



MARKSCHEME

May 2009

CHEMISTRY

Higher Level

Paper 2

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Subject Details: Chemistry HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A [**40 marks**] and **TWO** question 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. 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. Indicate this with **ECF** (error carried forward).
10. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper. Indicate this by writing **-1(U)** at the first point it occurs and **U** on the cover page.
11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

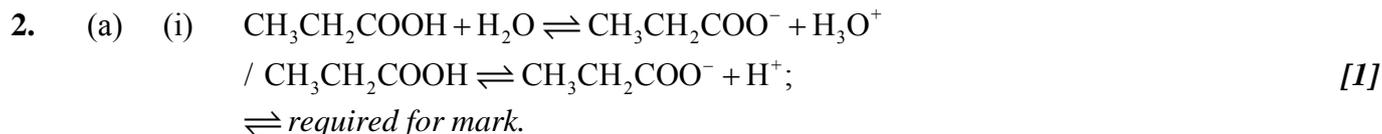
2	<i>reject</i>
1.6	accept
1.63	accept
1.631	accept
1.6314	<i>reject</i>

Indicate the mark deduction by writing **-1(SD)** at the first point it occurs and **SD** on the cover sheet.

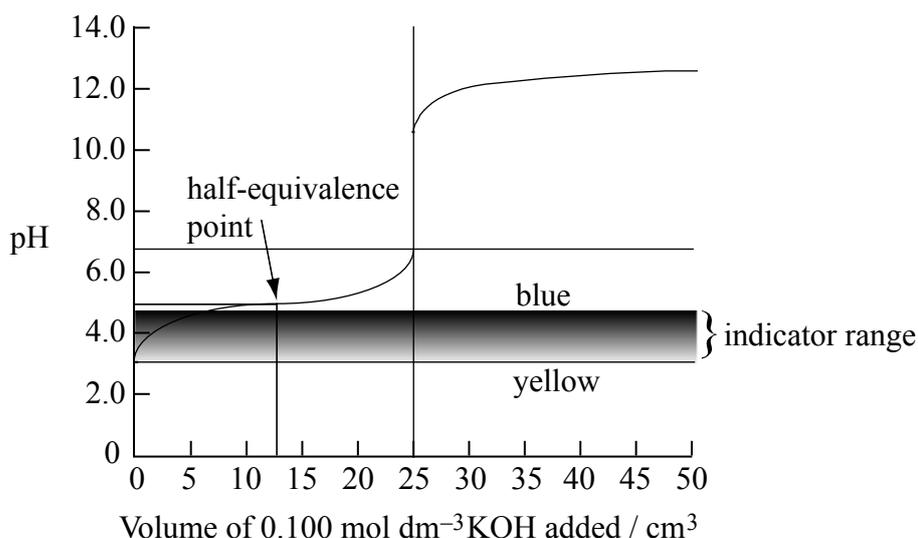
12. If a question specifically asks for the name of a substance, do not award a mark for a correct formula, similarly, if the formula is specifically asked for, do not award a mark for a correct name.
13. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the markscheme.
14. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

SECTION A

1. (a) ester; [1]
- (b) amount of oil = $\frac{1013.0}{885.6} = 1.144$ mol;
 amount of methanol = $\frac{200.0}{32.05} = 6.240$ mol;
 since three mol of methanol react with one mol of vegetable oil the amount of excess methanol = $6.240 - (3 \times 1.144) = 2.808$ mol; [3]
- (c) (i) rate of the forward reaction is equal to the rate of the reverse reaction / forward and reverse reactions occur **and** the concentrations of the reactants and products do not change / *OWTTE*; [1]
- (ii) $K_c = \frac{[\text{glycerol}] \times [\text{biodiesel}]^3}{[\text{vegetable oil}] \times [\text{methanol}]^3}$; [1]
- (iii) to move the position of equilibrium to the right/product side / increase the yield of biodiesel; [1]
- (iv) no effect (on position of equilibrium);
 increases the rate of the forward and the reverse reactions equally (so equilibrium reached quicker) / it lowers E_a for both the forward and reverse reactions by the same amount / *OWTTE*; [2]
No ECF for explanation.
- (d) vegetable oil is mainly non-polar **and** methanol is polar / *OWTTE*;
 stirring brings them into more contact with each other / increases the frequency of collisions / *OWTTE*; [2]
Do not allow simply mixing.
- (e) (relative molecular mass of biodiesel, $C_{19}H_{36}O_2 = 296.55$)
 maximum yield of biodiesel = 3.432 mol / 1018 g ;
 percentage yield = $\frac{811.0}{1018} \times 100 = 79.67\%$; [2]
Allow 80 % for percentage yield.
- (f) the carbon dioxide was absorbed by plants initially so there is no net increase / vegetable oil is not a fossil fuel / vegetable oil is formed from (atmospheric) carbon dioxide / *OWTTE*; [1]



(b) sketch to show:



indicator range between pH 3.0 and pH 4.6 (with “yellow” at pH 3.0 and “blue” at pH 4.6);

initial pH of acid at 2.9 ± 1.0 (when no KOH has been added);

half-equivalence point (does not need to be named) at pH 4.9 when 12.5 cm^3 of KOH have been added;

equivalence point at approx pH 8.5 – 9.0 when 25.0 cm^3 of KOH(aq) added;

upper part of curve from $25.0 - 50.0 \text{ cm}^3$ added identical to original curve;

[3 max]

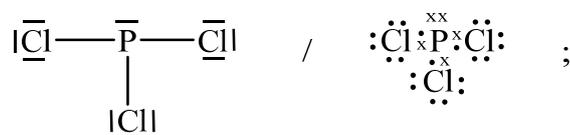
Award [1] each for any three points.

3. (a) energy required = C=C + H-H/612 + 436 and
 energy released = C-C + 2(C-H)/347 + 2(413) /
 energy required = C=C + H-H + 4(C-H)/612 + 436 + 4(413) and
 energy released = C-C + 6(C-H)/347 + 6(413);
- $$\Delta H = (1048 - 1173)/(2700 - 2825) = -125 \text{ kJ mol}^{-1}; \quad [2]$$
- (b) $\Delta H = -1411 + (-286) - (-1560)$ /correct energy cycle drawn;
 $= -137 \text{ kJ mol}^{-1}; \quad [2]$
Award [1 max] for incorrect or missing sign.
- (c) the actual values for the specific bonds may be different to the average values / the
 combustion values referred to the specific compounds / *OWTTE*;
- $$\text{(percentage difference)} = \frac{(137 - 125)}{137} \times 100 = 8.76\%; \quad [2]$$
- Accept* $\frac{(137 - 125)}{125} \times 100 = 9.60\%$.
- (d) (i) $-125 \text{ kJ mol}^{-1}; \quad [1]$
- (ii) average bond enthalpies do not apply to the liquid state / *OWTTE*;
 the enthalpy of vaporization/condensation of cyclohexene and cyclohexane /
OWTTE; [2]

4. (a) (i) $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{e}^{-}$; [1]
- (ii) $\text{MnO}_4^{-} + 8\text{H}^{+} + 5\text{e}^{-} \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$; [1]
- (iii) $\text{MnO}_4^{-} + 5\text{Fe}^{2+} + 8\text{H}^{+} \rightarrow \text{Mn}^{2+} + 5\text{Fe}^{3+} + 4\text{H}_2\text{O}$; [1]
- Accept e instead of e⁻.*
- (b) (i) amount of $\text{MnO}_4^{-} = \frac{11.6}{1000} \times 0.0200 = 2.32 \times 10^{-4}$ mol; [1]
- (ii) amount of $\text{Fe}^{2+} = 5 \times 2.32 \times 10^{-4} = 1.16 \times 10^{-3}$ mol; [1]
- (iii) mass of $\text{Fe}^{2+} = 55.85 \times 1.16 \times 10^{-3} = 6.48 \times 10^{-2}$ g;
percentage of Fe^{2+} in tablet = $\frac{6.48 \times 10^{-2}}{1.43} \times 100 = 4.53\%$; [2]
5. (a) in the solid state ions are in fixed positions / there are no moveable ions / *OWTTE*; [1]
Do not accept answer that refers to atoms or molecules.
- (b) $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^{-}$ / $\text{O}^{2-} \rightarrow \frac{1}{2}\text{O}_2 + 2\text{e}^{-}$; [1]
Accept e instead of e⁻.
- (c) (i) basic; [1]
Allow alkaline
- (ii) $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$ / $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Na}^{+} + 2\text{OH}^{-}$; [1]
Do not accept \rightleftharpoons

SECTION B

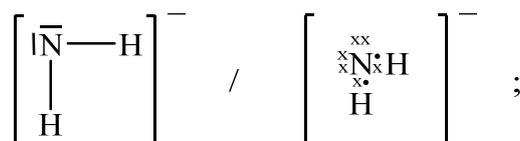
6. (a) (i)



trigonal pyramid;
in the range of 100–108°;

[3]

(ii)



Must include minus sign for the mark.

bent/V-shaped;
in the range of 100–106°;

[3]

(iii)



square planar;
90°;

Penalize once only if electron pairs are missed off outer atoms.

[3]

(b) (i) **c**: atomization (enthalpy);
d: electron affinity;

[2]

(ii) **d** and **e**;

[1]

(iii) $\Delta H_f = 90.0 + 418 + 112 + (-342) + (-670)$;
 $= -392 \text{ kJ mol}^{-1}$;

[2]

(iv) Ca^{2+} is smaller than K^+ **and** Ca^{2+} has more charge than K^+ / Ca^{2+} has a greater charge density;

so the attractive forces between the ions are stronger;

[2]

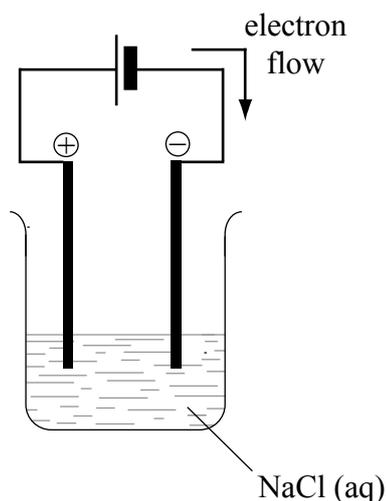
Do not accept 'stronger ionic bonds'

Award [1 max] if reference is made to atoms or molecules instead of ions.

- (c) (i) sigma bonds are formed by end on/axial overlap of orbitals with electron density between the two atoms/nuclei;
pi bonds are formed by sideways overlap of parallel p orbitals with electron density above **and** below internuclear axis/ σ bond; [2]
Accept suitably annotated diagrams
- (ii) 8 sigma/ σ ; [2]
1 pi/ π ;
- (iii) 109°/109.5° ; [2]
120° ;
- (iv) sp hybridization; [3]
1 sigma and 2 pi;
sigma bond formed by overlap between the two sp hybrid orbitals (on each of the two carbon atoms) / pi bonds formed by overlap between remaining p orbitals (on each of the two carbon atoms) / diagram showing 2 sp hybrid orbitals and 2 p orbitals;

7. (a) (i) the voltage obtained when the half-cell is connected to the standard hydrogen electrode;
 under standard conditions of 298 K **and** 1 mol dm⁻³ solutions;
 electrons flow (in the external circuit) from the half-cell to the hydrogen electrode / the metal in the half-cell is above hydrogen in the ECS / Fe is a better reducing agent than H₂ / Fe is oxidised more readily than H₂; [3]
- (ii) -0.28 V ; [1]
- (iii) Co²⁺/cobalt(II) ion; [1]
- (iv) $2\text{Al} + 3\text{Fe}^{2+} \rightarrow 3\text{Fe} + 2\text{Al}^{3+}$; [2]
Award [1] for correct reactants and products and [1] for correctly balanced, ignore states.
Do not accept \rightleftharpoons
- (v) to complete the electrical circuit / *OWTTE*;
 by allowing the movement of ions; [2]
- (b) (i) +2; [1]
- (ii) +3; [1]
- (iii) +2; [1]
Only penalize once if roman numerals are used or if written as 2+ or 3+.

- (c) (i) diagram to show:



- battery/source of electricity connected to two electrodes in the solution with positive **and** negative electrodes correctly labelled;
 electrons/current flowing from the cell to the negative electrode;
 labelled solution of sodium chloride; [3]
If the connecting wires to electrodes are immersed in the solution [1 max].

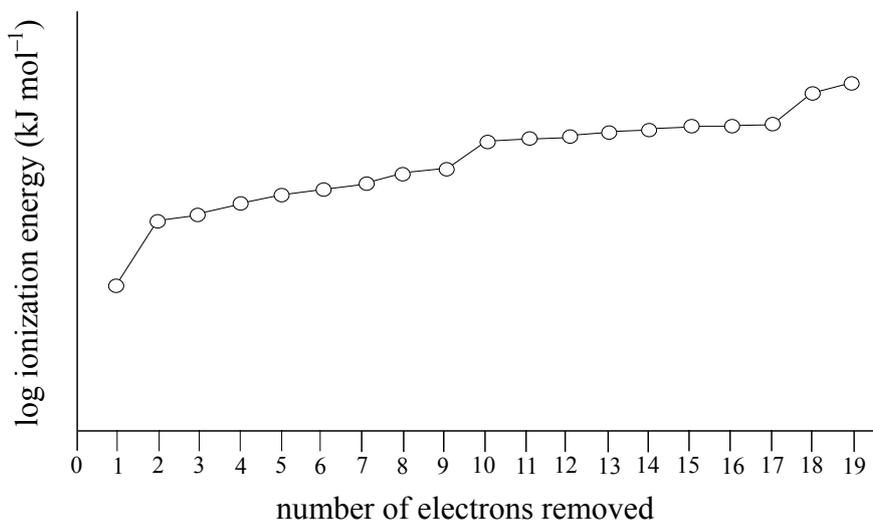
- (ii) Na⁺, H⁺/H₃O⁺, Cl⁻, OH⁻ [2 max]
All four correct [2], any three correct [1].

- (iii) hydrogen at (-)/cathode **and** oxygen at (+)/anode;
 $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ / $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$;
 $4\text{OH}^- \rightarrow \text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^-$ / $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^-$; [3]
Accept e instead of e⁻
If electrodes omitted or wrong way round [2 max].
- (iv) Ratio of H₂ : O₂ is 2 : 1; [1]
- (d) (i) (-)/(cathode) $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ / $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$;
(+)/(anode) $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$; [2]
Accept e instead of e⁻
If electrodes omitted or wrong way round [1 max]
- (ii) (-)/(cathode) $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$;
(+)/(anode) $2\text{Br}^- \rightarrow \text{Br}_2 + 2\text{e}^-$; [2]
Accept e instead of e⁻
If electrodes omitted or wrong way round [1 max].

8. (a) (i) a vaporized sample must be used;
 bombarded with (high energy) electrons to form positive ions;
 accelerated by passing through an electric field;
 deflected by passing through a magnetic field;
 detected by producing a current; [5]
Award [2 max] if just the words vaporization, ionization, acceleration, deflection and detection are used with no explanation.
- (ii) (size of the positive) charge (on the ion);
 mass (of the ion);
 strength of the magnetic field;
 velocity/speed (of the ions) / strength of electric field; [3 max]
m/z scores the first two marking points.
- (iii) $A_r = \frac{[(0.56 \times 84) + (9.90 \times 86) + (7.00 \times 87) + (82.54 \times 88)]}{100}$; [2]
 $= 87.71$;
Award [1 max] if answer not given to two decimal places.
Apply $-1(U)$ if answer quoted in g or $g \text{ mol}^{-1}$.
- (b) (i) first ionization energy: $M(g) \rightarrow M^+(g) + e^-/e$ / the (minimum) energy (in kJ mol^{-1}) to remove one electron from a gaseous atom / the energy required to remove one mole of electrons from one mole of gaseous atoms;
 periodicity: repeating pattern of (physical and chemical) properties; [2]
- (ii) (evidence for main levels)
 highest values for noble gases / lowest values for alkali metals / *OWTTE*;
 general increase across a period;
 (evidence for sub-levels)
 drop in I.E. from Be to B/Mg to Al/Group 2 to Group 3;
 drop in I.E. from N to O/P to S/Group 5 to Group 6; [4]
- (iii) $M^+(g) \rightarrow M^{2+}(g) + e^-$ / *OWTTE* ; [1]
Accept e instead of e^- .

(iv) Rough sketch to show:

Graph of successive ionization energies for potassium



correct use of axes **and** one electron relatively easy to remove;
 a jump in value then eight, another jump to another eight **and** finally another
 jump for the remaining two electrons ;

electronic configuration of K= $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ / first electron due to removal
 of $4s^1$, next eight due to third level/ $3s^2 3p^6$, next eight due to second
 level/ $2s^2 2p^6$ and last two due to removal of first level/ $1s^2$;
 the more electrons removed the more the positive nucleus attracts the
 remaining electrons and each main energy level is closer to the nucleus /
 OWTTE;

[4]

(c) (i) $(\text{Cu}) 1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10} / 1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$;
 Do not accept $[\text{Ar}]4s^1 3d^{10}$.

$(\text{Cu}^+) 1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$;
 Do not accept $[\text{Ar}]3d^{10}$.

[2]

(ii) Cu^{2+} has an incomplete d sub-level **and** Sc^{3+} has no d electrons;
 the d sub-level is split so the d electrons (in copper) can be excited by visible
 light / OWTTE;

[2]

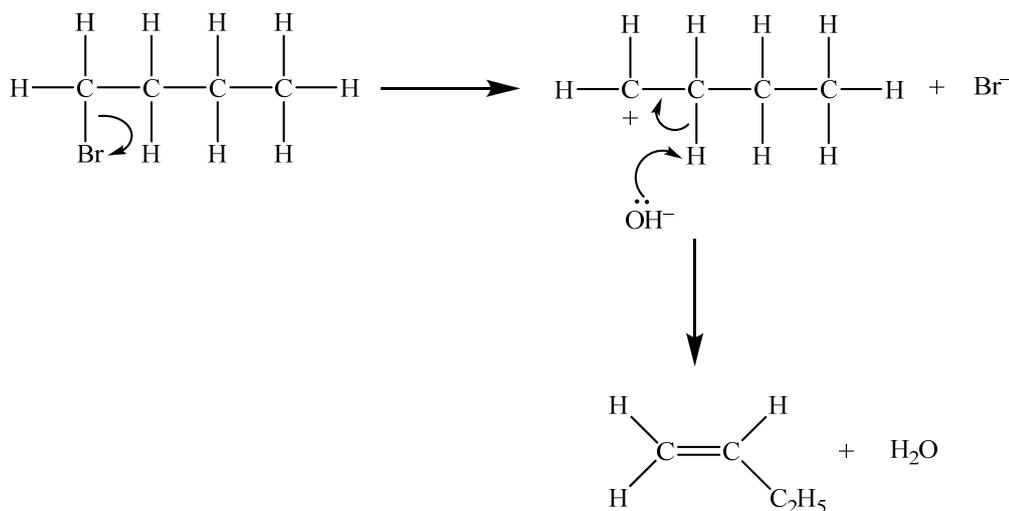
9. (a) (i) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \rightarrow \text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2 + \text{HBr}$ /
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2 + \text{H}_2\text{O} + \text{Br}^-$;
 alcoholic NaOH/OH⁻ ;
 reflux / heat ;

[3]

Penalize missing Hs once only throughout question 9

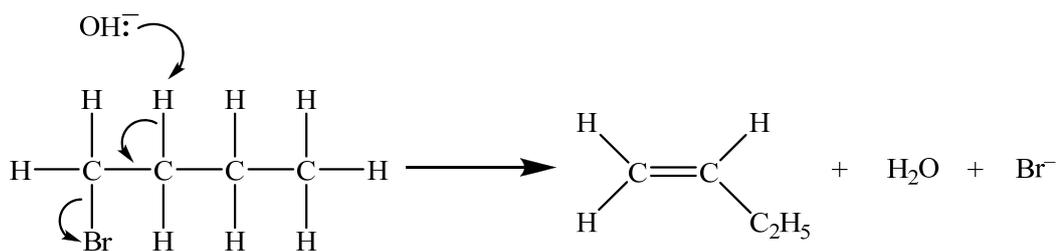
- (ii) elimination reaction ;
 Then accept either E1 or E2 mechanism.

E1



curly arrow showing bromine leaving the halogenoalkane;
 OH⁻ acting as base on the intermediate carbocation;

E2



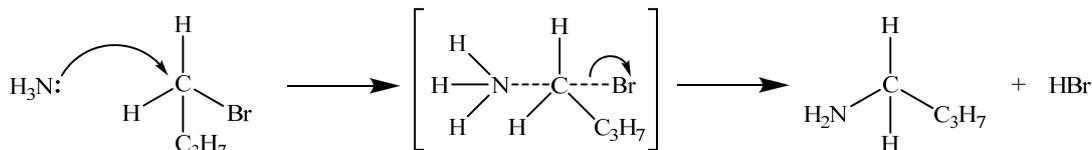
curly arrow showing OH⁻ acting as base on H bonded to C;
 concerted curly arrows showing Br leaving C-Br ;

[3]

- (iii) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 + \text{HBr}$;
 ammonia/NH₃;
 warm / excess ammonia (to prevent secondary amines etc.);

[3]

(iv)



curly arrow from ammonia (to form transition state);

correct transition state;

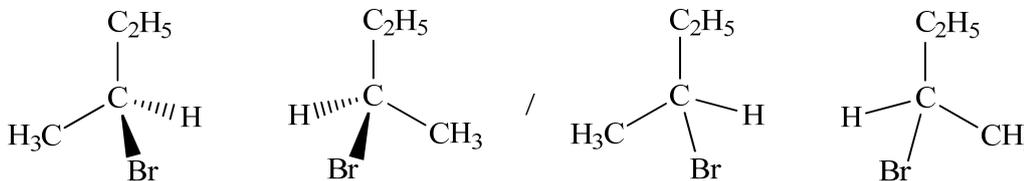
curly arrow from bond to Br atom in either the first or second step;

formation of HBr and organic product;

Accept a second molecule of NH₃ removing H⁺ from the transition state to give NH₄⁺ and Br⁻ as products.

[4]

(b) (i)



[2]

Award [1] for correct structure and [1] for correct 3-D representation of both enantiomers.

(ii) polarimeter (to measure angle of rotation);
the plane of plane-polarized light rotates in opposite directions (by the different enantiomers);

[2]

(iii) 2-bromo-2-methylpropane is tertiary / 1-bromobutane is primary;
2-bromo-2-methylpropane goes by S_N1 / 1-bromobutane by S_N2;
intermediate carbocation more stable for tertiary;

no space around tertiary carbon for five groups (in S_N2 transition state);

[3 max]

(c) (i) amide / peptide;

[1]

(ii) H₂N(CH₂)₆NH₂;
HOOC(CH₂)₈COOH / ClOC(CH₂)₈COCl;

[2]

(iii) nHOOC₆H₄COOH + nHOCH₂CH₂OH
→ HO--(--OCC₆H₄COOCH₂CH₂O--)_n-H + (2n - 1)H₂O ;

[2]

Award [1] for correct organic product and [1] for (2n - 1)H₂O.

Accept --(--OCC₆H₄COOCH₂CH₂O--)_n—for the organic product.