M10/4/CHEMI/HP2/ENG/TZ2/XX/M+

International Baccalaureate®
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MARKSCHEME

May 2010

CHEMISTRY

Higher Level

Paper 2

18 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 × 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.

SECTION A

1. (a) $n(\text{HCl})(= 0.200\ \text{mol dm}^{-3} \times 0.02720\ \text{dm}^3) = 0.00544 / 5.44 \times 10^{-3}\,(\text{mol})$; ***[1]***

(b) $n(\text{HCl})$ excess $(= 0.100\ \text{mol dm}^{-3} \times 0.02380\ \text{dm}^3) = 0.00238 / 2.38 \times 10^{-3}\,(\text{mol})$; ***[1]***

Penalize not dividing by 1000 once only in (a) and (b).

(c) $n(\text{HCl})$ reacted $(= 0.00544 - 0.00238) = 0.00306 / 3.06 \times 10^{-3}\,(\text{mol})$; ***[1]***

(d) $2\text{HCl(aq)} + \text{CaCO}_3\text{(s)} \rightarrow \text{CaCl}_2\text{(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)}$ /
$2\text{H}^+\text{(aq)} + \text{CaCO}_3\text{(s)} \rightarrow \text{Ca}^{2+}\text{(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)}$; ***[2]***

*Award **[1]** for correct reactants and products.*
*Award **[1]** if this equation correctly balanced.*
*Award **[1 max]** for the following equations:*
$2HCl\,(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2CO_3(aq)$
$2H^+(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + H_2CO_3(aq)$
Ignore state symbols.

(e) $n(\text{CaCO}_3) = (\frac{1}{2}\, n(\text{HCl})) = \frac{1}{2} \times 0.00306$;
$= 0.00153 / 1.53 \times 10^{-3}\ (\text{mol})$; ***[2]***

*Award **[2]** for correct final answer.*

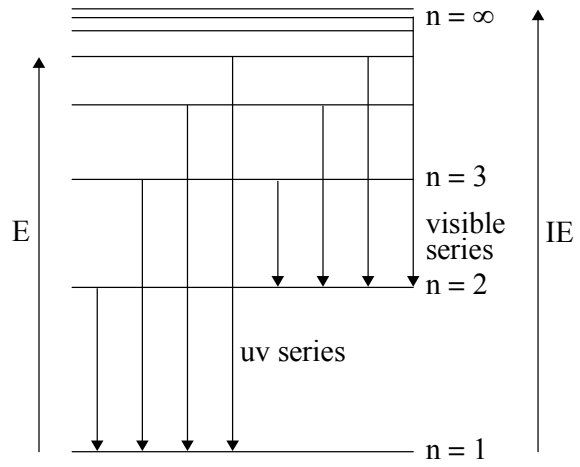
(f) $M_r(\text{CaCO}_3)\,(= 40.08 + 12.01 + 3 \times 16.00) = 100.09 / 100.1 /\ M = 100.09 / 100.1\,(\text{g mol}^{-1})$;
Accept 100.

$m(\text{CaCO}_3)\,(= nM) = 0.00153\,(\text{mol}) \times 100.09\,(\text{g mol}^{-1}) = 0.153\,(\text{g})$;
$\%\ \text{CaCO}_3\left(= \dfrac{0.153}{0.188} \times 100\right) = 81.4\ \% / 81.5\ \%$; ***[3]***

Accept answers in the range 79.8 to 81.5 %.
*Award **[3]** for correct final answer.*

(g) only CaCO_3 reacts with acid / impurities are inert/non-basic / impurities do not react with the acid / nothing else in the eggshell reacts with acid / no other carbonates; ***[1]***
Do not accept "all calcium carbonate reacts with acid".

2. (a)



showing *y*-axis labelled as energy/E / labelling at least two energy levels;
showing a minimum of four energy levels/lines with convergence;
showing jumps to $n = 1$ for ultraviolet series;
showing jumps to $n = 2$ for visible light series; ***[4]***
Must show at least two vertical lines per series to score third and fourth marks but penalize once only.
For third and fourth marks if transition not shown from higher to lower energy level penalize only once.

(b) for showing the energy to remove electron from $n = 1$ to $n = \infty$ on the above diagram;
to ionize an element, electron must be removed from the atom/no longer under influence of nucleus/removed beyond $n = \infty$ / *OWTTE*; ***[2]***

3. (a) as (cat)ion becomes more positive / Na^+, Mg^{2+}, Al^{3+} / size/radius decreases / charge density increases;
Do not allow increasing number of protons or increasing nuclear charge.

attraction for mobile/valence/delocalized/sea of electrons increases; ***[2]***
Do not accept "cloud of electrons".

(b) larger molecule / higher M_r/M / greater number of electrons;
Do not accept "larger/higher/greater mass".

greater van der Waals'/dispersion/London forces; ***[2]***

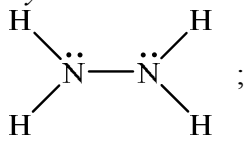
(c) *Si:* giant/network/macromolecular/3-D covalent bonding;
No mark for strong bonding without reference to covalent and network.
No mark for molecular.

Ar: (simple) atomic / (only weak) van der Waals'/dispersion/London forces; ***[2]***
No mark for (simple) molecular.

4. (a) $N_2H_4(g) + 2F_2(g) \rightarrow N_2(g) + 4HF(g)$

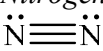
*Award **[1]** for reactants and products.*
*Award **[1]** if this equation is correctly balanced.* ***[2]***
Ignore state symbols.

(b) *Hydrazine:*



;

Nitrogen:


; ***[2]***

Accept lines, dots and crosses to show electron pairs.
Penalize missing lone pairs once only.

(c) $\sum$BE (bonds broken) $= (4 \times 391) + 158 + 2(158) / 2038\,(\text{kJ})$;
$\sum$BE (bonds formed) $= (945) + 4(568) / 3217\,(\text{kJ})$;
$\Delta H^{\ominus} = 2038 - 3217 = -1179\,(\text{kJ})$; ***[3]***

*Award **[3]** for correct final answer.*
*Award **[2]** for (+)1179(kJ).*

(d) (N_2H_4 / F_2) better rocket fuel;
ECF: answer must be consistent with equation in (a) and ΔH in (c).

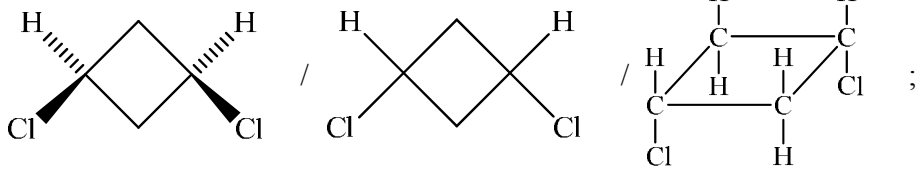
5 vol/mol (g) > 3 vol/mol (g)/more moles/greater amount of gas produced;
$\Delta H^{\ominus}(N_2H_4 / F_2) > \Delta H^{\ominus}(N_2H_4 / O_2)$ (per mole) / (N_2H_4 / F_2) reaction more exothermic; ***[2 max]***

(e) (N_2 inert) HF (weak) acid compared to H_2O / HF toxic / products of reactions of HF with environment/soil are harmful to environment / *OWTTE*; ***[1]***

5. (a) compounds with same structural formula;
Do not allow "same molecular or chemical formula without the same structural formula".

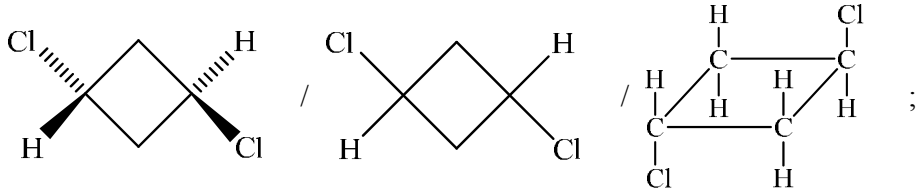
but different arrangement of atoms in space/spatial arrangement; ***[2]***

(b) (i)



;

Cis(-1,3-dichlorocyclobutane)



;

Trans(-1,3-dichlorocyclobutane) ***[2]***
Need clear cis/trans structure and name for each mark.
*Award **[1]** for 2 correct structures without names.*

(ii) cis (higher boiling point);
cis (more) polar / trans non-polar/less polar;
cis experiences stronger (permanent) dipole-dipole interaction / trans experiences no/(much) less dipole-dipole interaction; ***[3]***
Do not accept just strong forces without reference to dipole-dipole interaction.

SECTION B

6. (a) atomic number / Z; ***[1]***
Accept nuclear charge / number of protons.

(b) (i) power/strength/ability of an atom to attract electrons/shared electron pair / *OWTTE*;
in a (covalent) bond; ***[2]***
Accept the word "element" in place of "atom".
Do not accept electron (singular).

(ii) *Across period 3:*
increasing number of protons / atomic number / Z / nuclear charge;
(atomic) radius/size decreases / same shell/energy level / similar shielding/screening (from inner electrons);
No mark for shielding/screening or shielding/screening increases.

Noble gases:
do not form bonds (easily) / full/stable octet/shell/energy level / cannot attract more electrons; ***[3]***
Do not accept "inert" or "unreactive" without reference to limited ability/ inability to form bonds or attract electrons.

(c) (i) *Na*: 11 p, 11 / 2.8.1 e^- **and** Na^+: 11 p, 10 / 2.8 e^- / Na^+ has 2 shells/energy levels, Na has 3 / *OWTTE*;
Na^+: has greater net positive charge/same number of protons pulling smaller number of electrons; ***[2]***

(ii) Si^{4+}: 10 e^- in 2 (filled) energy levels / electron arrangement 2.8 / *OWTTE*;
P^{3-}: 18 e^- in 3 (filled) energy levels / electron arrangement 2.8.8, thus larger / *OWTTE*;

OR

Si^{4+}: has 2 energy levels where as P^{3-} has 3 / P^{3-} has one more (filled) energy level;
Si^{4+}: 10 e^- where as P^{3-}has 18 e^- / Si^{4+} has fewer electrons / P^{3+} has more electrons; ***[2]***

(d) $1s^2 2s^2 2p^6 3s^1$;

Do not accept [Ne] $3s^1$.

first electron easy/easiest to remove / 1 electron in outermost/n = 3 energy level / furthest from nucleus;
large increase between 1st and 2nd IE as electron now removed from n = 2;
next 8 electrons more difficult to remove / show (relatively) small increase as these electrons are in the same energy level/second energy level/n = 2;
large increase between 9th and 10th IE as electron now removed from n = 1 / 2 electrons very hard/most difficult to remove / innermost/lowest/closest to the nucleus/energy level/n = 1 / *OWTTE*;
electron 11 also comes from 1s, so shows a small increase; ***[4 max]***

(e) (i) outer electron in Al is in 3p/p orbital/sub-shell/sub-level;
higher orbital/sub-shell / e^- further from nucleus / shielded by 3s electrons; ***[2]***

(ii) in S, electron paired in 3p/p orbital/sub-shell/sub-level;

repulsion between paired electrons (and therefore easier to remove); ***[2]***

(f) (i) Lewis acid-base (reaction);
H_2O: e-pair donor, Fe^{3+}: e^- pair acceptor / H_2O donates an electron pair to Fe^{3+}; ***[2]***

(ii) d sub-levels are split into two sets of orbitals (of different energies);
electron transitions between (d) orbitals of different energies / d-d transition(s);
transmitted (visible) light is complementary colour; ***[3]***

(iii) (exothermic reactions) low temperature/less energy increases ammonia yield;
(iron) catalyst used to increase rate of reaction / equilibrium reached faster / same yield but produced faster/in shorter/less time; ***[2]***

7. (a) (i) $(K_w) = [H^+][OH^-] / (K_w) = [H_3O^+][OH^-]$; ***[1]***

Do not award mark if [ ] omitted or other brackets are used.

(ii) $[H^+]$ increases, $[OH^-]$ decreases but still some present (K_w constant) / $[OH^-]$ cannot go to zero as equilibrium present / $[OH^-] = \frac{K_w}{[H^+]}$, thus $[OH^-]$ cannot be zero / *OWTTE*; ***[1]***

(iii) (changing T disturbs equilibrium) endothermic reaction / forward reaction favoured / equilibrium shifts to the right;
to use up (some of the) heat supplied;
K_w increases (as both $[H^+]$ and $[OH^-]$ increase); ***[3]***

(iv) (as $[H^+]$ increases) pH decreases / pH < 7;
No mark for more acidic.
inverse relationship between pH and $[H^+] / \text{pH} = -\log[H^+] / \text{pH} = \log_{10} \frac{1}{[H^+]}$; ***[2]***
Accept $[H_3O^+]$ in place of $[H^+]$.

(b) (i) *Acid*: $H_2PO_4^-$;
(Conjugate) base: HPO_4^{2-};
No mark for NaH_2PO_4 or Na_2HPO_4.

$H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq)$; ***[3]***
Accept reverse equation or reaction with water.
Ignore state symbols, but equilibrium sign is required.
Accept OH^- (ions) react with H^+ (ions) to form H_2O.

(ii) strong base/OH^- replaced by weak base (HPO_4^{2-}, and effect minimized) / strong base reacts with acid of buffer / equilibrium in (i) shifts in forward direction;

$OH^-(aq) + H_2PO_4^-(aq) \rightarrow H_2O(l) + HPO_4^{2-}(aq)$; ***[2]***
Ignore state symbols, accept equilibrium sign.
Accept OH^- added reacts with H^+ to form H_2O.

(iii) strong acid/H^+ replaced by weak acid ($H_2PO_4^-$, and effect minimized) / strong acid reacts with base of buffer / equilibrium in (i) shifts in reverse direction;
$H^+(aq) + HPO_4^{2-}(aq) \rightarrow H_2PO_4^-(aq)$; ***[2]***
Accept reaction with H_3O^+.
Ignore state symbols.

(c) (i) NH_3 weak(er) base/partial dissociation;
$[OH^-] < 0.1(0)$ /pOH > 1 (thus pH < 13 / pH + pOH = 14); ***[2]***

(ii) around $pH = 5$;
Accept a value between 4 and 6.

strong acid–weak base titration, (thus acidic) / at equivalence point, NH_4^+ present is acidic / $NH_4^+ \rightleftharpoons NH_3 + H^+$; ***[2]***

(iii) $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$;
Ignore state symbols, but equilibrium sign required.

$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$; ***[2]***

(iv) $[NH_3] = [NH_4^+]$; ***[1]***

(v) $pOH = 14.00 - 9.25 = 4.75$;
$pK_b\ (= pOH) = 4.75$;
$K_b = 1.78 \times 10^{-5}$; ***[3]***
Ignore units.
*Award **[3]** for correct final answer.*

(vi) optimum/most effective/highest buffer capacity/50%–50% buffer/equally effective as an acidic buffer and a basic buffer / *OWTTE*; ***[1]***

8. (a) (i) $Pb: 0, PbO_2: +4, PbSO_4: +2$; ***[1]***

Need sign for mark.
Do not accept notations such as 4+, 2+, or IV, II.

(ii) *Negative/–/anode*

$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^- / Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$;

Positive/+/cathode

$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$ /

$PbO_2(s) + 4H^+(aq) + 2e^- \rightarrow Pb^{2+}(aq) + 2H_2O(l)$ /

$PbO_2(s) + H_2SO_4(aq) + 2H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$;

Accept $Pb^{4+} + 2e^- \rightarrow Pb^{2+}$.
Ignore state symbols.
Allow e instead of e^-.

oxidizing agent is PbO_2/lead(IV) oxide/lead dioxide **and** reducing agent is Pb/lead;
from negative/–/anode/Pb to positive/+/cathode/PbO_2 (through the external circuit/wire); ***[4]***

(iii) $Pb(s) + Cu^{2+}(aq) \rightarrow Pb^{2+}(aq) + Cu(s)$

$Pb(s) + 2Ag^+(aq) \rightarrow Pb^{2+}(aq) + 2Ag(s)$

$Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

*Award **[2]** for three correct, award **[1]** for any two correct, one correct scores no mark.*
Ignore state symbols.
Penalize unbalanced equations once only.

Pb is a stronger reducing agent than Cu and/or Ag / Pb most reactive as it can reduce/displace both Cu^{2+} and Ag^+;
Cu is a stronger reducing agent than Ag but not Pb / Cu in the middle (of the three) as it can reduce/displace Ag^+ but not Pb^{2+};
Accept converse argument.

Decreasing order: Pb, Cu, Ag / Pb > Cu > Ag; ***[5]***
Do not accept Pb^{2+}, Cu^{2+}, Ag^+.

(iv) MnO_4^-;

$2MnO_4^-(aq) + 16H^+(aq) + 10Cl^-(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5Cl_2(g)$

Accept equation with all coefficients divided by 2 (i.e. $MnO_4^- + 8H^+ + 5Cl^- \rightarrow Mn^{2+} + 4H_2O + 2\frac{1}{2}Cl_2$*).*
*Award **[1]** for correct reactants and products, **[1]** for correct balancing.*
Ignore state symbols.

$E^{\ominus}_{cell} = (1.51 - 1.36) = (+)\,0.15\,(V)$; ***[4]***

(b) (i) *Positive/+/anode*
$2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$;
Allow e instead of e^-.

Negative/–/cathode
$Na^+(l) + e^- \rightarrow Na(l)$;
Penalize missing or incorrect states such as (aq) or (s) once only.
*Award only **[1]** if electrodes not specified or if equations switched.*

$1Cl_2$ to $2Na$; ***[3]***

(ii) (choice of Cl^- or H_2O / OH^- to be oxidized), Cl^- oxidized because of concentrated solution/higher concentration / *OWTTE*;
(choice of Na^+ or H_2O / H^+ to be reduced), H_2O / H^+ reduced because Na^+ is a (much) weaker oxidizing agent/ Na^+ not reduced to Na in water / H^+ easier to reduce than Na^+ / *OWTTE*;

positive/+/anode
$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$;

negative/–/cathode
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq) / 2H^+(aq) + 2e^- \rightarrow H_2(g)$; ***[4]***
Penalize missing or incorrect states once only.
*Award only **[1]** out of the last two marks if electrodes not specified or if equations switched.*
Allow e instead of e^-.

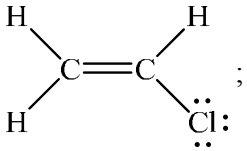
(c) *Positive/+/anode*
$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^- / H_2O(l) \rightarrow \frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$ /
$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$;

Negative/–/cathode
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$;
Ignore state symbols.
*Award only **[1]** if electrodes not specified or if equations switched.*
Allow e instead of e^-.

*Observations: **[2 max]***
blue colour of $Cu^{2+}(aq)$ fades;
Cu/metal deposited on negative/–/cathode/tin (jewellery);
gas produced/bubbles formed (at positive/+/anode);
pH of solution decreases/acidity increases (observed with indicator/pH paper); ***[4 max]***

9. (a) (i) colour change from yellow/orange/rust colour/red/brown to colourless; ***[1]***
No mark for change to clear, or for decolourized with no reference to original colour.

(ii) *Chloroethene:*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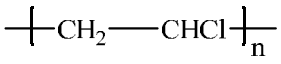
No mark if the lone pairs missing on Cl.
Accept lines, dots or crosses for e^- pairs.

Poly(chloroethene):

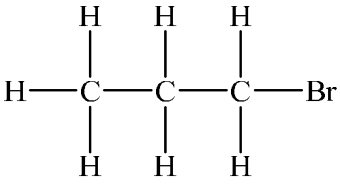

;

[2]

n and square brackets are not required.
Continuation bonds must be shown.

(iii) (hydration of ethene for the manufacture of) ethanol/ $C_2H_4 + H_2O \rightarrow C_2H_5OH$;
(synthesis of) CH_3COOH /ethanoic/acetic acid;
(synthesis of) ethylene glycol/1,2-ethanediol/ethane-1,2-diol;
(synthesis of) drugs/pesticides;
(hydrogenation of unsaturated oils in the manufacture of) margarine; ***[2 max]***
Accept other commercial applications.

(b) (i)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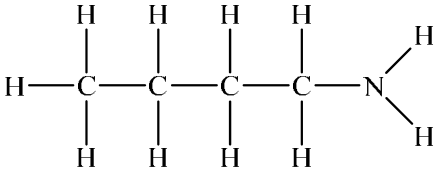

;

[1]

Accept $CH_3CH_2CH_2Br$. *Accept $CH_3CH_2CH_2CH_2NH_2$.*
Penalise missing H atoms.

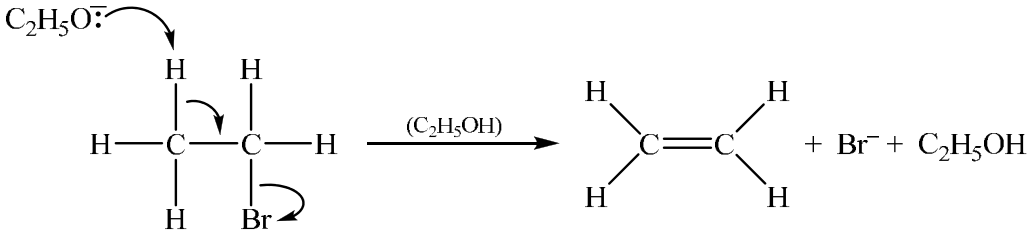
(ii) $CH_3CH_2CH_2Br + KCN \rightarrow CH_3CH_2CH_2CN + KBr$;
Accept ionic equation.

$CH_3CH_2CH_2CN + 2H_2 \rightarrow CH_3CH_2CH_2CH_2NH_2$;
Equation must be balanced for mark.
Accept $LiAlH_4$ in place of reaction with hydrogen.

For the second equation:
Ni (as catalyst);
heat/150 °C; ***[4]***

(c) (i) hot;
alcoholic OH^-/NaOH/KOH;
$C_2H_5Br + C_2H_5ONa \rightarrow C_2H_4 + NaBr + C_2H_5OH$ /
$C_2H_5Br + NaOH \rightarrow C_2H_4 + NaBr + H_2O$; ***[3]***
Accept ionic equation with $C_2H_5O^-$ or OH^-.

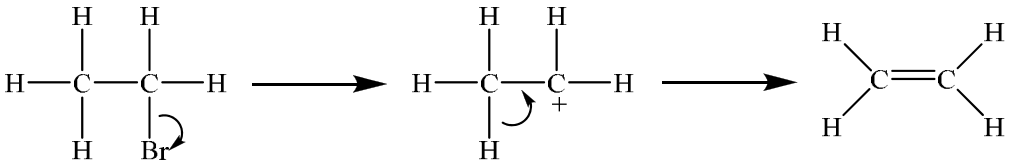
(ii) OH^- reacts with ethanol to form ethoxide ion/ $C_2H_5OH + OH^- \rightarrow C_2H_5O^- + H_2O$;



curly arrow going from lone pair/negative charge on O in $C_2H_5O^-$/$CH_3CH_2O^-$ to H on β–C;
Accept arrow origin from OH^- but do not allow curly arrow originating on H in OH^-.
Accept OH^- in place of $C_2H_5O^-$ (to form H_2O).

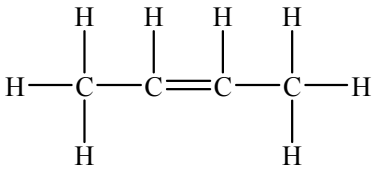
curly arrow going from CH bond to form C=C bond;
curly arrow showing Br leaving;
structural formula of organic product $CH_2=CH_2$;

*Award **[4 max]** for E1 mechanism (unstable primary carbocation)*

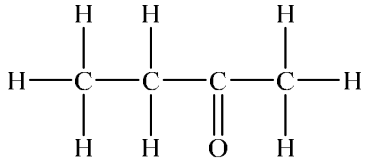


curly arrow showing Br leaving;
representation of primary carbocation;
curly arrow going from lone pair on O in H_2O to H on C adjacent to C^+ **and** curly arrow going from CH bond to form C=C bond;
structural formula of organic product $CH_2=CH_2$; ***[5]***

(d) (i)



/ $CH_3CH=CHCH_3$;



/ $CH_3CH_2COCH_3$;

[2]

Penalize missing H atoms once only.

(ii) $CH_3CH{=}CHCH_3 + H_2O \rightarrow CH_3CH(OH)CH_2CH_3$;

concentrated sulphuric acid/ H_2SO_4 / phosphoric acid/H_3PO_4 (catalyst) **and** heat/steam;

$3CH_3CH(OH)CH_2CH_3 + Cr_2O_7^{2-} + 8H^+ \rightarrow 3CH_3COCH_2CH_3 + 2Cr^{3+} + 7H_2O$;

Accept $CH_3CH(OH)CH_2CH_3 + [O] \rightarrow CH_3COCH_2CH_3 + H_2O$.

Accept C_2H_5 as CH_2CH_3.

dichromate(VI) (ion)/$Cr_2O_7^{2-}$ **and** acidic/H^+;

Accept MnO_4^- in place of $Cr_2O_7^{2-}$ for M3 and M4.

heat/reflux; ***[5]***