M10/4/CHEMI/HP2/ENG/TZ1/XX/M+

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MARKSCHEME

May 2010

CHEMISTRY

Higher Level

Paper 2

18 pages

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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** 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. 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	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

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.

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SECTION A

1. (a) (i) *Copper:*
0 to +2 / increases by 2 / +2 / 2+;
Allow zero/nought for 0.

Nitrogen:
+5 to +4 / decreases by 1 / –1 / 1–; ***[2]***
Penalize missing + sign or incorrect notation such as 2+, 2^+ or II, once only.

(ii) nitric acid/HNO_3 / NO_3^-/nitrate; ***[1]***
Allow nitrogen from nitric acid/nitrate but not just nitrogen.

(b) (i) 0.100×0.0285 ;
2.85×10^{-3} (mol); ***[2]***
*Award **[2]** for correct final answer.*

(ii) 2.85×10^{-3} (mol); ***[1]***

(iii) $(63.55 \times 2.85 \times 10^{-3}) = 0.181$ g ; ***[1]***
Allow 63.5.

(iv) $\left(\frac{0.181}{0.456} \times 100 =\right)$ 39.7 % ; ***[1]***

(v) $\left(\frac{44.2 - 39.7}{44.2} \times 100 =\right)$ 10/10.2 %; ***[1]***
Allow 11.3 % i.e. percentage obtained in (iv) is used to divide instead of 44.2 %.

(c) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$; ***[1]***
Do not allow [Ar]$3d^9$.

(ii) d orbitals are split;
(3d) electrons move between orbitals **and** absorb light/energy / complementary colour is transmitted when energy absorbed by d electrons moving; ***[2]***
Accept levels instead of orbitals.

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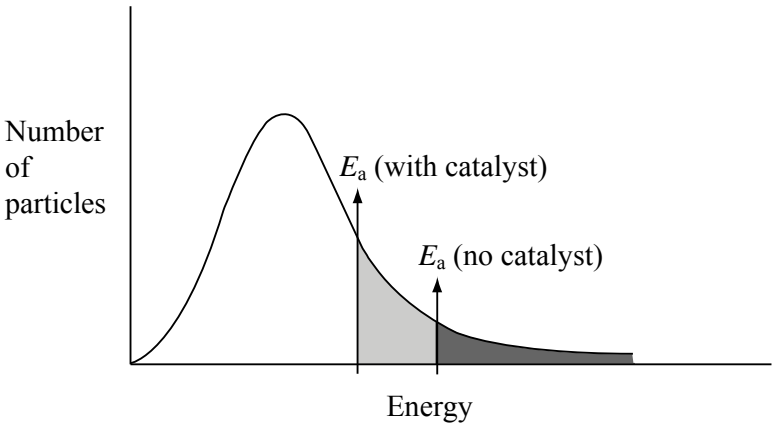
2. (a) to maintain a constant volume / *OWTTE*; ***[1]***

(b) (i) $[H^+]$ order 1, $[CH_3COCH_3]$ order 1, $[I_2]$ order 0;
(rate =)k $[H^+]$ $[CH_3COCH_3]$; ***[2]***
*Award **[2]** for correct rate expression.*
Allow expressions including $[I_2]^0$.

(ii) neither were correct / Alex was right about propanone and wrong about iodine / Hannah was right about propanone and hydrogen ions but wrong about iodine / *OWTTE*; ***[1]***

(c) $[CH_3COCH_3] = 0.100$ mol dm^{-3} **and** $[H^+] = 0.100$ mol dm^{-3};
$k = \dfrac{4.96\times10^{-6}}{(0.100\times0.100)} = 4.96\times10^{-4}$;
mol^{-1} dm^3 s^{-1}; ***[3]***
Ignore calculation of $[I_2]$.
No ECF here for incorrect units.

(d) (i)



axes correctly labelled x = energy/velocity/speed, y = number/% of molecules/particles/probability;
graph showing correct curve for Maxwell-Boltzmann distribution;
If two curves are drawn, first and second marks can still be scored, but not third.
Curve(s) must begin at origin and not go up at high energy.

two activation energies shown with E_{cat} shown lower; ***[3]***
Award the mark for the final point if shown on an enthalpy level diagram.

(ii) catalyst provides an alternative pathway of lower energy / *OWTTE*; ***[1]***
Accept catalyst lowers activation energy (of reaction).

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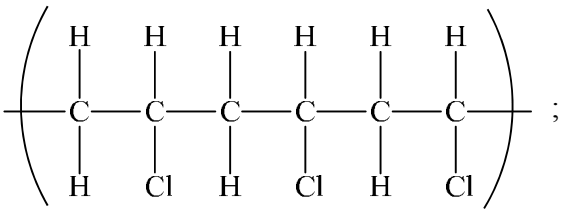
3. (a)



[1]

Brackets not required for mark.
Allow correct condensed structural formula.
Continuation bonds from each carbon are required.
Cl atoms can be above or below carbon spine or alternating above and below.

(b) plastics are cheap/versatile/a large industry / plastics have many uses / *OWTTE*;
plastics are not biodegradeable / plastics take up large amounts of space in landfill / pollution caused by burning of plastics / *OWTTE*; ***[2]***
Do not accept plastics cause litter.
Allow plastics don't decompose quickly / OWTTE.

(c) (i) *Step 1:*
$CH_2CHCl + H_2 \rightarrow CH_3CH_2Cl$;

Step 2:
$CH_3CH_2Cl + OH^- \rightarrow CH_3CH_2OH + Cl^-$; ***[2]***
Accept NaOH or NaCl etc. instead of OH^- and Cl^-.
Allow abbreviated formulas C_2H_3Cl, C_2H_5Cl,C_2H_5OH.

(ii) H_2SO_4/H^+/acidified **and** $Cr_2O_7^{2-}$/(potassium/sodium) dichromate;
Accept suitable oxidizing agents (e.g. $KMnO_4$ etc.) but only with acid.
Ignore missing or incorrect oxidation states in reagents.

(heat under) reflux; ***[2]***
Second mark can be scored even if reagent is incorrect.

(d) (i) $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$;

OR

$CH_3COOH(l) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$;

OR

$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$; ***[1]***
Must include $\rightleftharpoons$.
Ignore state symbols.

(ii) $K_a = 10^{-4.76} / 1.74 \times 10^{-5}$

$1.74 \times 10^{-5} = \frac{[H^+]^2}{0.200}$ / $[H^+] = 0.00187$;

pH = 2.73; ***[3]***
*Award **[3]** for correct final answer, allow mark for correct conversion of $[H^+]$ to pH even if $[H^+]$ incorrect.*

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(e) (initial) $[CH_3COOH] = 0.500$ mol dm^{-3} and) eqm $[CH_3COOH] = 0.200$ mol dm^{-3};
(initial) $[CH_3COO^-] = 0.300$ mol dm^{-3} and) eqm $[CH_3COO^-] = 0.300$ mol dm^{-3};
Allow 0.02 moles and 0.03 moles instead of 0.200 and 0.300 mol dm^{-3}.

$[H^+] = K_a \frac{[CH_3COOH]}{[CH_3COO^-]} = 1.16 \times 10^{-5}$ mol dm^{-3} / $pH = pK_a + \log \frac{[SALT]}{[ACID]}$;
pH = 4.94; ***[4]***
*Award **[3 max]** for correct final answer if no working shown.*

(f) (if acid added) $CH_3COO^- + H^+ \rightarrow CH_3COOH$;
(if alkali added) $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$; ***[2]***
Explanation marks cannot be awarded without equations.
Accept $H^+ + OH^- \rightarrow H_2O$ as OH^- reacts with H^+ in the buffer to form water.

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SECTION B

4. (a) average mass of isotopes of an element compared to (1/12 g of) ^{12}C / average mass of an atom relative to C–12 having a mass of exactly 12 */ OWTTE*; ***[1]***
Allow element instead of atom.
Must refer to average mass and C–12.

(b) *Diagram of mass spectrometer containing in the correct sequence:*
vaporization/vaporized sample;
ionization/electron gun;
acceleration/oppositely charged plates;
deflection/magnetic field;
detection; ***[5]***
*Award **[3]** for 5 correct labels, **[2]** for 3–4 correct labels, **[1]** for 2 correct labels.*
*Award **[1]** for correct order for at least 4 correct labels.*
*Award **[1]** for diagram which must at least show ionization (e.g. electron beam), acceleration (e.g. charged plates) and deflection (e.g. magnetic field) even if these are incorrectly labelled.*

(c) $63x + 65(1–x) = 63.55$;
(or some other mathematical expression).

$^{63}Cu = 72.5$ % **and** $^{65}Cu = 27.5$ %; ***[2]***
*Allow $^{63}Cu = 0.725$ **and** $^{65}Cu = 0.275$.*
*Award **[2]** for correct final answer .*

(d) ^{60}Co/ ^{131}I/^{125}I; ***[1]***
Must contain correct mass numbers.
Allow other formats such as cobalt-60, Co-60 etc.
Award no marks if a correct radioisotope is given with an incorrect radioisotope.
Allow any other radioisotope if you can verify its use.

(e) Sc has no d electrons as an ion / Cu has d electrons;
Cu compounds are coloured / Sc compounds are colourless;
Cu has more than one oxidation state / Sc has only one oxidation state;
Cu compounds can act as catalysts / Sc cannot act as catalysts; ***[3 max]***

(f) $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ / $Na(s) + H_2O(l) \rightarrow NaOH(aq) + \frac{1}{2}H_2(g)$ ***[2]***
*Award **[1]** for correct balanced equation.*
*Award **[1]** for correct state symbols for sodium, water, sodium hydroxide and hydrogen.*
Second mark is not dependent on equation being correctly balanced.

(g) (Rb more reactive because) electron lost further from nucleus so less tightly held;
Rb electron is in 5th energy level **and** (Na less reactive) as electron lost in 3rd energy level / *OWTTE*; ***[2]***
*Allow **[1 max]** for electron arrangements of Na (e.g. 2,8,1) and Rb if second mark is not scored.*

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(h) (i) $AlCl_3$ covalent **and** Al_2O_3 ionic;
$AlCl_3$ (simple) molecular **and** Al_2O_3 (giant ionic) lattice;

OR

$AlCl_3$ is covalent and simple molecular/small molecules held together by dipole–dipole attractions;
Al_2O_3 is ionic and Al^{3+} and O^{2-} ions are held together in a (giant) lattice; ***[2 max]***

(ii) $AlCl_3$ is acidic and Na_2O is basic and P_4O_{10} is acidic;

$AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$ / $AlCl_3 + 6H_2O \rightarrow \left[Al(H_2O)_6\right]^{3+} + 3Cl^-$ **and**

$\left[Al(H_2O)_6\right]^{3+} \rightarrow \left[Al(H_2O)_5OH\right]^{2+} + H^+$;

Accept suitable alternative hydrolysis expressions or reactions with a base.

$Na_2O + H_2O \rightarrow 2NaOH$;

$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$; ***[4]***

Accept suitable reactions with an acid or base.

(iii) $AlCl_3$ does not conduct in the solid/molten state;
Al_2O_3 conducts when molten (but not when solid);
Al_2O_3 contains mobile ions when molten **and** $AlCl_3$ has neither mobile ions nor delocalized electrons / *OWTTE*; ***[3]***
Reference to mobile ions or electrons must be made.

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5. (a) (i) correct substitution of values and numbers of bonds broken / $(1\times945)+(3\times436)/2253$;
correct substitution of values and numbers of bonds made / $(6\times391)/2346$;
$\Delta H =$ (sum of energies of bonds broken) – (sum of energies of bonds formed)
= (2253–2346) −93 (kJ); ***[3]***
Ignore units.
*Award **[3]** for correct final answer.*
*Award **[2 max]** for +93 or 93.*

(ii) entropy of products = $2\times192=384$;
entropy of reactants = $193+(3\times131)=586$;
$\Delta S^{\ominus}$ (= sum of entropies of products) – (sum of entropies of reactants) / (384–586) = –202 (J K^{-1} mol^{-1});
*Award **[3]** for correct final answer.*
*Award **[2 max]** for +202 or 202.*
Ignore units.

negative as more ordered/less disordered / four moles become two moles / fewer molecules of gas; ***[4]***

(iii) $(\Delta G^{\ominus}=\Delta H^{\ominus}-T\Delta S^{\ominus}=-93-298(-0.202))=-32.8$ (kJ mol^{-1}); ***[1]***

(iv) reaction becomes less spontaneous;
ΔG becomes more positive/less negative / $T\Delta S$ becomes larger; ***[2]***

(b) macroscopic properties remain constant / concentrations remain constant / no change to copper solution seen;
rate of reverse/backwards reaction = rate of forward reaction; ***[2]***

(c) $(K_c=)\ \dfrac{[NH_3]^2}{[N_2][H_2]^3}$; ***[1]***
Do not award mark if [ ] missing or round brackets used.

(d) (i) $[H_2]$ = 0.11 / 0.11 (mol dm^{-3});
$[N_2]$ = 0.17 / 0.17 (mol dm^{-3});
K_c = 16; ***[3]***
Ignore units.
Allow ECF from incorrect equilibrium expression and incorrect concentrations for third mark.

(ii) decrease;
heat is a product/reaction is exothermic so equilibrium moves to left / *OWTTE*; ***[2]***

(e) yield increases / equilibrium moves to the right / more ammonia;
4 gas molecules → 2 / decrease in volume / fewer gas molecules on right hand side; ***[2]***

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(f) high pressure expensive / greater cost of operating at high pressure / reinforced pipes *etc*. needed;
Do not accept "high pressure is dangerous" without further explanation.

lower temperature – greater yield, but lowers rate; ***[2]***
Do not award a mark just for the word "compromise".

(g) K_c unaffected;
position of equilibrium unaffected;
rate of forward and reverse reactions are increased (equally); ***[3]***

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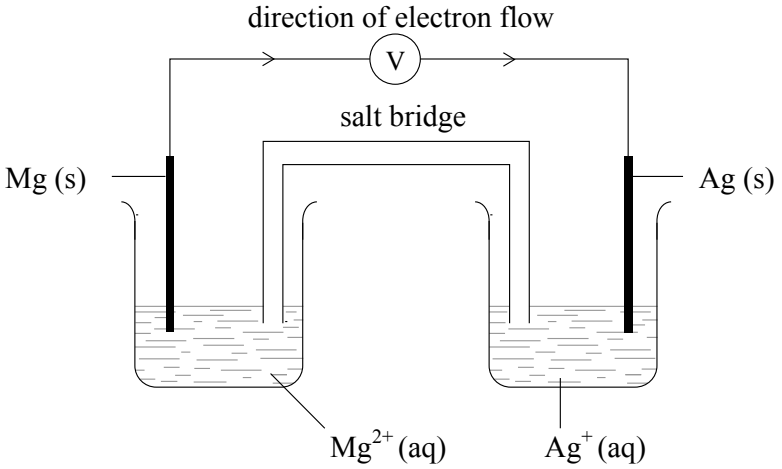
6. (a) (i)



correctly labelled electrodes **and** solutions;
labelled salt bridge;
voltmeter;
Allow bulb or ammeter.

direction of electron flow; ***[4]***

(ii) *Oxidation*:
$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^{-}$;

Reduction:
$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$; ***[2]***

Ignore state symbols.
*Award **[1 max]** if equations not labelled reduction or oxidation or labelled the wrong way round.*
Allow e instead of e^{-}.
Penalize equilibrium sign or reversible arrows once only in parts (a) (ii) and (d) (ii).

(iii) +0.80 – (–2.37) = 3.17 V
correct data;
answer with unit; ***[2]***
*Award **[1]** for –3.17 V or correct working of wrong values.*

(b) (i) Cd/Cd(s); ***[1]***
Do not allow Cd^{2+}.

(ii) $5Cd(s) + 2MnO_4^{-}(aq) + 16H^{+}(aq) \rightarrow 5Cd^{2+}(aq) + 2Mn^{2+}(aq) + 8H_2O(l)$
correct reactants and products;
correct balancing of this equation; ***[2]***
Ignore state symbols.

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(c) *Accept suitable diagram with the following indicated:*
Pt electrode;
$[H^+(aq)]$ = 1 mol dm^{-3}/0.5 mol dm^{-3} H_2SO_4;

H_2 gas;
at 1 atm / 1.01×10^5 Pa ;
Do not award mark for pressure if no hydrogen gas given.

298 K / 25 °C ; ***[4 max]***

(d) (i) sodium chloride crystals consist of ions in a (rigid) lattice / ions cannot move (to electrodes) / *OWTTE*;
when melted ions free to move / ions move when potential difference/voltage applied; ***[2]***

(ii) positive sodium ions/Na^+ move to the negative electrode/cathode **and** negative chloride ions/Cl^- move to the positive electrode/anode;

electrons are released to positive electrode/anode by negative ions and accepted from negative electrode/cathode by positive ions / reduction occurs at the negative electrode/cathode **and** oxidation occurs at the positive electrode/anode / Na^+ ions are reduced **and** Cl^- ions are oxidized;

(Positive electrode/anode):
$2Cl^- \rightarrow Cl_2 + 2e^-$ / $Cl^- \rightarrow \frac{1}{2}Cl_2 + e^-$;

(Negative electrode/cathode)
$2Na^+ + 2e^- \rightarrow 2Na$ / $Na^+ + e^- \rightarrow Na$; ***[4]***

*Award **[1 max]** if equations not labelled or labelled wrong way round.*
Allow e instead of e^-.
Penalize equilibrium sign or reversible arrows once only in parts (a) (ii) and (d) (ii).

(iii) *Products*:
oxygen at positive electrode **and** hydrogen at negative electrode;
moles of Mg = 0.5 / mole ratio of O_2:H_2 is 1:2;
Can be implied by calculation.

$$\text{mass oxygen} = \left(\frac{1}{2}\times\frac{12.16}{24.31}\times 32.00 =\right) 8.00 \text{ g};$$

$$\text{mass hydrogen} = \left(\frac{12.16}{24.31}\times 2.02 =\right) 1.01 \text{ g};$$ ***[4]***

Do not apply SD rule here.

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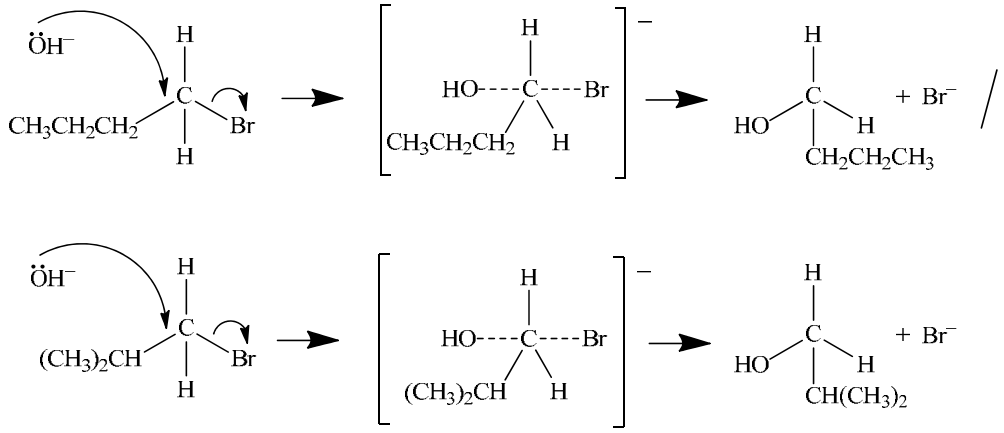
7. (a) **A**: l-bromobutane;
B: 2-bromobutane*;*
C: 2-bromo-2-methylpropane*;*
D: 1-bromo-2-methylpropane; ***[4]***
Penalize incorrect punctuation, e.g. commas for hyphens, only once.
*Accept 2-bromomethylpropane and 1-bromomethylpropane for **C** and **D** respectively.*

(b) (i) **C**/2-bromo-2-methylpropane;
unimolecular nucleophilic substitution; ***[2]***

(ii) $RBr \rightarrow R^+ + Br^-$; ***[1]***
Allow use of 2-bromo-2-methylpropane instead of RBr.

(iii) **A/**1-bromobutane/**D**/1-bromo-2-methylpropane;



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

curly arrow showing Br leaving;
Accept curly arrow either going from bond between C and Br to Br in 1-bromobutane or in the transition state.

representation of transition state showing negative charge, square brackets and partial bonds; ***[4]***
Do not penalize if HO and Br are not at 180^o to each other.
Do not award fourth mark if OH----C bond is represented.

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(c) (b) (i) no change as $[OH^-]$ does not appear in rate equation/in the rate determining step;
(b) (iii) rate doubles as the rate is proportional to $[OH^-]$ / OH^- appears in the rate-determining/slow step / first order with respect to OH^-; ***[2]***
*Award **[1]** if correctly predicts no rate change for S_N1 and doubling of rate for S_N2 of without suitable explanation.*

(d) rate of 1-bromobutane is faster;
C–Br bond is weaker/breaks more easily than C–Cl bond; ***[2]***

(e) 2-bromobutane/**B**;
(plane-) polarized light shone through;
enantiomers rotate plane of plane-polarized light to left or right/opposite directions (by same amount);
Accept "turn" instead of "rotate" but not "bend/reflect".

physical properties identical (apart from effect on plane-polarized light);
chemical properties are identical (except with other chiral compounds); ***[5]***
Do not accept "similar" in place of "identical".

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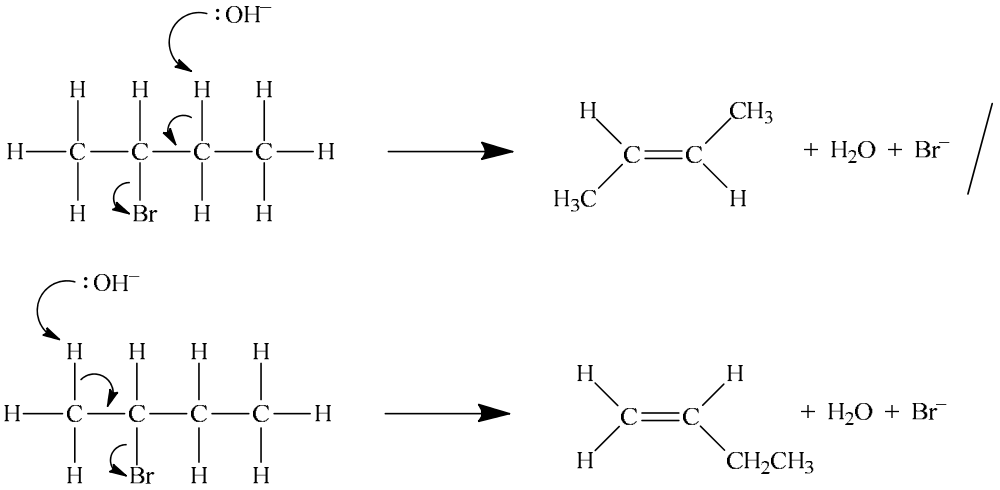
(f) (i) elimination; ***[1]***

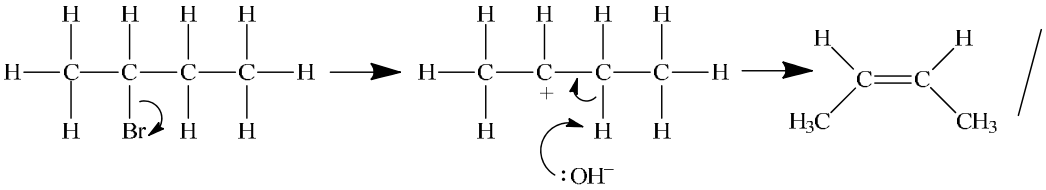
(ii)

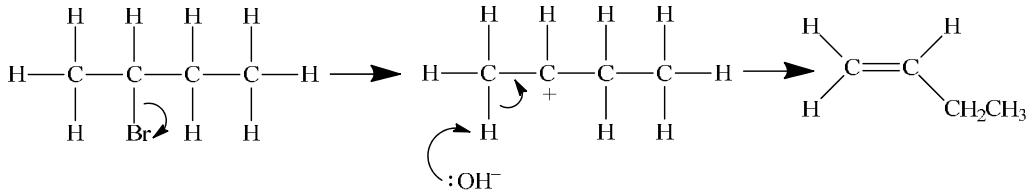


curly arrow going from lone pair/negative charge on O in OH^- to H on β-C;
Do not allow curly arrow originating on H in OH^-.
Allow $C_2H_5O^-$ instead of OH^-.

curly arrow going from CH bond to form C=C bond;
curly arrow showing Br leaving;

Accept the following for first 3 marks.





curly arrow showing Br leaving;
representation of carbocation;
curly arrow going from lone pair/negative charge on O in OH^- to H on C adjacent to C^+ **and** curly arrow going from CH bond to form C=C bond;

two products formed: but-1-ene / but-2-ene/(cis) but-2-ene/(trans) but-2-ene; ***[4 max]***
*Award **[1]** for two correct answers.*

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