals;
d orbitals split (into two sets of different energies);
(colour due to) electron transition between (split) d orbitals / d to d transitions / frequencies of visible light absorbed by electrons moving from lower to higher d levels ;
colour due to remaining frequencies / complementary colour seen; ***[3 max]***
Allow wavelength as well as frequency.

3. (a) (solution containing significant/equal amounts of a) weak acid **and** its salt / (solution containing) strong base to which excess of weak acid has been added / *OWTTE*; ***[1]***

*Accept (solution containing) weak acid **and** conjugate base.*
Do not accept descriptions with specific compounds alone (e.g. CH_3COOH and CH_3COONa) unless compounds are stated as weak acid and its salt.
Accept answer such as (solution containing) x mol of weak acid and $\frac{1}{2}x$ mol of strong base.

(b) $M_r(CH_3COOH) = 60.06$ **and** $M_r\, CH_3COONa = 82.04$;

$[CH_3COOH] = 6.66\times10^{-1}/0.666\ \text{mol dm}^{-3}$;

$[CH_3COO^-] = 4.88\times10^{-1}\ /\ 0.488\ \text{mol dm}^{-3}$;

$[H_3O^+]/[H^+] = (1.8\times10^{-5}\times6.66\times10^{-1})/4.88\times10^{-1} = 2.46\times10^{-5}\ /\ 0.0000246\ \text{mol dm}^{-3}$;

$\text{pH} = \left(-\log[H_3O^+] = -\log(2.46\times10^{-5}) = \right)4.61\,(2\text{dp})$;

*Award **[5]** for correct final answer of pH = 4.61 with some working shown.*
*Award **[2 max]** for pH = 4.61 without any working at all shown.*
Two decimal places are required for M5.

OR

$M_r(CH_3COOH) = 60.06$ **and** $M_r\, CH_3COONa = 82.04$;

$[CH_3COOH] = 6.66\times10^{-1}/0.666\ \text{mol dm}^{-3}$;

$[CH_3COO^-] = 4.88\times10^{-1}/0.488\ \text{mol dm}^{-3}$;

$\text{pH} = -\log(1.8\times10^{-5}) + \log\dfrac{[\text{salt}]}{[\text{acid}]}$;

$= \left(4.74 + \log\dfrac{0.488}{0.666} = 4.74 - 0.135 = \right)4.61\,(2\text{dp})$; ***[5]***

M4 can be scored even if not explicitly stated if M5 is correct based on previous values.
*Award **[5]** for correct final answer of pH = 4.61 with some working shown.*
*Award **[2 max]** for pH = 4.61 without any working at all shown.*
Two decimal places are required for M5.

SECTION B

4. (a) (i) *Oxidation:* loss of electrons **and** *Reduction:* gain of electrons; ***[1]***

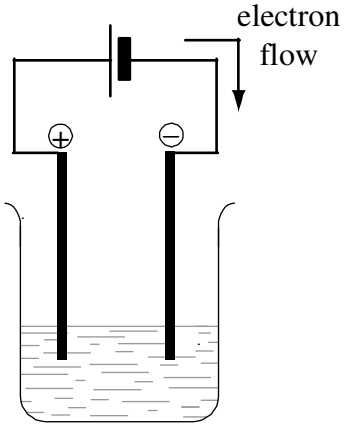
(ii) As_2O_3: +3;
NO_3^-: +5;
H_3AsO_3: +3;
N_2O_3: +3; ***[4]***
Penalize incorrect notation e.g. III, V, 3+, 5+, 3, 5 once only.

(iii) *Oxidizing agent:* substance reduced / removes electrons from another substance / causes some other substance to be oxidized / *OWTTE* **and** *Reducing agent*: substance oxidized / gives electrons to another substance / causes some other substance to be reduced / *OWTTE*; ***[1]***
*Accept Oxidizing agent: electron/e/e^- acceptor / causes oxidation / oxidation number/state decreases **and** Reducing agent: electron/e/e^- donor / causes reduction / oxidation number/state increases.*

(iv) $As_2O_3(s) + 2NO_3^-(aq) + 2H^+(aq) + 2H_2O(l) \rightarrow 2H_3AsO_4(aq) + N_2O_3(aq)$
correct coefficients for As_2O_3, H_3AsO_4 **and** NO_3^-, N_2O_3;
correct balanced equation;
Ignore state symbols.
M1 must be correct to award M2.

Oxidizing agent: $NO_3^-(aq)$ /nitrate **and** *Reducing agent:* $As_2O_3(s)$ / arsenic(III) oxide; ***[3]***
Accept HNO_3(aq)/nitric acid.
Accept arsenic oxide.
Species must be fully correct to score M3.
Ignore state symbols.

(b) (i) *Diagram to show*:



Labels are not required.
one container, two electrodes, battery (and electrolyte);

Allow + and – for representation of battery (could be long and short lines for example) but M1 is not scored if a voltmeter/V if shown or labelled.
Ignore designation of electrodes (e.g. do not penalize Cu electrodes).

correct direction of electron flow (from negative pole to positive pole); ***[2]***
Allow arrow without stating e^- explicitly.
To score M2, the polarity of the battery or the cathode and anode must be shown.
If a voltmeter/V is shown, M1 is not awarded but M2 may be scored if the cathode and anode are identified with the correct direction of electron flow.

(ii) *Half-equation at positive electrode (anode)*:
$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$ / $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ /
$2OH^-(aq) \rightarrow \frac{1}{2}O_2(g) + H_2O(l) + 2e^-$;
Allow e instead of e^-.

Half-equation at negative electrode (cathode):
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$;
Allow e instead of e^-.
*Award **[1 max]** for M1 and M2 if correct equations are given but at wrong electrodes.*
Penalize $\rightleftharpoons$ once only in (b)(ii) and (b)(iii).

correct state symbols in **all** equations;
M3 can only be scored if the correct species are given in M1 and M2 (i.e. do not award ECF from M1 and M2 for incorrect species).

Observation at positive electrode (anode):
bubbles / gas;
Award mark for observation even if type of gas is incorrect (e.g. hydrogen).

Observation at negative electrode (cathode):
red/brown/copper/metal (deposit);
Allow mass increases / gets thicker/larger / OWTTE.

Change in colour (in any) of the solution:
solution loses blue colour/becomes paler;

Change in acidity (if any) of the solution:
becomes (more) acidic / pH decreases; ***[7]***

(iii) *Half-equation at positive electrode (anode)*:
$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$;
Allow e instead of e^-.

Half-equation at negative electrode (cathode):
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$;
Allow e instead of e^-.
*Award **[1 max]** for M1 and M2 if correct equations are given but at wrong electrodes.*
Penalize $\rightleftharpoons$ once only in (b)(ii) and (b)(iii).

correct state symbols in **all** equations;
M3 can only be scored if the correct species are given in M1 and M2 (i.e. do not award ECF from M1 and M2 for incorrect species).

Observation at positive electrode (anode):
(slowly) dissolves / *OWTTE*;
Allow mass decreases / gets smaller/thinner / OWTTE;
Accept impurities deposited under positive electrode/anode.

Observation at negative electrode (cathode):
red/brown/copper/metal deposit;
Allow mass increases / gets thicker/larger / OWTTE.

Change in colour (if any) of the solution:
blue colour remains;
Allow no change or solution remains same colour.

Change in acidity (if any) of the solution:
solution does not become (more) acidic / no change / *OWTTE*; ***[7]***

5. (a) energy needed to break (1 mol of) a bond in a gaseous molecule/state/phase;
average calculated from a range of similar compounds / *OWTTE*; ***[2]***
Do not accept similar bonds instead of similar compounds.
M2 can be scored independently.

(b) (i) *Bonds breaking*:
$4 \times (N{=}O) + 4 \times (N{-}N) + 8 \times (C{-}H) + 4 \times (N{-}O) + 8 \times (C{-}N)$ /
$= (4)(607) + (4)(158) + (8)(413) + (4)(201) + (8)(286)$ /
$= 9456 \text{ (kJ mol}^{-1}\text{)}$;

Bonds forming:
$4 \times (N{\equiv}N) + 4 \times (C{\equiv}O) + 8 \times (O{-}H)$ /
$= (4)(945) + (4)(1072) + (8)(464) / = 11780 \text{ (kJ mol}^{-1}\text{)}$;

Enthalpy change:
$(9456 - 11780 =) - 2324 \text{ (kJ mol}^{-1}\text{)}$;
M3 is scored from M1-M2.
*Award **[2 max]** for (+)2324 (kJ mol^{-1}).*
*Award **[3]** for –2324 (kJ mol^{-1}) without working.*

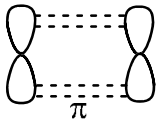
$\left(10.0 \times \frac{-2324}{296.2} = \right) - 78.5 \text{ (kJ)}$; ***[4]***
M4 is scored from 10.0/296.2 × M3.
Allow answers of –78.2, –78 and –79 (kJ), but negative sign must be included.
*Award **[4]** for correct final answer.*

(ii) NH_4^+/ammonium / $N_2H_5^+$/hydrazinium / $CH_3NH_3^+$/methylammonium/ methanaminium / $H_2NO_3^+$ /nitrooxonium; ***[1]***

(iii) *Sigma bonds*:

result from head-on/end-on overlap of orbitals / *OWTTE*;
Allow symmetric (orbital) with respect to same plane / OWTTE.

Pi bonds:



result from sideways overlap of orbitals / *OWTTE*;
Allow antisymmetric (orbitals) with respect to (defining) plane (containing at least one atom) / OWTTE.

suitable diagrams showing σ **and** π bonds after formation; ***[3]***

*Award **[1 max]** for correct diagram without description given or **[2 max]** for description given without diagram.*

(iv) *σ bonds*: 28;
π bonds: 4; ***[2]***

(v) mixing/combining/merging of atomic orbitals to form new/molecular orbitals (for bonding);
A: sp^2;
B: sp^3; ***[3]***
*Award **[1 max]** for M2 and M3 for sp^2 **and** sp^3 if **A** and **B** are not identified explicitly but do not award M2 and M3 if sp^3 is given for **A** and sp^2 for **B**.*

(c) (i) (entropy decreases) negative/-/minus;
gaseous reactant more disordered / product more ordered than reactants / amount of gas decreases / *OWTTE*; ***[2]***
Allow number of moles of gas decreases.
M2 can only be scored if M1 is correct.

(ii) heat/enthalpy change when 1 mol of a compound is formed from its elements;
in their standard states / at 100 kPa/10^5 Pa/1bar (pressure); ***[2]***
Allow 1.01×10^5 Pa / 101kPa / 1 atm.
Allow under standard conditions or standard ambient temperature and pressure.
Temperatures not required in definition, allow if quoted (e.g. 298 K/25 °C – most common) but correct pressure value must be stated if given.
Only award M2 for a correct M1 or a near miss at M1.

(iii) $\Delta H^{\ominus} = (-485 + 111 + 239 =) -135 \text{ (kJ mol}^{-1}\text{)}$; ***[1]***

(iv) $\Delta S^{\ominus} = (160 - 198 - 240) = -278 \text{ (J K}^{-1}\text{ mol}^{-1}\text{)}$; ***[1]***

(v) $\Delta G^{\ominus} = \left(\Delta H^{\ominus} - T\Delta S^{\ominus} = -135 + 298 \times \frac{278}{1000} = \right) -52.2 \text{ (kJ mol}^{-1}\text{)}$;
spontaneous (since negative $\Delta G^{\ominus}$); ***[2]***
Answer to M2 depends on sign given in M1.

(vi) (K_c) decreases;
exothermic / $\Delta H < 0$; ***[2]***
M1 and M2 depend on sign of ΔH in (iii).

6. (a) (i) change in concentration of reactant/product with time / rate of change of concentration; ***[1]***
Increase can be used instead of change for product or decrease can be used instead of change for reactant.
Allow mass/amount/volume instead of concentration.
Do not accept substance.

(ii) concentration;
particle size / surface area;
light;
pressure; ***[2 max]***
Allow pH.

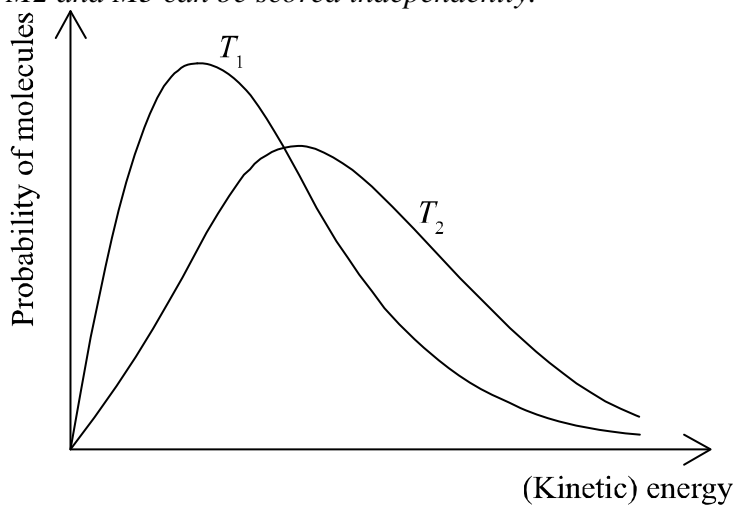
(iii) (measuring electrical) conductivity / (measuring) pH; ***[1]***
Accept other suitable method.

(b) (i) minimum/least/smallest energy needed (by reactants/colliding particles) to react/start/initiate a reaction; ***[1]***
Allow energy difference between reactants and transition state.
Minimum/least/smallest required for the mark.

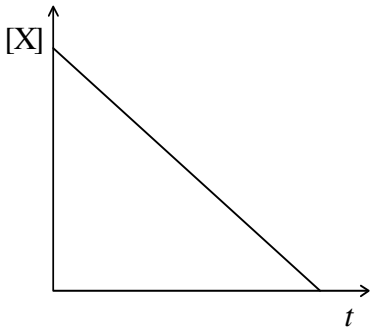
(ii) *x-axis label*: (kinetic) energy/(K)E **and** *y-axis label*: probability/fraction of molecules/particles / probability density;
Allow number of molecules/particles for y-axis.

correct shape of a typical Maxwell–Boltzmann energy distribution curve;
Do not award mark if curve is symmetric, does not start at zero or if it crosses x-axis.

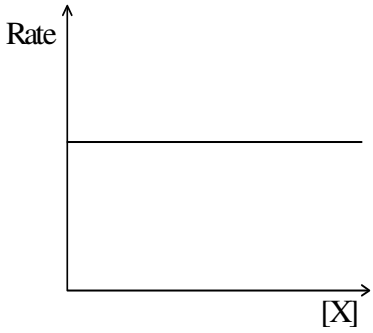
two curves represented with second curve for $T_2 > T_1$ to right of first curve, peak maximum lower than first curve and after the curves cross going to the right, T_2 curve needs to be above T_1 curve as illustrated;
M2 and M3 can be scored independently.



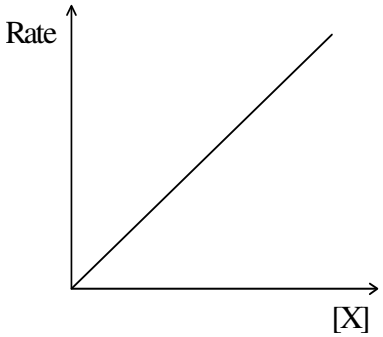
[3]

(c) (i) 

; ***[1]***

(ii) 

; ***[1]***

(iii) 

; ***[1]***

(d) (i) second order in ClO_2 **and** first order in OH^-;
rate $= k[ClO_2]^2[OH^-]$; ***[2]***
*Award **[2]** for correct final answer.*

(ii) $k = 2.30 \times 10^2 / 230$;
$mol^{-2}\ dm^6\ s^{-1}$; ***[2]***

(iii) $1.22 \times 10^{-3} / 0.00122$ ($mol\ dm^{-3}\ s^{-1}$); ***[1]***

(e) (i) ethyl ethanoate; ***[1]***
Do not allow ethyl acetate.

(ii) as temperature/*T* increases, (value of) rate constant/*k* increases (exponentially); ***[1]***
Do not allow answers involving ln k from the Arrhenius equation.
Do not allow T directly proportional to k.

(iii) slope $= -5.6 \times 10^3 / -5600$ (K);
$E_a = -\text{slope} \times R$ / slope $= -E_a / R$;
$E_a (= 5.60 \times 10^3 K \times 8.31 \text{J K}^{-1} \text{mol}^{-1}) = 4.65 \times 10^4 (\text{J mol}^{-1})$ / 46.5 (kJ mol^{-1});
Accept answers in range 4.60×10^4 *J mol*$^{-1}$ *to* 4.67×10^4 *J mol*$^{-1}$.

J mol^{-1} / kJ mol^{-1}; ***[4]***
Accept J or kJ.
Unit mark can be scored independently but correct E_a *values with incorrect units scores only* ***[3 max]*** *(for example 46.5 J mol*$^{-1}$*).*

Award ***[4]*** *for correct final answer.*

(f) (i) $3\text{ClO}^-(\text{aq}) \rightarrow \text{ClO}_3^-(\text{aq}) + 2\text{Cl}^-(\text{aq})$; ***[1]***
Ignore state symbols.

(ii) *Step 1*: rate $= k[\text{ClO}^-]^2$;
Step 2: rate $= k[\text{ClO}_2^-][\text{ClO}^-]$; ***[2]***
Penalize missing k once only.

Penalize missing hydrogens or incorrect bonding (e.g. C–H_3C) once only in 7.

7. (a) (i) compounds with same structural/displayed formula but different arrangements of atoms (in space); ***[1]***
Do not accept different 3D structures.
Do not allow similar instead of same.

(ii) (*cis*-)but-2-ene / (*Z*)but-2-ene / but-2-ene;
Accept (cis-)2-butene / Z-2-butene.
Ignore missing hyphens.

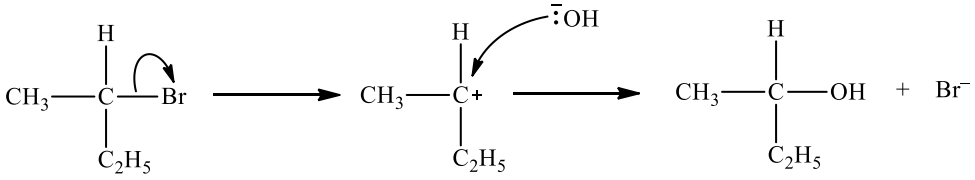
$CH_3CH_2CH{=}CH_2$;
$H_2C{=}C(CH_3)_2$; ***[3]***
Accept either full or condensed structural formulas.
Allow structural formula of trans-but-2-ene. Accept other alternative suitable isomers.

(iii) $(CH_3)CH{=}CH(CH_3) + HBr \rightarrow CH_3CHBrCH_2CH_3$; ***[1]***
Allow $C_4H_8 + HBr \rightarrow C_4H_9Br$.

(iv) secondary/ 2^o; ***[1]***

(v) *Since secondary could be either S_N1 or S_N2 so allow S_N1 or S_N2 for M1–M4.*

S_N1:



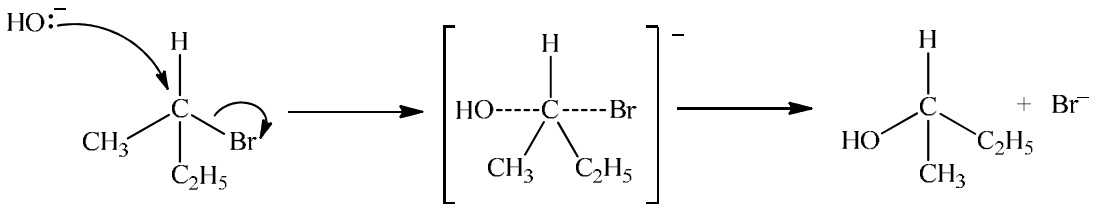
curly arrow showing Br leaving;
Do not allow arrow originating from C to C–Br bond.

representation of secondary carbocation;
curly arrow going from lone pair/negative charge on O in HO^- to C^+;
Do not allow arrow originating on H in HO^-.

formation of organic product $CH_3CH(OH)C_2H_5$/C_4H_9OH **and** Br^-;
Allow formation of NaBr instead of Br^-.

OR

S_N2:



curly arrow going from lone pair/negative charge on O in HO^- to C;
Do not allow curly arrow originating on H in HO^-.

curly arrow showing Br leaving;
Accept curly arrow either going from bond between C and Br to Br in 2-bromobutane or in the transition state.
Do not allow arrow originating from C to C–Br bond.

representation of transition state showing negative charge, square brackets and partial bonds;
Do not penalize if HO and Br are not at 180° to each other.
Do not award M3 if OH ---- C bond is represented.

formation of organic product $CH_3CH(OH)C_2H_5$/C_4H_9OH **and** Br^-; ***[4]***
Allow formation of NaBr instead of Br^-.

*For primary **Z** from (iv), for ECF S_N2 required.*
*For tertiary **Z** from (iv), for ECF S_N1 required.*
*But curly arrow showing Br leaving and formation of C_4H_9OH **and** Br^- can be scored for either mechanism (even if incorrect type).*

*For primary **Z** from (iv) with 1-bromobutane stated in (v), correct S_N2 can score full marks.*
If (iv) is not answered and incorrect starting reagent is given in (v), M1, M2 and M3 may be scored but not M4 for either correct S_N1 or S_N2.

(vi) $CH_3COCH_2CH_3$; ***[1]***
Full or condensed structural formula may be given.
*For primary **Z** from (iv), accept $CH_3CH_2CH_2COOH$/C_3H_7COOH but not $CH_3CH_2CH_2CHO$.*

(b) (i) *Mass of C*: $\frac{6.93\times10^{-3}\times12.01}{44.01}=1.89\times10^{-3}$ /0.00189 (g) **and**

Mass of H: $\frac{2\times1.01\times2.83\times10^{-3}}{18.02}=3.17\times10^{-4}$ /0.000317 (g);

Mass of O: $3.00\times10^{-3}-1.89\times10^{-3}-3.17\times10^{-4}=7.93\times10^{-4}$ /0.000793 (g);

n_C: $\frac{1.89\times10^{-3}}{12.01}=1.57\times10^{-4}$ /0.000157 (mol) **and**

n_H: $\frac{3.17\times10^{-4}}{1.01}=3.14\times10^{-4}$ /0.000314 (mol) **and**

n_O: $\frac{7.93\times10^{-4}}{16.00}=4.96\times10^{-5}$ /0.0000496 (mol) ;

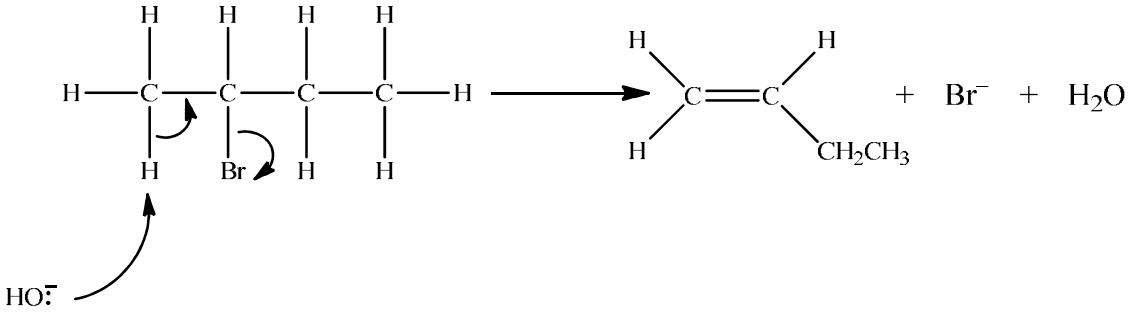
Empirical formula $=C_3H_6O$; ***[4]***

Allow $C_{19}H_{38}O_6$.
*Award **[4]** for correct final answer if alternative working is used.*
*Award **[1 max]** for C_3H_6O/$C_{19}H_{38}O_6$ without working.*

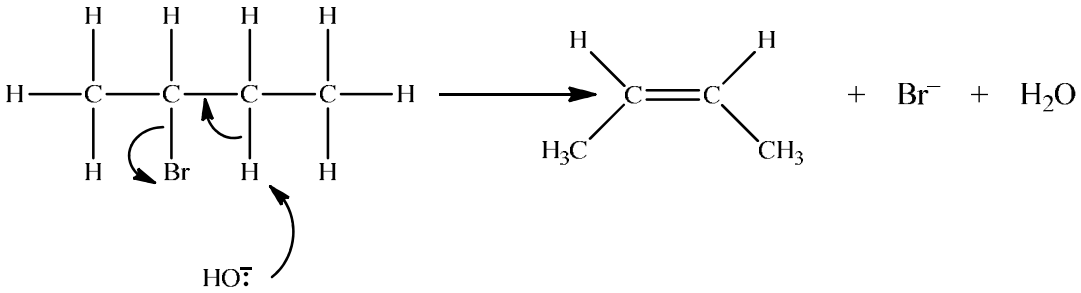
(ii) $C_6H_{12}O_2$; ***[1]***

(iii) fragrances/perfumes / solvents / plasticizers / adhesives/glue / biodiesel; ***[1]***
Accept a named painkiller (e.g. aspirin) or anaesthetic (e.g. procaine, benzocaine) containing the ester functional group.
Accept "some painkillers".
Allow a specific named polyester (e.g. polyethylene terephthalate/PET), but polyester alone is not sufficient to score the mark.

(c) (i) *Accept either one of the following two E2 mechanisms:*



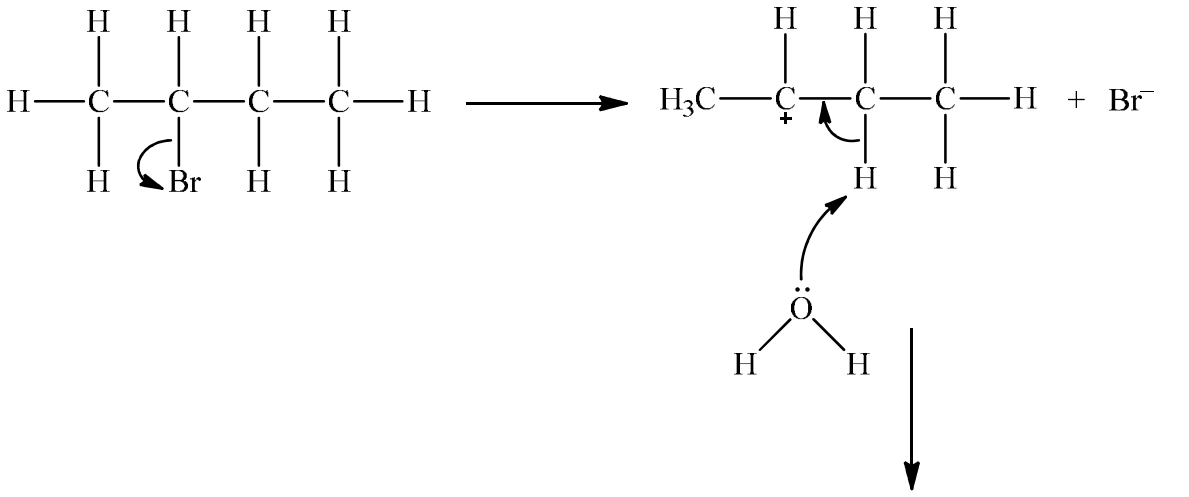
OR



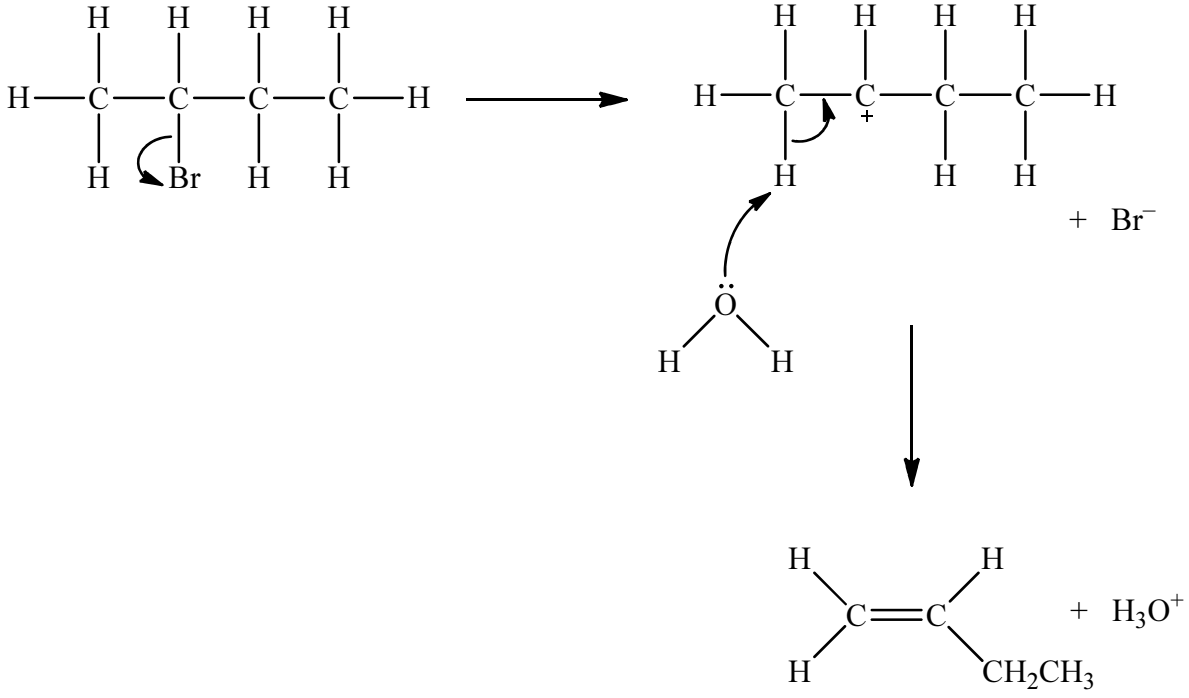
curly arrow going from lone pair/negative charge on O in HO^- to H on β–C;
Do not allow curly arrow originating on H in HO^-.

curly arrow going from CH bond to form C=C bond;
curly arrow showing Br leaving;
formation of organic product $H_2C{=}CH(CH_2CH_3)$ / $H(CH_3)C{=}CH(CH_3)$ **and** Br^- **and** H_2O;
For this reaction since a strong negatively charged base, HO^- is used, resultant mechanism will be E2. However, accept the corresponding E1 mechanism.

If E1, allow the following mechanism:



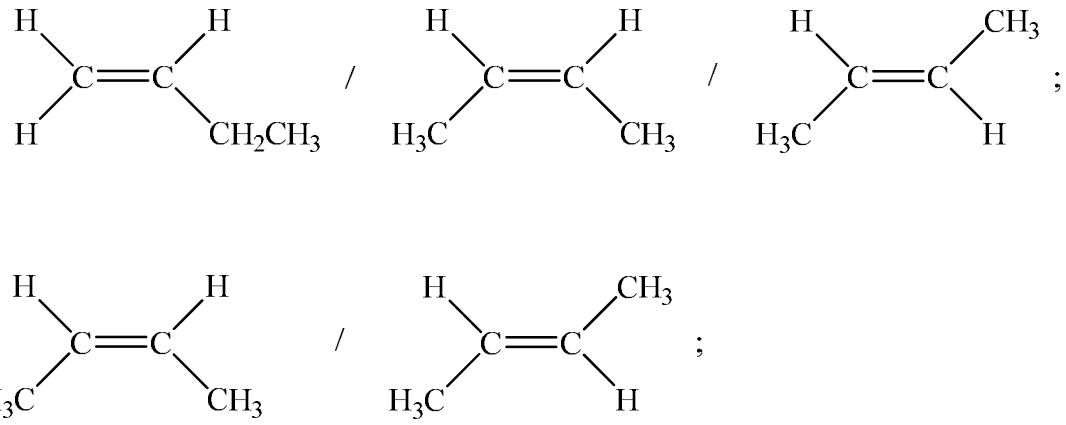
OR



curly arrow showing Br leaving;
representation of secondary carbocation;
curly arrow going from lone pair on O in H_2O to H on C adjacent to C^+ **and** curly arrow going from CH bond to form C=C bond;
formation of organic product $(H_3C)CH=CH(CH_3)$ / $H_2C=CH(CH_2CH_3)$ **and** Br^- **and** H_3O^+; ***[4]***

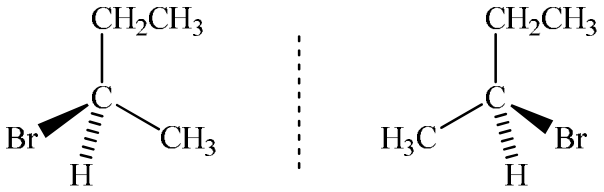
For E1 HO^- is an alternative to H_2O, but if used, H_2O forms instead of H_3O^+.

(ii) *Depending on product in (i):*



[2]

(iii) 3D representation of two enantiomers of 2-bromobutane;



Tapered (wedge/dash) notation not necessary but non-superimposeable mirror images must be shown clearly.

two optical isomers rotate plane of plane-polarized light in (equal and) opposite directions (all other physical properties identical) **and** identical chemical properties (in reactions with non-chiral compounds) / *OWTTE*; ***[2]***

Allow different chemical properties only if reference is made to their reaction with other optically active compounds/chiral reagents / biological sensors / OWTTE.