M15/4/CHEMI/HP2/ENG/TZ2/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2015

Chemistry

Higher level

Paper 2

17 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.

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.

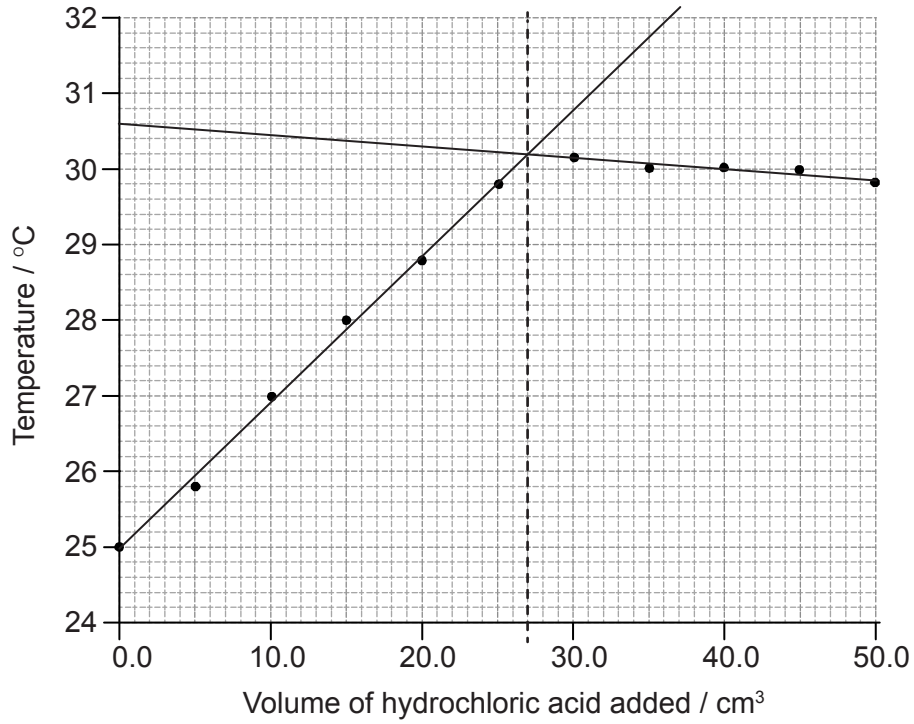
12. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the markscheme.

13. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

14. Penalize missing hydrogens or incorrect bond linkages (*eg* C–H_3C) once only.

Section A

1. (a) (i)



drawing best-fit straight lines to show volume;
There should be approximately the same number of points above and below for both lines.

27.0 (cm^3); **[2]**
Accept any value in the range 26.0 to 28.0 (cm^3) if consistent with student's annotation on the graph.
Accept ECF for volumes in the range 27.0–30.0 cm^3 if it corresponds to maximum temperature of line drawn.
Volume should be given to one decimal place.

(ii) $([HCl]) = \frac{1.00 \times 0.0250}{0.0270}$;
$= 0.926\,mol\,dm^{-3}$; **[2]**
Volume of 26.0 gives [HCl] = 0.962 $moldm^{-3}$. Volume of 28.0 gives [HCl] = 0.893 $moldm^{-3}$.
*Award **[2]** for correct final answer with units.*
*Award **[1 max]** for correct concentration without units.*
Accept M, mol L^{-1}, mol/dm^3 as units.

(b) (i) $(30.2 - 25.0 =)(+)5.2\,(^{\circ}\text{C/K})$; **[1]**

Any *accepted value must be consistent with student's annotation on the graph but do not accept* $\Delta T < 5.1$.
Accept (+)5.6 $(^{\circ}\text{C/K})$ *(ie, taking into account heat loss and using T when volume = 0.0 cm^3).*

(ii) $Q = (m \times c \times \Delta T = (25.0 + 27.0) \times 4.18 \times 5.2 = 1130.272\,\text{J} =) 1.13\,(\text{kJ})$;
$n = (1.00 \times 0.0250 =) 0.0250\,(\text{mol})$;
$\Delta H = (-\frac{Q}{n} = -45210.88\,\text{J mol}^{-1} =) -45\,(\text{kJ mol}^{-1})$; **[3]**

*Award **[3]** for correct final answer.*
*Award **[2]** for +45 (kJ mol $^{-1}$).*
Apply ECF for M3 even if both m and ΔT *are incorrect in M1.*
Accept use of c = 4.2 Jg^{-1}K^{-1}.

(iii) $\left(\left| \frac{-45 - (-58)}{(-58)} \right| \times 100 = \right) 22\ (\%)$; **[1]**

Answer must be given to two significant figures.
Ignore sign.

(iv) heat losses;
better (thermal) insulation / using a polystyrene cup / putting a lid on the beaker; **[2]**
Accept other suitable methods for better thermal insulation but do not accept just "use a calorimeter" without reference to insulation.

2. (a) change in concentration of reactant/product with time / rate of change of concentration; **[1]**
Accept "increase" instead of "change" for product and "decrease" instead of "change" for reactant.
Accept "mass/amount/volume" instead of "concentration".
Do not accept substance.

(b) surface area decreases;
frequency/probability of collisions decreases; **[2]**
Accept number of collisions per unit time decreases.

(c) (i) step 2 / $X + NO \rightarrow Y + H_2O$ / slow; **[1]**

(ii) invalid / unlikely as order most likely one (with respect to hydrogen);
rate = $k[NO]^2[H_2]$ / H_2 only involved once in the formation of the intermediate before the slow step / *OWTTE*; **[2]**
Award M2 only if M1 is correct.

3. (a) $(-239.0 - [-110.5] =) -128.5\,(\text{kJ mol}^{-1})$; **[1]**

(b) $(-166.0 - [-137.2] =) -28.8\,(\text{kJ mol}^{-1})$; **[1]**

(c)
$$\left(\Delta G^{\ominus} = -28.8 = -128.5 - \left[\frac{298 \times \Delta S^{\ominus}}{1000}\right]\right)$$
$(\Delta S^{\ominus} =) -335\,(\text{J mol}^{-1}\text{K}^{-1})$; **[1]**

(d) $\Delta S^{\ominus} = \sum S^{\ominus}_{products} - \sum S^{\ominus}_{reactants}$ / $-335 = 126.8 - 197.6 - 2S^{\ominus}_{H_2}$;
$S^{\ominus}_{H_2} = (+)132\,(\text{J mol}^{-1}\,\text{K}^{-1})$; **[2]**
*Award **[2]** for correct final answer.*
*Award **[1 max]** for $S^{\ominus}_{H_2} = (+)264\,(\text{J mol}^{-1}\,\text{K}^{-1})$.*

4. (a) a solution that resists changes in pH / changes pH slightly / *OWTTE*;
when small amounts of an acid/H^+ or a base/alkali/OH^- are added; **[2]**

(b) *addition of acid:*
$CH_3CH_2COO^-(aq) + H^+(aq) \rightarrow CH_3CH_2COOH(aq)$ / propanoate ions combine with H^+ ions to form undissociated propanoic acid;

addition of base:
$CH_3CH_2COOH(aq) + OH^-(aq) \rightarrow CH_3CH_2COO^-(aq) + H_2O(l)$ / addition of OH^- removes H^+ and more propanoic acid dissociates/ionizes; **[2]**

Ignore state symbols.
Accept reversible arrows.
*Award **[1 max]** if correct equations are given without reference to addition of acid or alkali.*

(c) $K_a = \frac{[H^+(aq)][CH_3CH_2COO^-(aq)]}{[CH_3CH_2COOH(aq)]}$ / $\text{pH} = \text{p}K_a + \log\left(\frac{[\text{base}]}{[\text{acid}]}\right)$;
$K_a = 1.3 \times 10^{-5}/10^{-4.87}$ **and** $[H^+] = 1.3 \times 10^{-4}/10^{-3.87}\,(\text{mol dm}^{-3})$ *I*
$\log\frac{\left[CH_3CH_2COO^-\right]}{\left[CH_3CH_2COOH\right]} = 3.87 - 4.87 = -1$;
$\left([CH_3CH_2COOH] = \frac{7.41}{74.09} =\right) 0.100/1.00 \times 10^{-1}\,(\text{mol dm}^{-3})$;
$([CH_3CH_2COONa] =) 0.010/1.0 \times 10^{-2}\,(\text{mol dm}^{-3})$; **[4]**
*Award **[4]** for correct final answer.*
Accept corresponding use of $[H_3O]^+$ for $[H^+]$, [acid] for $[CH_3CH_2COOH]$, and [base] or [salt] for $[CH_3CH_2COO^-]$ throughout.

5. (a) same functional group;
same general formula;
(successive members) differ by CH_2;
similar chemical properties;
gradation in physical properties; **[2 max]**
Do not accept "same" instead of "similar", or vice-versa.

(b) Initiation:
$Br_2 \xrightarrow{UV/hf/h\nu} 2Br\bullet$;
Reference to UV light or high temperatures must be included.
Propagation:
$Br\bullet + C_2H_6 \rightarrow C_2H_5\bullet + HBr$;
$C_2H_5\bullet + Br_2 \rightarrow C_2H_5Br + Br\bullet$;
Termination:
$Br\bullet + Br\bullet \rightarrow Br_2$ / $C_2H_5\bullet + Br\bullet \rightarrow C_2H_5Br$ / $C_2H_5\bullet + C_2H_5\bullet \rightarrow C_4H_{10}$; **[4]**
Accept representation of radical without • (eg, Br, C_2H_5) if consistent throughout mechanism.
Penalize reference to heterolytic fission once only.
*Award **[0]** to any mechanism involving ions.*
Accept further bromination.
*Award **[3 max]** if initiation, propagation **and** termination are not stated or are incorrectly labelled for equations.*
Accept correct description of processes without equations.

6. (a) *Positive electrode (anode):*
$2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$ / $Cl^-(l) \rightarrow \frac{1}{2}Cl_2(g) + e^-$;
Negative electrode (cathode):
$Mg^{2+}(l) + 2e^- \rightarrow Mg(l)$;
Accept e *instead of* e^-.
*Award **[1 max]** for correct half-equations given at the wrong electrode.*
Penalize use of reversible arrows once only.

correct state symbols in both equations; **[3]**

(b) aluminium/Al is less dense (compared to iron/Fe) / Al is more ductile or malleable / aluminium forms a protective oxide layer / Al does not corrode / iron/Fe rusts / *OWTTE*; **[1]**
Do not accept "Al is lighter" OR "less expensive" OR "Al can be recycled".

Section B

7. (a) (i) rates of forward **and** reverse reactions are equal / opposing changes occur at equal rates;
the concentrations of all reactants **and** products remain constant / macroscopic properties remain constant;
closed/isolated system; **[2 max]**
Accept "the same" for "equal" in M1 and for "constant" in M2.

(ii) *The volume of the container is increased:*
position of equilibrium shifts to the left/reactants **and** fewer moles of gas on the right hand side/pressure decreases / *OWTTE*;

Ammonia is removed from the equilibrium mixture:
position of equilibrium shifts to the right/products **and** $[NH_3]$ decreases so $[N_2]$ and $[H_2]$ must also decrease to keep K_c constant
OR
position of equilibrium shifts to the right/products **and** rate of reverse reaction decreases / *OWTTE*; **[2]**
*Award **[1 max]** if both predicted changes are correct.*
Do not accept "to increase $[NH_3]$" or reference to LCP without explanation.

(iii) <u>minimum</u> energy needed (by reactants/colliding particles) to react/start/ initiate a reaction; **[1]**
Accept "energy difference between reactants and transition state".

(b) rate increases;
more effective/successful collisions per unit time / greater proportion of collisions effective;

alternative pathway **and** a lower activation energy
OR
lowers activation energy so that more particles have enough energy to react; **[2 max]**
Do not accept just "lowers/reduces the activation energy".
Accept "provides a surface for reacting/reactants/reaction".

(c) (i) slower rate / *OWTTE*;
uneconomic / *OWTTE*; **[2]**

(ii) high cost for building/maintaining plant / high energy cost of compressor / *OWTTE*; **[1]**
Do not accept "high pressure is expensive" without justification.
Accept high pressure requires high energy.

(d) (i) $(K_c =)\frac{[NH_3(g)]^2}{[N_2(g)] \times [H_2(g)]^3}$; **[1]**

Ignore state symbols.
Concentrations must be represented by square brackets.

(ii) moles at equilibrium: nitrogen 0.27, hydrogen 0.81 / concentrations at equilibrium: nitrogen 0.27 ($mol\,dm^{-3}$), hydrogen 0.81 ($mol\,dm^{-3}$) (and ammonia 1.46 $mol\,dm^{-3}$);
$K_c = 15$; **[2]**

Actual calculation gives $K_c = 14.86$.
*Award **[2]** for correct final answer.*
*Award **[1 max]** if $K_c \left(= \frac{1.46^2}{3^3 \times 1} \right) = 0.079$*

(e) (i) electron pair donor; **[1]**
Accept lone pair donor.

(ii) proton acceptor **and** partially/slightly ionized; **[1]**
*Accept "proton acceptor **and** partially/slightly dissociated".*

(iii)

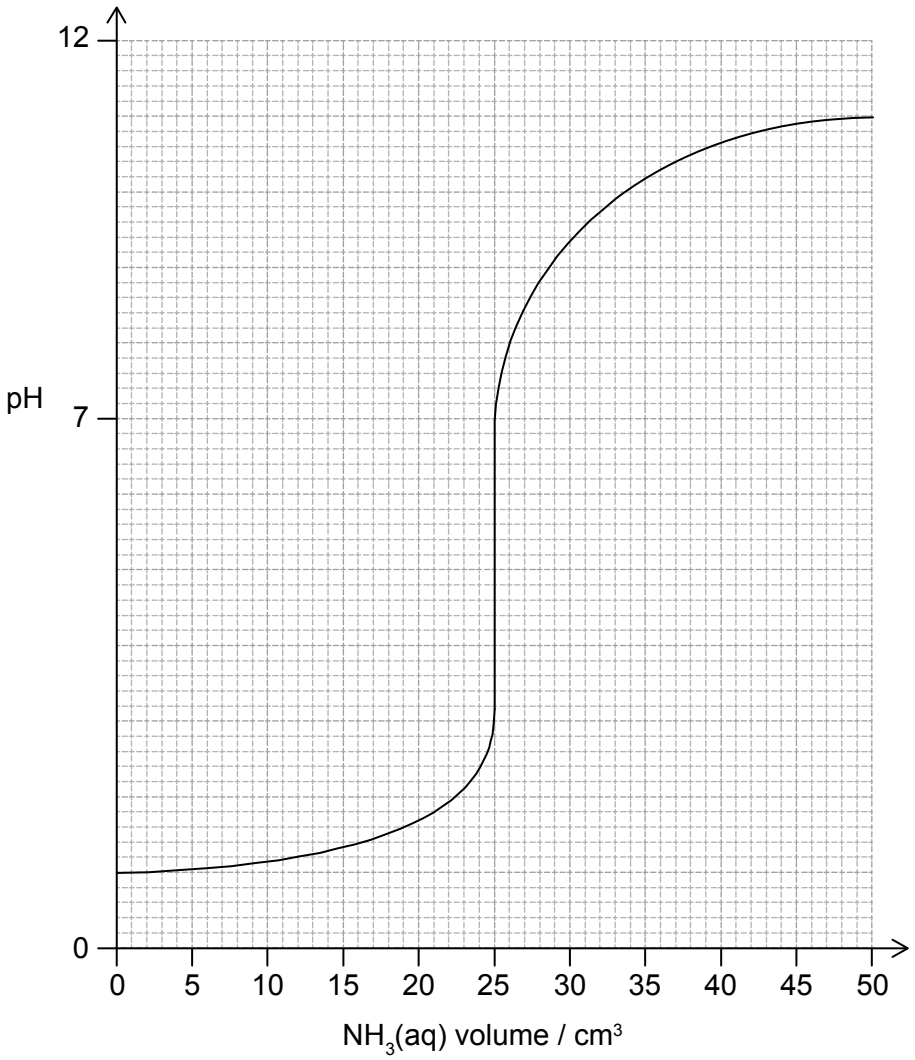
Acid		*Conjugate base*
$CH_3NH_3^+$	**and**	CH_3NH_2;
H_2O	**and**	OH^-;

[2]

*Award **[1 max]** for two correct acids OR two correct conjugate bases.*

(f) $K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = 1.8 \times 10^{-5} / 10^{-4.75}$;
$[NH_4^+] = [OH^-]$ **and** $[NH_3] \approx 1.00 \times 10^{-1}\,(mol\ dm^{-3})$;
$[OH^-] = (\sqrt{1.8 \times 10^{-6}} =) 1.3 \times 10^{-3}\ (mol\ dm^{-3})$ / $pOH = 2.89$;
$pH = (14.0 - 2.89 =) 11.1$; **[4]**
*Award **[4]** for correct final answer.*

(g) (i)



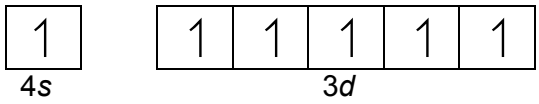
For volume = 0: pH = 1;

vertical jump should be positioned in volume range 24 cm^3 to 26 cm^3 and include pH range between 3 to 6;

For volume = 50: pH between 8 to 11; **[3]**

(ii) methyl orange / bromophenol blue / bromocresol green / methyl red; **[1]**

8. (a) (i)



[1]

Accept full-arrows.
Accept boxes in reverse order or at different energy levels.
Do not award the mark if sub-levels are incorrectly labelled or if no boxes are drawn.

(ii) (electrostatic) attraction between (lattice of) cations/positive/Cr^{3+} ions and delocalized electrons; **[1]**

(iii) (delocalized electrons allows) the layers/rows of cations/positive/Cr^{3+} ions to slide past each other (without disrupting the metallic bonding); **[1]**
Accept atoms instead of ions.

(b) (i) chromium(III) oxide; **[1]**
Do not award the mark for chromium oxide.

(ii) (electrostatic) attraction between positive and negative ions/oppositely charged ions/Cr^{3+} and O^{2-};
formed as a result of electron transfer from chromium atoms to oxygen atoms / *OWTTE*; **[2]**
Ignore reference to number of electrons transferred or charges of ion for M2.

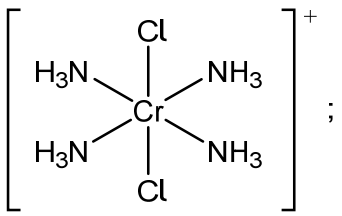
(iii) ions are not free to move (when solid) / ions in rigid lattice / *OWTTE*; **[1]**

(c) (i) III / +3; **[1]**
Do not cccept incorrect notation such as 3+/3.

(ii) ligand has lone/non-bonding electron pair /
dative (covalent)/coordinate/coordination bond forms;

ligand is Lewis base / ion is Lewis acid; **[2]**

(iii) partially filled/incomplete d sub levels/orbitals;
d orbitals split into two levels;
energy difference is in visible part of spectrum / electrons absorb visible light/one colour/frequency/wavelength;
electron transitions occur from lower to higher energy level (within d sub-level);
complementary colour/colour not absorbed is seen; **[4 max]**
Do not accept complementary colour "emitted".

(iv) 

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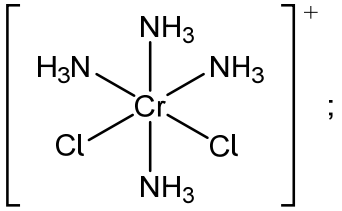


; **[2]**

Accept any other octahedral arrangement of ligands.
Ignore missing square brackets and charge.

(d) (i) *Half equation:*
$I^-(aq) + 3H_2O(l) \rightarrow IO_3^-(aq) + 6H^+(aq) + 6e^-$;
Accept e instead of e^-.
Accept reversible arrows.

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

Ignore state symbols.

(ii) oxidized **and** increase (in oxidation number) of 6/from –1/–I to +5/+V; **[1]**

(e) (i) potential (of reduction half-reaction) under standard conditions measured relative to standard hydrogen electrode/SHE / *OWTTE*; **[1]**
Accept "solute concentration of 1 mol dm^{-3}" or "1 bar/1 atm (pressure) for gases" instead of "standard conditions".
Accept voltage/emf for potential.

(ii) (+)1.08 (V); **[1]**

(iii) $2Cr(s) + 3Cu^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Cu(s)$; **[1]**
Ignore state symbols.
Do not accept reversible arrows.

(iv) *Negative electrode:* chromium/Cr **and** *Positive electrode:* copper/Cu; **[1]**
*Accept "Cr is the anode **and** Cu the cathode".*

(v) from chromium/Cr to copper/Cu; **[1]**
Accept "from negative electrode/anode to positive electrode/cathode" if electrodes correctly identified in (iv).

(vi) negative ions/anions towards the chromium(III) solution **and** positive ions/cations towards the copper(II) solution / *OWTTE*; **[1]**

9. (a) (i) $MgCl_2$ conducts electricity **and** PCl_3 does not;
$MgCl_2$ is ionic **and** PCl_3 is covalent/molecular;
ions/charged particles can move in $MgCl_2$ / no free charged particles in PCl_3; **[3]**
*Award **[1 max]** if all three points correct for one substance but not other.*

(ii) *$MgCl_2$:*
$4 \leq pH \leq 6.9$;
high charge density/high charge **and** small size of Mg^{2+} makes $[Mg(H_2O)_6]^{2+}$ hydrolyse / polarizes water to produce H^+;

PCl_3:
$0 \leq pH \leq 4$;
(reacts with water to) form HCl/H_3PO_3; **[4]**
Do not accept H_3PO_4.

(b) (i) *Na, Mg (oxides):* basic

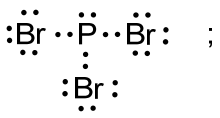
Al (oxide): amphoteric
Do not accept amphiprotic.

Si to Cl (oxides): acidic **[2]**

*Award **[2]** for all three listed sets correct.*
*Award **[1]** for one or two listed sets correct.*
*Award **[1]** for stating oxides become more acidic towards right/Cl or more basic towards left/Na.*
Do not penalize if reference is to Ar instead of Cl.
Do not penalize for incorrect formulas of oxides.

(ii) $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$;
$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$; **[2]**
Ignore state symbols.
Accept $P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(aq)$.
Do not award marks if incorrect formulas of the oxides are used.

(c) (i)



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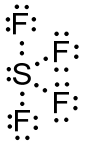


;

[2]

Penalize lone pairs missing on Br and F once only.
Accept any combination of lines, dots or crosses to represent electron pairs.

(ii)

PBr_3	SF_4
Shape: trigonal pyramidal; *Accept triangular pyramidal.*	*Shape:* see-saw/K-shaped; *Accept distorted tetrahedral.*
No ECF for shape if Lewis structure is incorrect.	
Bond angle: *Any value* 99°<109°; *Literature value = 101°.*	*Bond angle:* *Any two for **[1]** of:* (F_{eq}–S–F_{eq}): *Any value* 100°<120° *Literature value = 103°* (F_{ax}–S–F_{ax}): *Any value* 175°<185° *Literature value = 179°/180°* (F_{ax}–S–F_{eq}): *Any value* 85°< 95° *Literature value = 89°*
No ECF for angle if shape is incorrect. *Do not award mark for correct angles if shape is incorrect.*	

[4]

(iii) P–Br and S–F bonds are polar / bonds in both molecules are polar;
non-symmetrical distribution of electron cloud / polar bonds/dipoles do not cancel because of non-symmetrical shape; **[2]**
M2 may also be scored with a suitable diagram showing the vectorial addition of the individual S–F dipole moments to show a net dipole moment centred along the axis between the F_{eq}–S–F_{eq} bond.

(d) (i) *EITHER*
(electrostatic) attraction between (positively charged) nuclei and a pair of electrons;
formed as a result of electron sharing (between the carbon and hydrogen nuclei);

OR

sigma bond formed by overlap of atomic orbitals;
s orbital from H and p/sp^2 from carbon; **[2]**

(ii) *α:* sp^3 **and** *β:* sp^2; **[1]**
Accept if numbers are given as subscripts.

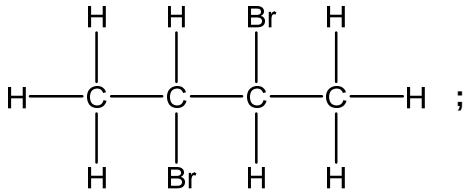
(iii) *σ bond:*
end-on / axial overlap of two orbitals;

π bond:
sideways overlap of two (parallel) p orbitals; **[2]**

Accept suitable diagrams for both marks.

(iv) 11 σ **and** 3 π; **[1]**

Penalize missing hydrogens only once in Question 10.

10. (a) (i)  ; **[1]**

Accept bromine atoms cis to each other.

(ii) 2,3-dibromobutane; **[1]**

Do not penalize the incorrect use of spaces, comma or hyphen.

(iii) red/brown/orange/yellow to colourless/decolourized; **[1]**

Do not accept clear.

Do not accept just "decolorized".

(b) (i) (synthesis of) plastics/polymers/organic materials not naturally available / synthetic materials;

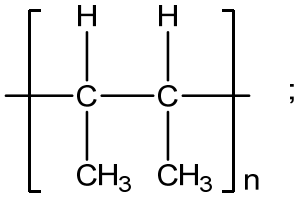
wide range of uses/physical properties / versatile;

large industry / many tons of plastics consumed by society / *OWTTE*; **[2 max]**

Do not accept "useful" for M2.

*Award **[1 max]** if specific addition polymer and its use is given.*

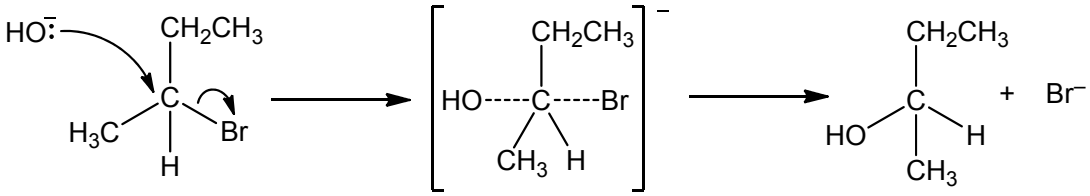
Penalize reference to condensation polymers once only.

(ii)  ; **[1]**

Ignore n.

Brackets are not required for the mark, but continuation bonds are.

Do not penalize if methyl groups are trans to each other.

(c) (i) 

curly arrow going from lone pair/negative charge on O in HO^- to C;

Do not accept curly arrow originating on H in HO^-.

curly arrow showing Br leaving;

Accept curly arrow either going from bond between C and Br to Br in 2-bromobutane or in the transition state.

Accept if arrow goes from C–Br bond to/or beyond Br.

representation of transition state showing negative charge, square brackets and partial bonds;

Do not penalize if HO and Br are not at 180° to each other.

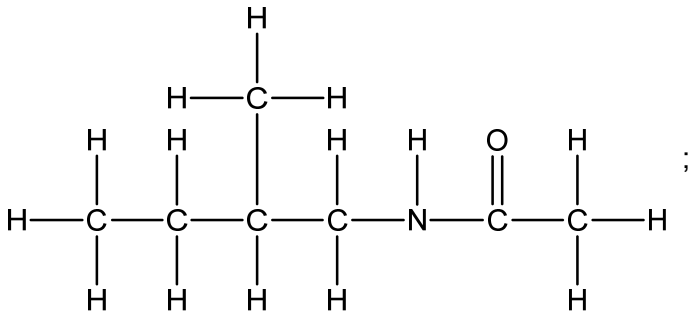
Do not award M3 if OH----C bond is represented.

formation of organic product $CH_3CHOHCH_2CH_3$ **and** KBr/Br^-; **[4]**

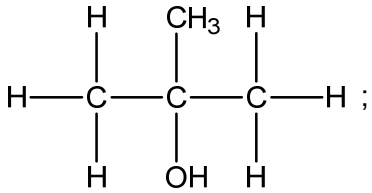
(ii) OH^- has a negative charge/higher electron density;
stronger attraction to the carbon atom with the partial positive charge / *OWTTE*; **[2]**
Do not accept just stronger attraction.
Reference to carbon atom needed for M2.

(d) (i) 2-methylbutanenitrile; **[1]**
Accept small errors in spelling.
Accept 2-cyanobutane.
Do not accept butan-2-nitrile.

(ii) hydrogen/H_2 **and** nickel/Ni; **[1]**
Accept other suitable metal catalysts such as platinum/Pt, palladium/Pd.

(iii) 
; **[1]**
Accept condensed CH_3 branch in structural formula as this was present in structure given in question.

(e) (i) carbonyl; **[1]**
Accept ketone.

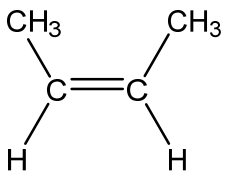
(ii) 
; **[1]**
Accept condensed or full structural formula.

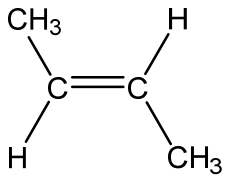
(f) hydrogen bonding in compound **C**;
dipole-dipole forces in **C** / **C** is more polar;
C has greater molar mass/more dispersion/London/instantaneous induced dipole-induced dipole forces/van der Waal forces; **[2 max]**
Accept converse argument.
*Award **[1 max]** for stronger intermolecular forces.*

(g) $C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$; **[1]**
Ignore state symbols.

(h) (i) compounds with the same structural formula **and** different arrangement in space/3D structures; **[1]**
Accept molecular formula instead of structural formula.
Do not accept "similar" instead of "same".

(ii) restricted rotation around a (double) bond;
carbon atoms of the C=C/carbon-carbon double bond (in alkene)/carbon atoms of the C–C/carbon-carbon single bond (in cycloalkane) must have two different atoms/groups of atoms / *OWTTE*; **[2]**
Do not accept "functional groups" for "groups of atoms" in M2.

(iii) 

and


;

cis **and** *trans* ; **[2]**
*Award **[1 max]** if cis and trans isomers are correctly drawn and identified for alkene other than but-2-ene.*
*Award **[1 max]** if student draws and labels one structure correctly but not the other.*