IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

MARKSCHEME

May 2007

CHEMISTRY

Higher Level

Paper 2

19 pages

Subject Details: Chemistry HL Paper 2 Markscheme

General

- Each marking point has a separate line and the end is signified by means of a semicolon (;).
- Alternative answers are separated by a slash (/) – this means that either answer is acceptable.
- Words that are underlined are essential for the mark.
- Material in brackets (…) is not needed for the mark.
- The order in which candidates score marks does not matter (unless stated otherwise).
- The use of ***OWTTE*** in a markscheme (the abbreviation for "or words to that effect") means that if a candidate's answer contains words different to those in the markscheme, but which can be interpreted as having the same meaning, then the mark should be awarded.
- Please remember that many candidates are writing in a second language, and that effective communication is more important than grammatical accuracy.
- In some cases there may be more acceptable ways of scoring marks than the total mark for the question part. In these cases, tick each correct point, and if the total number of ticks is greater than the maximum possible total then write the maximum total followed by **MAX**.
- In some questions an answer to a question part has to be used in later parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in later parts then "follow through" marks can be scored. Show this by writing **ECF** (error carried forward). This situation often occurs in calculations but may do so in other questions.
- Units for quantities should always be given where appropriate. In some cases a mark is available in the markscheme for writing the correct unit. In other cases the markscheme may state that units are to be ignored. Where this is not the case, penalize the omission of units, or the use of incorrect units, once only in the paper, and show this by writing **–1(U)** at the first point at which it occurs.
- Do not penalize candidates for using too many significant figures in answers to calculations, unless the question specifically states the number of significant figures required. If a candidate gives an answer to fewer significant figures than the answer shown in the markscheme, penalize this once only in the paper, and show this by writing **–1(SF)** at the first point at which this occurs.
- 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.
- 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 the question specifically asks for this. In some cases, where more complicated equations are to be written, more than one mark may be available for an equation – in these cases follow the instructions in the mark scheme.
- Ignore missing or incorrect state symbols in an equation unless these are specifically asked for in the question.
- Mark positively. Give candidates credit for what they have got correct, rather than penalizing them for what they have got wrong.
- If candidates answer a question correctly, but by using a method different from that shown in the markscheme, then award marks; if in doubt consult your Team Leader.

SECTION A

1. (a) *order of NO*: second/2 - [NO] doubled, rate $\times 4$ / *OWTTE*;
order of Br_2 : first/1 - as [Br_2] doubled, rate of reaction doubled / *OWTTE*; ***[2]***
Reason needed for each mark.

(b) rate = $k[\mathrm{NO}]^2[\mathrm{Br_2}]$; ***[1]***
Allow ECF from (a).

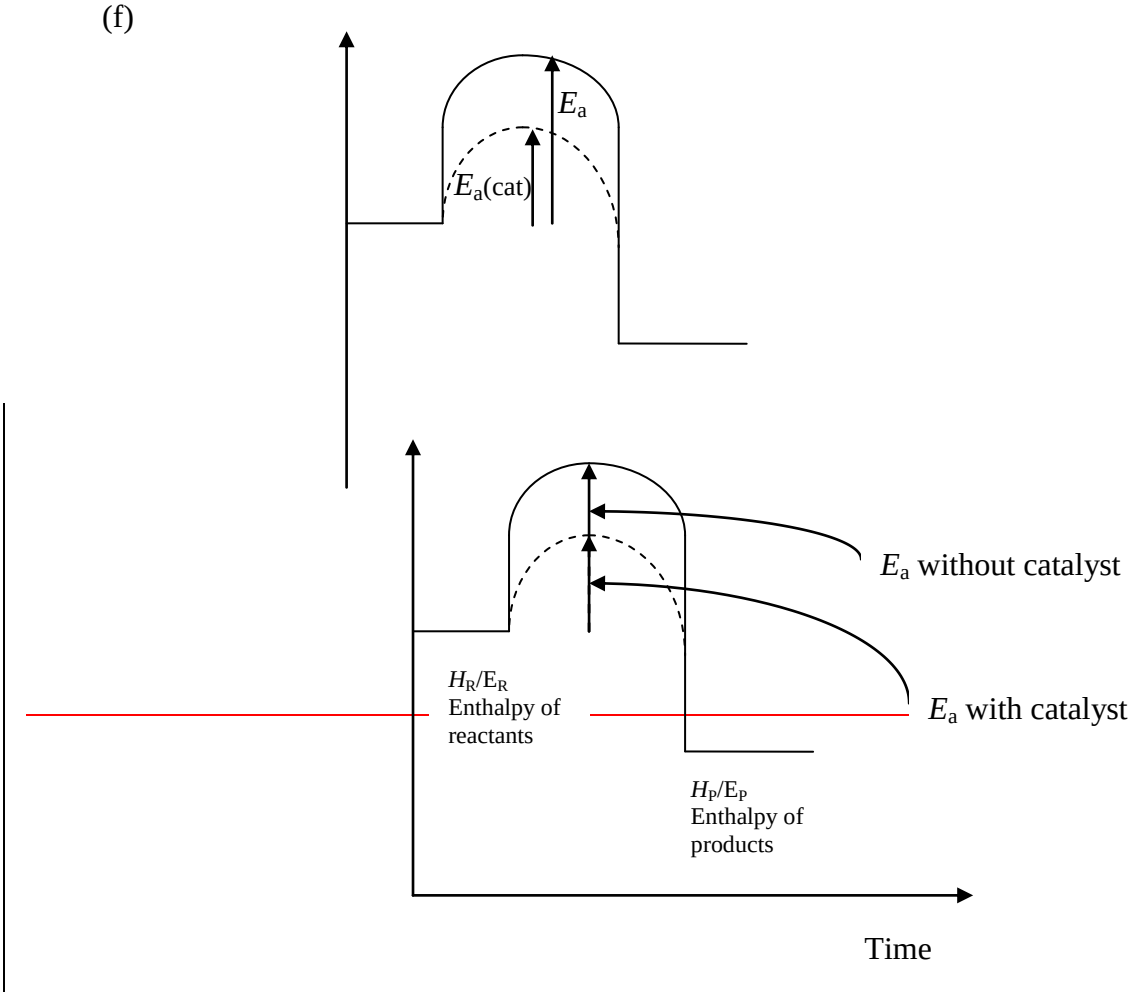
(c) $3.20\times10^{-3} = k\ (2.00\times10^{-2})^2 \times 5.00\times10^{-3}$
$k = 1.60\times10^{3}$;
$\mathrm{dm^6\ mol^{-2}\ s^{-1}}$; ***[2]***
Allow ECF from (b).

(d) (i) no effect / K changes only with temperature / OWTTE; ***[1]***

(ii) decrease (by a factor of 2); ***[1]***

(e) gases adsorb on surface of catalyst / provides surface for the reaction / OWTTE;
lowers activation energy / provides alternative pathway for reaction; ***[2]***

(f)



curve clearly showing E_a without catalyst (E_a);
curve clearly showing E_a with catalyst ($E_{a(cat)}$);

labelling for x axis; ***[3]***
Accept time / progress of reaction / course of reaction / OWTTE.

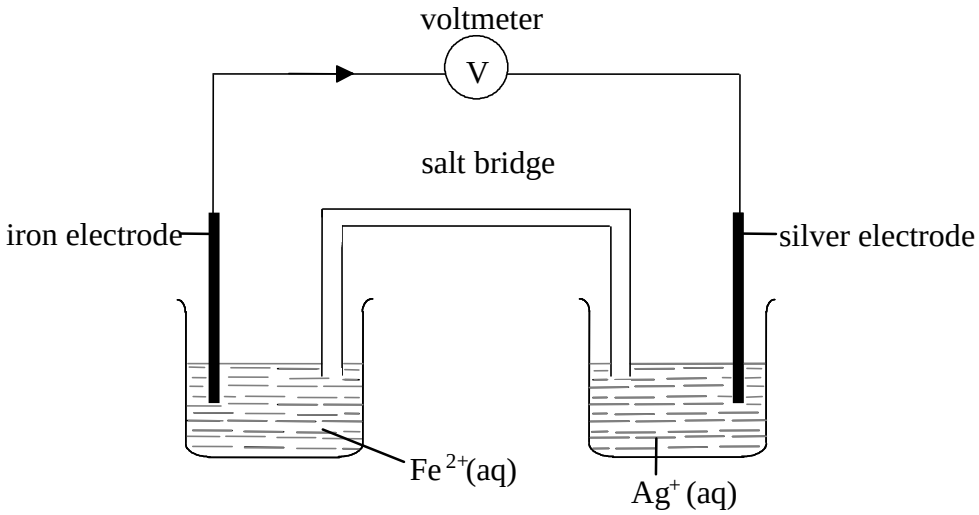
*Award **[2 max]** if an enthalpy level diagram for an endothermic reaction has been correctly drawn.*

2. (a) $Fe + 2Ag^+ \rightarrow Fe^{2+} + 2Ag$; ***[1]***
Ignore state symbols.
Accept $Fe + 3Ag^+ \rightarrow Fe^{3+} + 3Ag$

(b) the potential difference / EMF / Voltage between a standard half-cell and standard hydrogen electrode / *OWTTE*; ***[1]***

(c) (+) 1.24 (V); ***[1]***
ECF from (a).

(d) electron flow indicated on wires; ***[1]***
ECF from (a).



3. (a) *oxidizing agent*: (acidified) potassium permanganate(VII) / (H^+) and MnO_4^- and *reducing agent*: Sn^{2+}; ***[1]***
*Both oxidizing agent and reducing agent required for **[1]**.*

(b) $\underline{5}Sn^{2+} + \underline{2}MnO_4^- + \underline{16}H^+ \rightarrow \underline{5}Sn^{4+} + \underline{2}Mn^{2+} + \underline{8}H_2O$; ***[1]***

4. (a) 60.0 dm^3 CO_2;
80.0 dm^3 H_2O;
20.0 dm^3 O_2; ***[3]***
Apply –1(U).

(b) overall there will be no change to the pressure;
double absolute temperature and the pressure doubles;
double volume and the pressure halves;
Apply ECF if points 2 and 3 are incorrect.

OR

Use PV = nRT, Since n and R are constant;
V and T are both doubled;
P will remain unchanged;

OR

OWTTE *for mathematical interpretation*
e.g. T α P, therefore 2P;
V α 1/P, therefore ½ P;
No change to P, ½P x 2 P = P; ***[3]***

(c) (i) $n(C)\left(= n(CO_2) = 2.68 \text{ g} \div 44.01 \text{ g mol}^{-1}\right) = 0.0609 \text{ mol}$;
$n(H)\left(= 2 \times n(H_2O) = 0.657 \text{ g} \div 18.02 \text{ g mol}^{-1}\right) = 0.0729 \text{ mol}$;
$m(C) = 0.0609 \text{ mol} \times 12.01 \text{ g mol}^{-1} = 0.731 \text{ g}$
and $m(H) = 0.0729 \text{ mol} \times 1.01 \text{ g mol}^{-1} = 0.0736 \text{ g}$;
$m(O) = (1.00 - 0.731 - 0.0736)\text{g} = 0.195 \text{ g}$;

n(C)	n(H)	n(O)
0.0609	0.0730	$\frac{0.195}{16.00}$
0.0609	0.0730	0.0122
$\frac{0.0609}{0.0122}$	$\frac{0.0730}{0.0122}$	$\frac{0.0122}{0.0122}$
4.99	5.98	1.00 ;

empirical formula: C_5H_6O; ***[6]***
*For C_5H_6 award **[4 max]**.*
Steps used to arrive at the correct amounts (in moles) are required for full marks.

(ii) $M(\text{crocetin}) = 98.5 \text{ g} \div 0.300 \text{ mol} = 328 \text{ (g mol}^{-1})$;
$(\frac{328}{82.11} = 4)$
molecular formula: $C_{20}H_{24}O_4$; ***[2]***
ECF from (c) (i).

5. (a) an acid that partially dissociates/ionizes / doesn't fully dissociate/ionize; ***[1]***

(b) $CH_3CH_2COOH + H_2O \rightleftharpoons CH_3CH_2COO^- + H_3O^+ / CH_3CH_2COOH \rightleftharpoons CH_3CH_2COO^- + H^+$;
$\rightleftharpoons$ *required for mark.*
CH_3CH_2COOH and $CH_3CH_2COO^- / H_3O^+$ and H_2O; ***[2]***

(c) conductivity - propanoic acid will be lower because lower ion concentration / less dissociated;
reaction with metal/metal carbonate/metal hydrogencarbonate - propanoic acid will react slower/less vigorously because lower $[H^+]$ / less dissociated;
reaction with alkali - temperature change will be less for propanoic acid because lower $[H^+]$ / less dissociated; ***[2 max]***
*Award **[1]** mark each for two.*

(d) (pK_a (propanoic) = 4.87)
$K_a = \dfrac{[CH_3CH_2COO^-][H_3O^+]}{[CH_3CH_2COOH]}$;
$[H_3O^+] = 1.16 \times 10^{-3}$ (mol dm^{-3});
pH = 2.94; ***[3]***
*Award **[3]** for correct answer.*

SECTION B

6. (a) (i) shifts to the right/toward products / forward reaction favoured;
to consume excess Br^- added; ***[2]***
Do not accept "due to Le Chatelier's principle".

(ii) shifts to the left/toward reactants / reverse reaction favoured;
NaOH reacts to consume H^+ / an increase in the amount of H_2O resulting from neutralization; ***[2]***
Do not accept "due to Le Chatelier's principle".

(iii) no effect;
catalyst increases the rate of the forward and backward reactions equally / lowers the activation energy of both forward and backward reaction equally / lowers E_A so rate of forward and backward reactions increase equally; ***[2]***

(b) equilibrium constant decreases;
forward reaction is exothermic/produces heat / reverse reaction is endothermic/absorbs heat; ***[2]***

(c) colour change from red-brown to darker red-brown of Br_2 / red-brown colour intensifies / OWTTE;
equilibrium position shifts to the right/products;
to consume H^+; ***[3]***

(d) the enthalpy change when one mole of compound is formed from its elements in their (standard state);
at (standard conditions of) 298 K / 25 °C and 101 325 Pa / 1 atm; ***[2]***

(e) (i) $\Delta H_P = (4 \times -242 + 4 \times -394)\ kJ\ mol^{-1}$;
$\Delta H_R = 1\ kJ\ mol^{-1}$;
$\Delta H^\ominus = (\Sigma \Delta H^\ominus_P - \Sigma \Delta H^\ominus_R) = -2545 / -2.55 \times 10^3 / -2550\ (kJ\ mol^{-1})$; ***[3]***
Allow ECF.

(ii) products more stable than reactants;
bonds are stronger in products than reactants / $H_P < H_R$ / enthalpy / stored energy of products less than reactants; ***[2]***

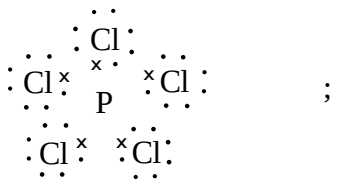
(iii) same/equal, because the same bonds are being broken and formed; ***[1]***

(f) (i) $S_P = (4\times189 + 4\times214)$ J K^{-1} mol^{-1} and $S_R = (306 + 6\times205)$ J K^{-1} mol^{-1};
$\Delta S^{\ominus}$ (=$S^{\ominus}{}_P$ - $S^{\ominus}{}_R$) = + 76 / +76.0 (J K^{-1} mol^{-1}); ***[2]***

(ii) $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$
$= -2545 - (298\times76\times10^{-3})$;
$= -2568 / -2570 / -2.57x10^{3}$ kJ mol^{-1}; ***[2]***
Allow ECF.
Appy –1(U).

(g) all reactions are spontaneous;
ΔG is negative (at high temperatures and low temperatures); ***[2]***

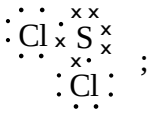
7. (a) (i)



;

trigonal bipyramidal;
90^{o} ;
120^{o};
180^{o};
*Award **[1]** for 2 correct bond angles.* ***[3]***

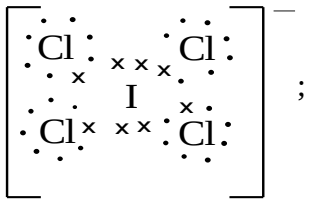
(ii)



;

Bent / angular / V-shaped;
100^{o} – 107^{o};
[3]

(iii)



;

square planar;
90^{o}; ***[3]***
No ECF allowed.
*Penalize once only **[1]** mark for missing lone pairs.*
Accept structures using lines to represent bonding and lone electron pairs.

(b) A
covalent bonding **and** network structure / giant covalent;
high melting point / due to strong bonds throughout the structure;
(no conductivity) due to lack of mobile charged ions/electrons / charged particles;

B
ionic bonding (3D/lattice structure);
high melting point /due to strong bonds/interactions / electrostatic forces between ions throughout structure/crystal;
(conductivity in liquid state and aqueous solutions) due to the presence of mobile ions; ***[6]***

(c) (i) mixing/combining of atomic orbitals / OWTTE; ***[1]***

(ii) C_{60} *fullerene*: sp^2;
graphite: sp^2;
diamond: sp^3; ***[3]***

(iii) each carbon atom is bound to 3 other carbon atoms / π bonding;
leading to delocalized electrons; ***[2]***

(d) (i) sigma/σ bonds are formed by orbitals overlapping end to end / along the internuclear axis / along line directly between nuclei;
Accept suitable diagram.
pi/π bonds are formed by p orbitals overlapping sideways; ***[2]***
Accept suitable diagram.

(ii) 12 sigma bonds;
2 pi bonds; ***[2]***

8. (a) (i) to produce positively charged ions;
by the bombardment of fast moving electrons; ***[2]***

(ii) magnetic field at right angles to path of ions / accept suitably labelled diagram;
moves ions in curve path / deflects ions;
dependent on mass/charge ratio;
*Award **[1]** each for any 2 points.* ***[2 max]***

(iii) acceleration of the ions by electric field / towards negative plate/cathode; ***[1]***

(b) (i) atoms with the same number of protons/positive charges/atomic number but different number of neutrons/mass number; ***[1]***

(ii) $A_r(\text{Rb}) = 85.47 = \frac{85x + 87(100 - x)}{100}$;
Accept other valid mathematical alternatives
$^{85}\text{Rb} = 76.5$ and $^{87}\text{Rb} = 23.5\,\%$; ***[2]***

(iii) mass;
density;
boiling point;
melting point;
rate of diffusion in the gas phase;
enthalpy of vaporization;
enthalpy of fusion;
rate of reaction in the gas/liquid phase; ***[1 max]***
Any two for one mark

(iv) Si: $1s^2 2s^2 2p^6 3s^2 3p^2$;
Fe^{3+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$;
P^{3-} : $1s^2 2s^2 2p^6 3s^2 3p^6$; ***[3]***
*Allow **[1 max]** for 3 correct abbreviated structures using noble gas symbols.*

(c) (i) the ability of an atom to attract a <u>bonding</u> pair of electrons;
inert / do not react / do not attract electrons / stable electron configuration / full outer electron shell / do not form bonds; ***[2]***

(ii) electronegativity increases (along period 3 from Na to Cl);
number of protons increases / nuclear charge increase / core charge increase / size of atom decreases; ***[2]***
Do not accept "greater nuclear attraction".

(iii) Cl_2 stronger oxidising agent;
Cl_2 has greater attraction for electrons / has a higher electron affinity; ***[2]***
Accept converse statements for Br_2.

(d) MgO – basic oxide / alkali;
$MgO + 2HCl \rightarrow MgCl_2 + H_2O / MgO + H_2O \rightarrow Mg(OH)_2$;

Al_2O_3 – amphoteric oxide / acidic and basic oxide;
$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$;
$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^- / Al_2O_3 + 2OH^- \rightarrow 2AlO_2^- + H_2O$;

P_4O_6 – acidic oxide;
$P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$; ***[7]***
All equations must be balanced.

9. (a) a hydrocarbon that contains at least one C=C (or C≡C)/carbon-carbon double bond (or triple bond)/carbon to carbon multiple bond; ***[1]***
Do not accept just "double bond".

(b) $C_2H_4 + H_2O \rightarrow C_2H_5OH$;
addition/hydration reaction; ***[2]***

(c) heat under reflux;

EITHER

potassium dichromate(VI) / $K_2Cr_2O_7$ / $Cr_2O_7^{2-}$ and acidified / H^+;
orange to green;

OR

potassium permanganate / manganate(VII) / $KMnO_4$ / MnO_4^- and acidified / H^+;
purple to colourless;
Penalise wrong oxidation state, but not missing oxidation state.

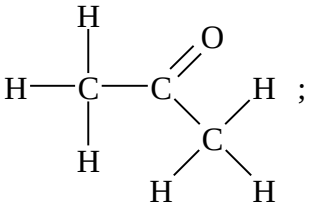
ethanoic acid; ***[4 max]***

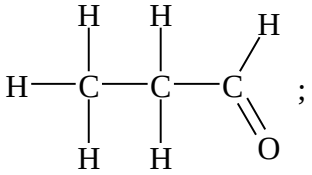
(d) $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$;
accept equations including H^+.
Reversible arrow not required for the mark.
sulfuric acid / H_2SO_4 / (ortho)phosphoric acid / H_3PO_4;
Z – ethyl ethanoate;
solvent / flavouring / perfumes / plasticizers; ***[4]***

(e) similar absorption band: 1680 – 1750 cm^{-1} / C=O bond;
differences: **X –** absorption at 2500 – 3300 cm^{-1} / O–H bond;
Z absorption at 1000 – 1300 cm^{-1} / C–O bond; ***[3]***

(f) **Y** is ethanal;
similarity: both **X** and **Y** have two peaks in the ratio of 3 : 1;
differences: **Y** has a peak at ~ 9.7 ppm for CHO / **X** has a peak at ~11.5 ppm for COOH; ***[3]***

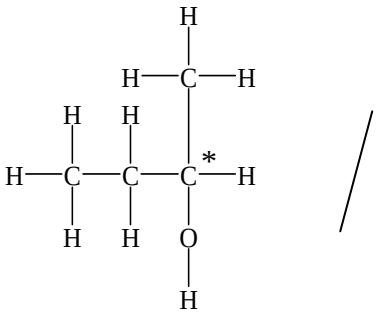
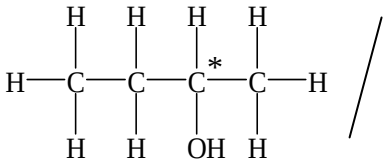
(g) (i) same molecular formula but different structural formulae / arrangement of atoms within a molecule / OWTTE; ***[1]***

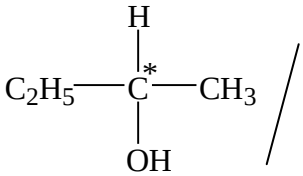
(ii) CH_3COCH_3 /  ;

CH_3CH_2CHO /  ; ***[2]***

Accept unsaturated alcohol and cyclic alcohol as alternative answers.
*If more than two correct isomers given – no penalty – but a third incorrect structure cancels a correct one. i.e. two correct, one incorrect equals **[1]**.*

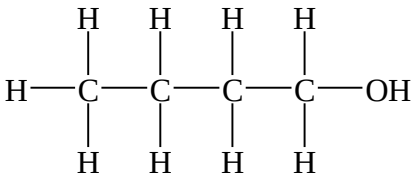
(iii) isomers that can rotate plane polarized light in opposite directions;
Accept two molecules/compounds, which are mirror images of each other.
Do not accept bend, reflect plane-polarized light.

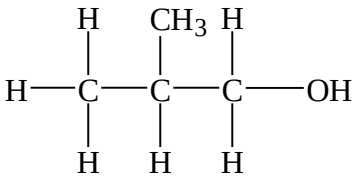
 /  /

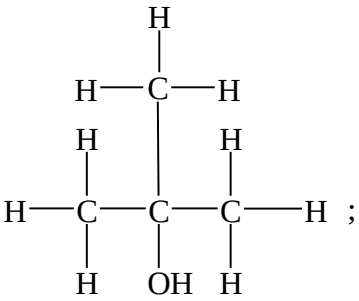
 / other correct structure;

correct identification of chiral carbon (*); ***[3]***

(iv)

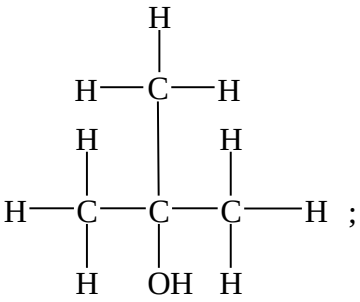






*Award **[1]** mark for 3 structures*

2-methylpropan-2-ol /



[2]

*Penalize **[1]** mark for the omission of H in (g) (i) to (iv).*