N11/4/CHEMI/HP2/ENG/TZ0/XX/M

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MARKSCHEME

November 2011

CHEMISTRY

Higher Level

Paper 2

22 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. 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 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) *Ionic:*
(electrostatic) attraction between oppositely charged ions/cations and anions/positive and negative ions;
Do not accept answers such as compounds containing metal and non-metal are ionic.

Metallic:
(electrostatic attraction between lattice of) positive ions/cations/nuclei and delocalized electrons / (bed of) positive ions/cations/nuclei in sea of electrons / *OWTTE*; ***[2]***

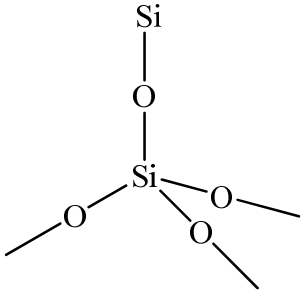
(b) (i) *T*: 4 **and** *m*: 3 **and** *p*: 3; ***[1]***

(ii) $n = (65.0 / 65.02) = 1.00\,(\text{mol})$; ***[1]***
No penalty for using whole number atomic masses.

(iii) $n(\text{N}_2) = \left(\frac{3}{2} \times 1.00 = \right) 1.50\,(\text{mol})$;
$T = \left((25.00 + 273.15) = \right) 298.15\,\text{K} / \ (25.00 + 273) = 298\,\text{K}$;
$p = 1.08 \times 1.01 \times 10^5\ \text{Pa} / 1.08 \times 1.01 \times 10^2\ \text{kPa} / 1.09 \times 10^5\ \text{Pa} / 1.09 \times 10^2\ \text{kPa}$;
$V = \frac{nRT}{p} = \frac{(10^3)(1.50)(8.31)(298.15 / 298)}{(1.08 \times 1.01 \times 10^5)} = 34.1\,(\text{dm}^3)$; ***[4]***
*Award **[4]** for correct final answer.*
*Award **[3 max]** for 0.0341 (dm^3) or 22.7 (dm^3).*
*Award **[3 max]** for 34.4 (dm^3).*
*Award **[2 max]** for 22.9 (dm^3).*
*Award **[2 max]** for 0.0227 (dm^3).*
*Award **[2 max]** for 0.034 (dm^3).*

(c) (i) sodium could react violently with any moisture present / sodium is (potentially) explosive / sodium (is dangerous since it is flammable when it) forms hydrogen on contact with water / *OWTTE*; ***[1]***
Do not accept answers such as sodium is dangerous or sodium is too reactive.

(ii) *Structure:*
drawing of giant structure showing tetrahedrally arranged silicon;
Minimum information required for mark is Si and 4 O atoms, in a tetrahedral arrangement (not 90° bond angles) but with each of the 4 O atoms showing an extension bond.



Bonding:
(giant/network/3D) covalent; ***[2]***

(d) (i) $\left(\frac{34.1}{0.0400}\right) = 853\ \text{dm}^3\ \text{s}^{-1} / \left(\frac{1.50}{0.0400}\right) = 37.5\ \text{mol}\ \text{s}^{-1}$; ***[1]***
Accept 851 $dm^3\ s^{-1}$.
Units required for mark.

(ii) more energetic collisions / more species have energy $\geq E_a$; ***[1]***
Allow more frequent collisions / species collide more often.

2. (a)

Symbol	$^{59}Co^{3+}$	^{60}Co	^{125}I
Number of protons	27	27	53
Number of neutrons	32	33	72
Number of electrons	24	27	53

[2]

*Award **[2]** for all four correct.*
*Award **[1]** for two or three correct.*

(b) Co-60 emits (penetrating) gamma radiation/rays / *OWTTE*; ***[1]***
Allow because Co-60 emits radiation which kills/treats cancer cells.
Do not allow answers such as Co-60 is radioactive or Co-60 treats cancer as single statements.

(c) $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^6$; ***[1]***
Do not award mark for [Ar]$3d^6$.
Do not allow $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^1\,3d^5$.

3. (a) energy required to break (1 mol of) a bond in a gaseous molecule/state;
Accept energy released when (1 mol of) a bond is formed in a gaseous molecule/ state / enthalpy change when (1 mol of) bonds are formed or broken in the gaseous molecule/state.

average values obtained from a number of similar bonds/compounds / *OWTTE*; ***[2]***

(b) $CH_3(CH_2)_3OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$; ***[1]***
Allow C_4H_9OH or $C_4H_{10}O$ for $CH_3(CH_2)_3OH$.
Ignore state symbols.

(c) *Bonds broken:*
$(6)(O{=}O) + (3)(C{-}C) + (1)(O{-}H) + (1)(C{-}O) + (9)(C{-}H)$ /
$((6)(498) + (3)(347) + (1)(464) + (1)(358) + (9)(413) =) 8568\ (kJ\ mol^{-1})$;

Bonds formed:
$(8)(C{=}O) + (10)(O{-}H)$ / $((8)(746) + (10)(464) =) 10608\ (kJ\ mol^{-1})$;

$\Delta H = (8568 - 10608 =) - 2040\ (kJ\ mol^{-1})$; ***[3]***
*Award **[3]** for correct final answer.*
*Award **[2]** for $+2040\ (kJ\ mol^{-1})$.*

(d) hydrogen bonding in butan-1-ol;
stronger than dipole-dipole attractions in butanal; ***[2]***
Accept converse argument.
Do not penalize dipole-dipole bonding instead of dipole-dipole attractions.

4. (a) $(K_w =)[H^+(aq)][OH^-(aq)]$; ***[1]***

Do not penalize if (aq) not stated.
H_3O^+ may be given instead of H^+.
Do not mark awarded if square brackets are omitted or are incorrect.

(b) (i) $(pK_b = (14.00 - 7.52 =)\ 6.48$ and) $K_b = (10^{-6.48}) = 3.3 \times 10^{-7}$; ***[1]***

Do not award mark if answer just left as $10^{-6.48}$.

(ii) $K_b = \dfrac{[HOCl][OH^-]}{[OCl^-]} = \dfrac{x^2}{0.705} = 3.3 \times 10^{-7}$;

$[OH^-] = 4.8 \times 10^{-4} (mol\ dm^{-3})$;

*Award **[2]** for correct value of $[OH^-]$.*

OCl^- only partially hydrolysed / *x* negligible (compared to $[OCl^-]$) / *OWTTE*; ***[3]***

Accept $[HOCl] = [OH^-]$.

(iii) $[H_3O^+]/[H^+] = \dfrac{K_w}{[OH^-]} = \dfrac{1.00 \times 10^{-14}}{4.8 \times 10^{-4}} = 2.1 \times 10^{-11}$;

$pH = (-\log_{10}[H_3O^+]/-\log_{10}[H^+] = -\log_{10}(2.1 \times 10^{-11}) =) 10.68$; ***[2]***

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

5. (a) negative;
liquid more ordered than gaseous phase or *vice-versa* / *OWTTE*; ***[2]***

(b) (i) $\Delta H_f^\ominus$ of an element (in its most stable state) is zero (since formation of an element from itself is not a reaction) / *OWTTE*; ***[1]***

Do not allow an answer such as because they are elements.

(ii) $\Delta H^\ominus (= (1)(-20.6) - (1)(-53.1)) = 32.5\ (kJ\ mol^{-1}) / 32500\ (J\ mol^{-1})$; ***[1]***

Allow 32.5(kJ) or 3.25×10^4 (J).

(iii) $\Delta G^\ominus (= (1)(-33.6) - (1)(-53.6)) = 20.0\ (kJ\ mol^{-1}) / 20000\ (J\ mol^{-1})$;

Allow 20.0(kJ) or 2.00×10^4 (J).

non-spontaneous; ***[2]***

(iv) $\Delta S^\ominus (= (\Delta H^\ominus - \Delta G^\ominus)/T = (32.5 - 20.0)(1000)/298) = 41.9\ (J\ K^{-1}\ mol^{-1}) /$
$4.19 \times 10^{-2}\ (kJ\ K^{-1}\ mol^{-1})$; ***[1]***

Allow 41.9($J\ K^{-1}$) or 4.19×10^{-2} ($kJ\ K^{-1}$).

(v) $T (= \Delta H/\Delta S = (32.5 \times 1000)/(41.9)) = 776\ (K)$; ***[1]***

SECTION B

6. (a) *Na*, *Mg*: basic
Al: amphoteric
Do not accept amphiprotic.

Si to Cl: acidic
*Award **[2]** for all three listed sets correct, **[1]** for one or two listed sets correct.*
*Award **[1]** for stating oxides become more basic towards left/Na and more acidic towards right/Cl.*
Do not penalize incorrect formulas of oxides.

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$;
$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$; ***[4]***
Ignore state symbols.
Allow $P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(aq)$.

(b) (i) $MgCl_2$ conducts **and** PCl_5 does not;
$MgCl_2$ ionic **and** PCl_5 covalent/molecular/(consists of) molecules;
*Award **[1 max]** for $MgCl_2$ conducts **and** ionic.*
*Award **[1 max]** for PCl_5 does not conduct **and** covalent/molecular/(consists of molecules).*

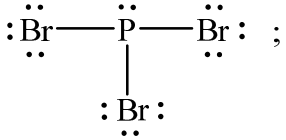
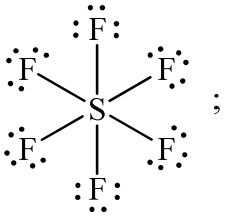
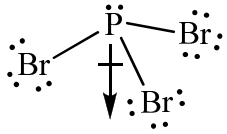
ions can move in liquid (in $MgCl_2$) / *OWTTE*; ***[3]***

(ii) *$MgCl_2$*:
pH = 6;
Accept pH range from 5 to <7.

high charge density on Mg^{2+} releases H^+ from water /
$[Mg(H_2O)_6]^{2+} \rightleftharpoons [Mg(H_2O)_5(OH)]^+ + H^+$ / forms slightly acidic solution because of salt hydrolysis / salt of a weak base and a strong acid;
Do not penalize if equilibrium sign is not given.

PCl_5:
pH = 0 to 3;
HCl formed / <u>strong</u> acid formed / forms phosphoric acid/ H_3PO_4 **and** hydrochloric acid/HCl; ***[4]***
*Allow forms phosphoryl chloride/$POCl_3$ **and** hydrochloric acid/HCl.*
Do not penalize if an incorrect product other than H_3PO_4 is given as long as HCl is mentioned (either in words or in an equation).

(c)

	PBr_3	SF_6
(i)	*Lewis structure:*  ; *Allow* x*'s, dots or lines to represent electrons.* *Penalize missing lone pairs on terminal atoms once only for the two Lewis structures.*	*Lewis structure:*  ; *Allow* x*'s, dots or lines to represent electrons.* *Penalize missing lone pairs on terminal atoms once only for the two Lewis structures.*
(ii)	*Shape:* trigonal/triangular pyramidal; *Bond angle:* less than 109.5° ; *Allow any angle less than 109.5° but greater than or equal to 100° (experimental value is 101°).*	*Shape:* octahedral; *Bond angle:* 90° ; *Ignore extra correct bond angles (e.g. 90° and 180° scores but not 90° and 120°).*
(iii)	*Polarity:* polar **and** *Explanation:* net dipole (moment) / polar PBr bonds **and** molecule not-symmetrical / bond dipoles do not cancel / asymmetric distribution of electron cloud /  / *OWTTE*;	*Polarity:* non-polar **and** *Explanation:* no net dipole (moment) / polar SF bonds but molecule symmetrical / bond dipoles cancel / symmetric distribution of electron cloud / *OWTTE*;

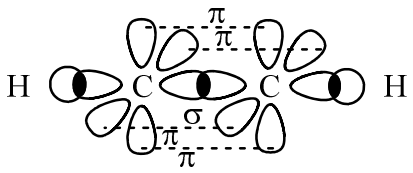
[8]

Do not allow ECF in this question from incorrect Lewis structure.
Allow ***[1 max]*** *for stating that PBr_3 is polar and SF_6 is non-polar without giving a reason or if explanations are incorrect.*
Allow polar bonds do not cancel for PBr_3 and polar bonds cancel for SF_6.
Do not allow asymmetric molecule as reason for PBr_3 or symmetric molecule for SF_6 as reason alone.

(d) (i) σ *bond:*
end-on/axial overlap with electron density between the two carbon atoms/nuclei / end-on/axial overlap of orbitals so shared electrons are between atoms / *OWTTE*;

π *bond:*
sideways/parallel overlap of p orbitals with electron density above **and** below internuclear axis/σ bond / sideways/parallel overlap of p orbitals so shared electrons are above **and** below internuclear axis/σ bond / *OWTTE*; ***[2]***

Marks can be scored from a suitable diagram.
*Award **[1 max]** for stating end-on/axial overlap for σ and sideways/parallel overlap for π only i.e. without mentioning electron density **OR** stating electron density between the two atoms/nuclei for σ and above and below internuclear axis for π.*



(ii) 11 σ **and** 3 π; ***[1]***

(iii) (strong) intermolecular hydrogen bonding in *trans* but (strong) intramolecular hydrogen bonding in *cis* so attraction between different molecules is less (hence lower melting point); ***[1]***
Allow between molecules for intermolecular and within molecules for intramolecular.

(iv) in *cis* two carboxylic acid groups close together so on heating cyclic anhydride forms (with elimination of water) / *OWTTE*; ***[1]***
Allow converse argument for trans.

(e) O of OH sp^3 **and** O of C=O sp^2; ***[1]***
Oxygens must be identified.

7. (a) *Oxidation:* increase in oxidation number **and** *Reduction:* decrease in oxidation number / *OWTTE*; ***[1]***

(b) Cr_2O_3 :
chromium(III) oxide;
Do not award mark for chromium oxide.

CrO_3 :
chromium(VI) oxide; ***[2]***
Do not award mark for chromium oxide.
Do not award any marks if chromium oxide without Roman numerals is given for both.

(c) (i) substance reduced / causes other substance to be oxidized / increase oxidation number of another species / gains electrons / *OWTTE*; ***[1]***

(ii) *Oxidizing agent:*
$Cr_2O_7^{2-}$ / dichromate (ion);

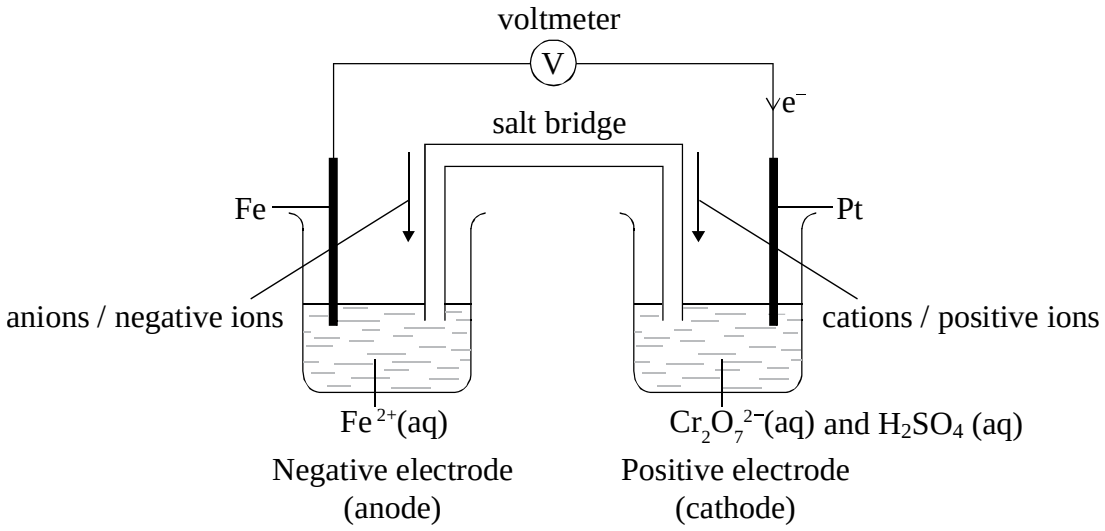
$Cr_2O_7^{2-}(aq) + I^-(aq) + 8H^+(aq) \rightarrow 2Cr^{3+}(aq) + IO_3^-(aq) + 4H_2O(l)$ ***[3]***

*Award **[1]** for coefficients: $Cr_2O_7^{2-}(aq)$, $I^-(aq)$, $2Cr^{3+}(aq)$, $IO_3^-(aq)$.*

*Award **[1]** for coefficients: $8H^+(aq)$, $4H_2O(l)$.*

*Award **[1 max]** if coefficients of reactants only correct i.e. $Cr_2O_7^{2-}$, I^- and $8H^+$.*
*Award **[1 max]** if coefficients of products only correct i.e. $2Cr^{3+}$, IO_3^- and $4H_2O$.*
*Award **[1 max]** for correct reactants and products.*
Ignore state symbols.

(d) (i)



Voltaic cell showing:
labelled positive electrode (cathode) **and** negative electrode (anode);
direction of electrons in external circuit **and** direction of ions in salt bridge;
Award mark if correct direction of electrons is indicated but e^- not labelled in external circuit.
Allow e instead of e^-.
Cations/positive ions and anions/negative ions must be identified in salt bridge.
Allow correct movement of ions in electrolyte instead of movement of ions in salt bridge (e.g. Fe^{2+} from Fe at negative electrode/anode etc.).
If both movement of ions in salt bridge and movement of ions in electrolyte is given but one is incorrect do not award mark.

Positive electrode (cathode):
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$;

Negative electrode (anode):
$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$;

Penalize $\rightleftharpoons$ once only.
Penalize once only if electrodes or equations reversed.
For both electrodes allow e instead of e^-.

Overall cell reaction:
$Cr_2O_7^{2-}(aq) + 3Fe(s) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3Fe^{2+}(aq) + 7H_2O(l)$; ***[5]***
Ignore state symbols throughout (d) (i).

(ii) potential under standard conditions relative to standard hydrogen electrode/SHE; ***[1]***
Reference must be made to standard conditions.
Instead of standard conditions allow either solute concentration of 1 mol dm^{-3}/1 M/1 mol L^{-1} or 100 kPa/10^5 Pa for gases.
Allow 1 bar for 100 kPa/10^5 Pa.
Allow 1 atm/1.01×10^5 Pa.
Allow voltage instead of potential.

(iii) (+)1.78 (V); ***[1]***

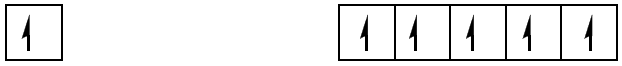
(e) (i) catalysts;
variable oxidation state/numbers;
Allow variable valency.

magnetic (properties);
(form) coloured ions/compounds;
Allow just coloured.

(form) complexes/complex ions; ***[2 max]***
Allow other metallic physical properties such as high densities/high melting points etc.
Allow partially filled/incomplete d subshell/sub-level.

(ii) dative (covalent)/coordinate;
Lewis base / (species/ion/molecule with) lone/non-bonding pair; ***[2]***

(iii) 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 / 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.

(iv) 

[1]

Accept half-arrows or full arrows and boxes in reverse order.
Do not penalize if additional sub-levels are shown, if sub-levels are not labelled or if no boxes are drawn (providing system of arrows correct).
Do not award mark if sub-levels are incorrectly labelled.
Orbital diagram may also be represented with sub-levels shown at different relative energy positions.

(f) *Positive electrode (anode):* chromium;
Allow lead/titanium/platinum/graphite.

Negative electrode (cathode): object to be plated;
Allow specific example here e.g. spoon.

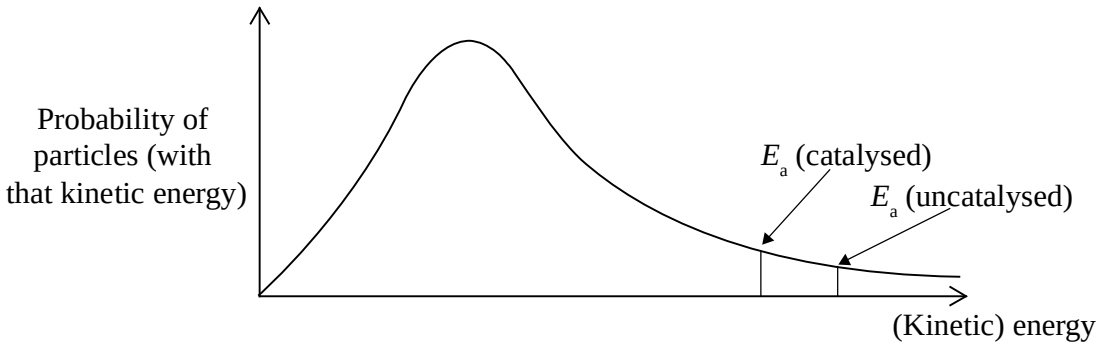
Electrolyte: $Cr^{3+}(aq)$; ***[3]***
Allow (mixture of) $Cr^{3+}(aq)$ ***and*** $CrO_4^{2-}(aq)$*/chromate/chromic acid/*H_2CrO_4.
Ignore state symbols.
Allow any soluble salt of Cr^{3+}.

8. (a) minimum energy needed (by reactants/colliding particles) to react/start/initiate a reaction; ***[1]***
Allow energy difference between reactants and transition state.

(b) catalyst;
regenerated at end of reaction / *OWTTE*; ***[2]***

(c) (i) (system) absorbs/takes in heat from surroundings / *OWTTE*; ***[1]***
Allow standard enthalpy change/ $\Delta H^{\ominus}$ *positive.*
Allow bond breaking more energetic then bond formation / OWTTE.
Absorbs/takes in heat alone not sufficient for mark.

(ii) *Curve showing:*
general shape of Maxwell-Boltzmann energy distribution curve;
correct position of E_a (catalysed) **and** E_a (uncatalysed);
labelled y-axis: probability of particles (with that kinetic energy) **and** *labelled x-axis:* (kinetic) energy; ***[3]***
Allow number/fraction/proportion of particles (with kinetic energy) for y-axis label, but do not allow amount or particles.



Award ***[2 max]*** *if a second curve is drawn, but at a higher temperature, M2 will not be scored here.*

(d) (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) pressure is lower/moderate **and** temperature is higher in Haber process / ~ 200 atm (pressure) **and** ~ 700 K (temperature) used in Haber process;

Pressure:
high pressure shifts equilibrium to right;
high pressure (faster rate but) expensive/dangerous / greater capital and running costs;

Temperature:
low temperature shifts equilibrium (even further) to right;
low temperature gives slower rate (but high yield);

high pressure increases yield **and** lower temperature decreases rate;
Accept converse argument.

(not possible to have high yield and fast rate simultaneously therefore) compromise needed / *OWTTE*; ***[4 max]***

(e) (i) dative (covalent)/coordinate;
carbon monoxide/CO / hydronium (ion)/ H_3O^+ / ammonium (ion)/ NH_4^+ / aluminium chloride/Al_2Cl_6 / any relevant transition metal complex (*e.g.* $[Ni(NH_3)_6]^{2+}$); ***[2]***
Accept $AlCl_3$.

(ii) rate $= k[BF_3][NH_3]$;
second (order)/2°;
$k = 3.40\ dm^3\ mol^{-1}\ s^{-1}$; ***[3]***
Allow units of L mol^{-1} s^{-1} or M^{-1} s^{-1}.
Units required for mark.

(f) (i) N_2O_2; ***[1]***

(ii) ($[H_2]$ appears in rate expression so) step 2 rate-determining/rds/slow step; ***[1]***
Allow "since step 1 involves 2NO and step 2 involves H_2 and as all 3 molecules are involved in rate expression, then two steps must have approximately same rate" / OWTTE.

(g) ($k_2 >> k_1$ so) step 1 rate-determining/rds/slow step;
two molecules of NO_2 involved in step 1 consistent with rate expression / rate of overall reaction must equal rate of step 1 which is rate = $k_1 [NO_2]^2$ / *OWTTE;* ***[2]***

(h) $E_a = -R \times m$;

measurement of gradient from **two** points on line;

Accept a gradient in range -2.14×10^4 *K to* -2.27×10^4 (K).

correct answer for E_a;

correct units kJ mol^{-1}/J mol^{-1} corresponding to answer; ***[4]***

Allow kJ or J.

A typical answer for $E_a = 1.85 \times 10^2$ *kJ* mol^{-1}.

Allow answers for E_a *in range* 1.75×10^2 *kJ* mol^{-1} *to* 1.91×10^2 *kJ* mol^{-1}.

*Award **[4]** for correct final answer with some working shown.*

*Award **[2 max]** for correct final answer without any working shown.*

9. (a) same functional group;
successive/neighbouring members differ by CH_2;
same general formula;
similar chemical properties;
gradation in physical properties; ***[2 max]***

(b) (i) ***D***: 4-methylpentan-1-ol;
Allow 4-methyl-1-pentanol.
E: 4-methylpentanal;
F: 4-methylpentanoic acid;
G: 4-methylpentyl ethanoate; ***[2 max]***
Allow 4-methylpentyl acetate.
*Award **[2]** for all four correct, **[1 max]** for two or three correct.*
*Award **[1 max]** if all suffices correct but prefix (4-methyl or pent) not correct.*

(ii) $(CH_3)_2CHCH_2CH_2CON(CH_3)_2$; ***[1]***
Allow full or condensed structural formula.
Allow formation of $(CH_3)_2CHCH_2CH_2CO_2^-(CH_3)_2NH_2^+$ salt (as amide only forms on strong heating at ~200 °C).
Penalize missing hydrogens or incorrect bonds (e.g. C–HO, N–HC) once only in (b) (ii), (d) (i) and (e).

(iii) *For both reactions reagents*:
named suitable <u>acidified</u> oxidizing agent;
Suitable oxidizing agents are potassium dichromate(VI)/$K_2Cr_2O_7$ / sodium dichromate(VI)/$Na_2Cr_2O_7$ / dichromate/$Cr_2O_7^{2-}$ / potassium manganate(VII)/ potassium permanganate/$KMnO_4$ / permanganate/manganate(VII)/MnO_4^-.
Accept H^+/H_2SO_4 instead of sulfuric acid and acidified.
Allow potassium dichromate or sodium dichromate (i.e. without (VI)) or potassium manganate (i.e. without (VII).

Conditions:
distillation for **D** to **E and** reflux for **D** to **F**; ***[2]***
*Award **[1 max]** if correct reagents and conditions identified for one process only.*

(iv) *Volatility*:
E more volatile than **F**;
hydrogen bonding in carboxylic acid/**F**; ***[2]***
Accept converse argument.

(c) (i) $\left(\left(\frac{2\times1.01}{18.02}\right)(0.089)=\right)1.0\times10^{-2}$ g H **and** $\left(\left(\frac{12.01}{44.01}\right)(0.872)=\right)2.38\times10^{-1}$ g C;

$\left(\left(\frac{0.238}{1.30}\right)(100)=\right)18.3\%$ C;

$\left(\frac{1.0\times10^{-2}}{1.30}\right)(100)=0.77\%$ H; ***[3]***

*Award **[3]** for correct final answer of 18.3 % C and 0.77 % H without working.*
Allow whole numbers for molar masses.

(ii) $\left((1.75)\left(\frac{35.45}{143.32}\right)=\right)0.433$ g (Cl) **and** $\left(\left(\frac{0.433}{0.535}\right)(100)=\right)80.9\%$ (Cl); ***[1]***

Allow whole numbers for molar masses.

(iii) $\left(\frac{18.3}{12.01}\right)=1.52$ mol C **and** $\left(\frac{0.77}{1.01}\right)=0.76$ mol H **and** $\left(\frac{80.9}{35.45}\right)=2.28$ mol Cl;

Allow whole numbers for atomic masses.

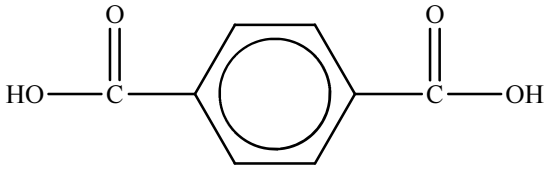
Empirical formula $=C_2HCl_3$;

*Award **[2]** for correct empirical formula without working.*

$M_r=(24.02+1.01+106.35)=131.38$, so molecular formula is C_2HCl_3; ***[3]***

*Award **[3]** for correct final answer without working.*
Allow whole numbers for atomic masses.

(d) (i) $HOOC–C_6H_4–COOH$ structure **and** $HOCH_2CH_2OH$ structure;
Accept either full or condensed structural formula.



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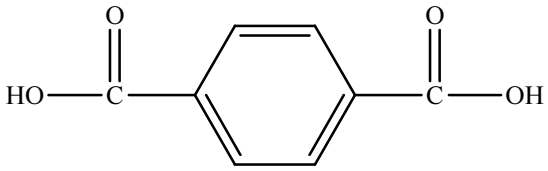
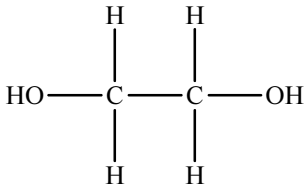
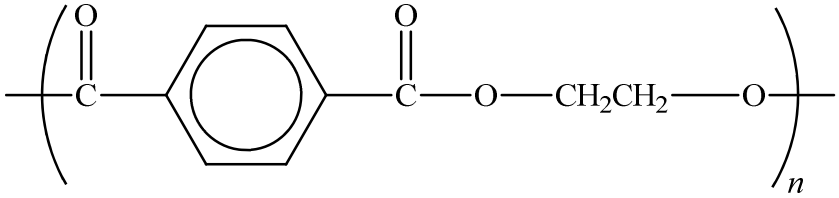




polyethene terephthalate structure; ***[2]***



Allow Kekulé structure.

No penalty for missing brackets or n, but continuation bonds must be shown.
Penalize missing hydrogens or incorrect bonds (e.g. C–HO, N–HC) once only in (b) (ii), (d) (i) and (e).

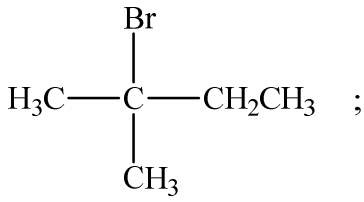
(ii) *Polyester*:
high tensile strength / high tenacity;
good durability / strong fibre;
Allow just strong.

hydrophobic (fibres) / water-resistant;
(chains flexible so) fibres easily woven;
Allow resistant to insects.

Nylon:
high specific strength;
good durability / strong fibre;
Allow just strong.
high strength;
Accept just strong.

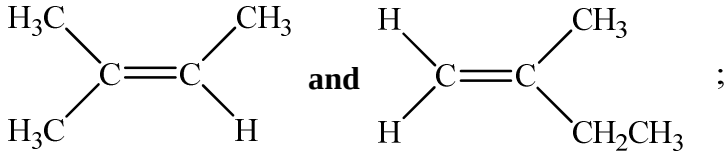
resists/withstands abrasion/scratching;
resists/withstands chemicals/oil;
resists UV/sunlight; ***[2 max]***
Apply /OWTTE throughout.
*If strong is given as property for both polyester and nylon award **[1 max]**.*

(e) *Penalize missing hydrogens or incorrect bonds (e.g. C–HO, N–HC) once only in (b) (ii), (d) (i) and (e).*
Structure of 2-bromo-2-methylbutane:



;

*Structures of 2-methylbut-2-ene **and** 2-methylbut-1-ene:*



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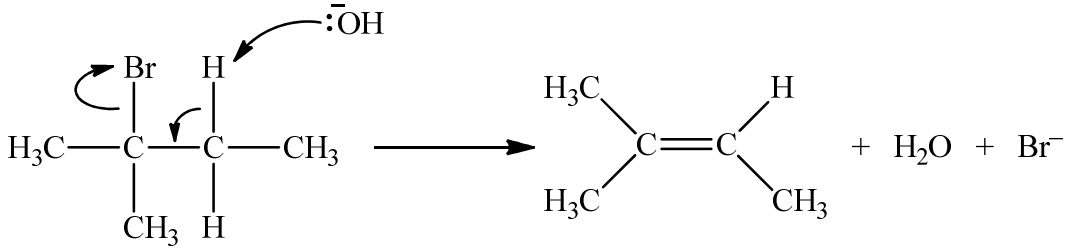
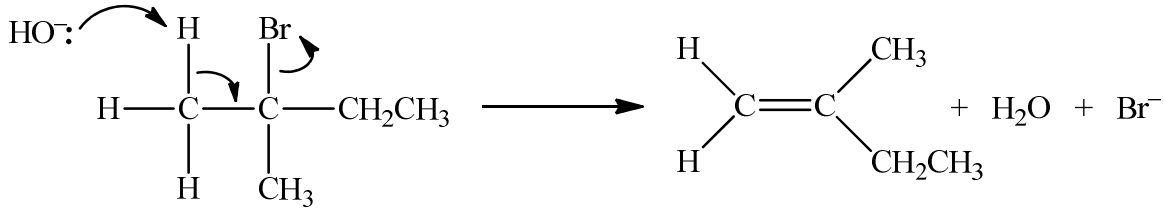
Mechanism:



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; ***[5]***
Allow alternative E1 mechanism also.
curly arrow showing Br leaving;
representation of tertiary carbocation;
*curly arrow going from lone pair/negative charge on O in HO^- to H and C adjacent to C^+ **and** curly arrow going from CH bond to form C=C bond;*