



MARKSCHEME

May 2008

CHEMISTRY

Higher Level

Paper 2

*This markscheme is **confidential** and for the exclusive use of examiners in this examination session.*

*It is the property of the International Baccalaureate and must **not** be reproduced or distributed to any other person without the authorization of IB Cardiff.*

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 mark scheme, 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:

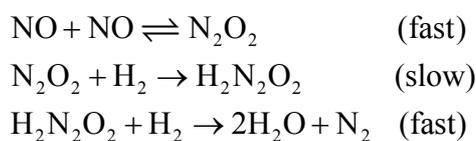
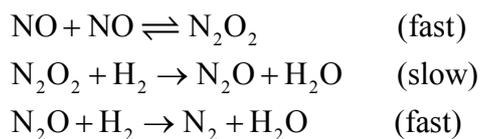
2	<i>reject</i>
1.6	<i>accept</i>
1.63	<i>accept</i>
1.631	<i>accept</i>
1.6314	<i>reject</i>

Indicate the mark deduction by writing **-1(SD)** at the first point it occurs and **SD** on the cover page.

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) doubling $[H_2]$ doubles the rate / *OWTTE*; [1]
Accept alternative mathematical explanation.
- (b) 2; [2]
 (using experiments 1 and 4) as $[NO]$ is halved, rate goes down to $\frac{1}{4}$ / *OWTTE* ;
Accept alternative mathematical explanation.
- (c) (rate =) $k[H_2][NO]^2$; [1]
- (d) *Experiment 3 rate:* 1.2×10^{-2} (mol dm⁻³ s⁻¹);
Accept 12×10^{-3} .
- Experiment 5 rate:* 2.5×10^{-4} (mol dm⁻³ s⁻¹); [2]
Accept 0.25×10^{-3} .
- (e) $k = \frac{4.0 \times 10^{-3}}{(2.0 \times 10^{-3})(4.0 \times 10^{-3})^2} = 1.3 \times 10^5$;
Accept 125 000 or 1.25×10^5 .
- mol⁻² dm⁶ s⁻¹; [2]
Apply ECF throughout question 1(a) - (e).
- (f) $NO + H_2 \rightleftharpoons H_2NO$ / intermediate / X (fast)
 H_2NO /intermediate/ X + NO \rightarrow $H_2N_2O_2$ /intermediate/Y (slow)
 $H_2N_2O_2$ /intermediate/ Y + $H_2 \rightarrow 2H_2O + N_2$ (slow) [2]

OR**OR**

Three correct steps in correct sequence award [2].

Two correct steps in correct sequence award [1].

Award [1] if mechanism is incorrect, but sum of steps equals overall reaction.

No credit or penalty for labelling steps fast or slow.

No penalty if \rightleftharpoons is not stated.

- (g) a substance that (increases the rate and) is in a different phase/state from that of the reactants;

diagram showing reactants higher than products **and** transition state above both;

trace of catalyzed reaction identified above reactants but below transition state;

[3]

No penalty if reactants or products are not labelled on diagram.

No penalty if transition state is not labelled on diagram.

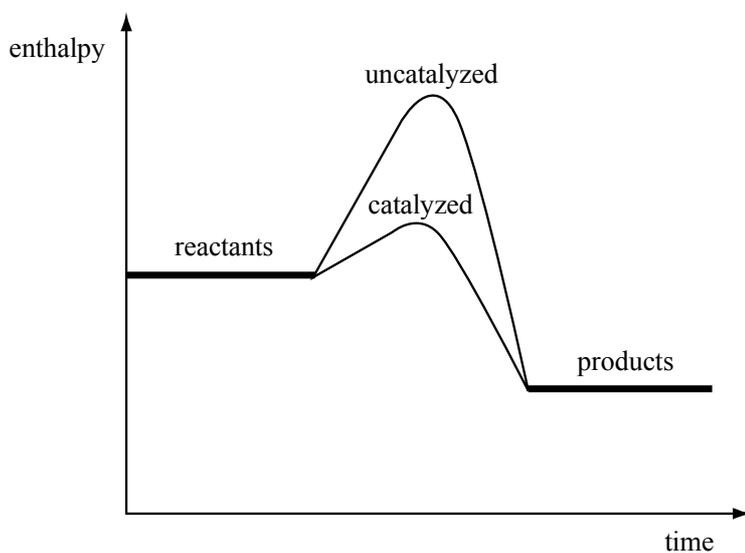
Allow enthalpy/H / (potential) energy as possible y-axis labels.

Allow time/t /reaction progress/coordinate as possible x-axis labels.

Ignore any connecting lines or curves.

E_a or ΔH labels do not need to be labelled on the diagram.

Deduct [1 max] if either the x-axis or the y-axis or both are incorrectly labelled on the diagram or if E_a or ΔH labels or both are incorrectly labelled.



2. (a) $n(\text{Ba}(\text{OH})_2) = 0.0250 \times 0.146 = 3.65 \times 10^{-3}$ (mol);
 $n(\text{HNO}_3) = 3.65 \times 10^{-3} \times 2 = 7.3(0) \times 10^{-3}$ (mol);

$$[\text{HNO}_3] = \left(\frac{7.30 \times 10^{-3}}{0.0287} \right) = 0.254 \text{ (mol dm}^{-3}\text{)}; \quad [3]$$

Correct final answer scores [3]

No penalty for too many significant figures.

- (b) 0.0710 (mol); [1]
Allow 0.071 (mol).

- (c) amount of gas = $\frac{0.010 \times 5}{2} = 0.025$ (mol);

$$V = \frac{nRT}{P} = \frac{0.025 \times 8.31 \times 387}{1.12 \times 10^5} / 7.2 \times 10^{-4} \text{ m}^3;$$

$$= 720 \text{ cm}^3 / 7.2 \times 10^2 \text{ cm}^3;$$

Allow 720 / 718 cm³ but not 717 cm³.

ECF throughout question 2.

Award only [1] if $PV = nRT$ rearrangement incorrect or values of P or T changed.

[3]

3. (a) the energy needed to remove one/first/most loosely bound electron from a (neutral) atom;
in the gaseous state;
 $\text{Mg(g)} \rightarrow \text{Mg}^+(\text{g}) + \text{e}^-$; [3]
Gaseous state symbols needed.
Only penalize omission of gas phase once in either the second marking point or the third marking point.
- (b) electron removed (from Al) is in a p sub-level/subshell while that from Mg is in an s sub-level/subshell / *OWTTE*;
p sub-level is of higher energy / further from nucleus (than s) / experiences greater shielding from nucleus; [2]
Allow less energy needed to remove electron from a p sub-level/subshell for second marking point.
Accept orbital instead of sub-level or subshell throughout.
- (c) third electron more difficult to remove because it is taken from a positively charged ion;
and from a (main) energy level closer to nucleus / from second energy level/n=2 while the first electron comes from the third energy level/n=3 / *OWTTE*; [2]
Allow argument of removing an electron from a full energy level for second marking point.
Accept shell instead of energy level.
- (d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$;
No penalty for reversing order of 3d and 4s.

4s; [2]

4. (a) $\text{CH}_2\text{ClCOOH} \rightleftharpoons \text{CH}_2\text{ClCOO}^- + \text{H}^+$ / $\text{CH}_2\text{ClCOOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_2\text{ClCOO}^- + \text{H}_3\text{O}^+$;
 Do not award mark if \rightarrow is used.
 Ignore state symbols.

$$K_a (= 10^{-\text{p}K_a}) = 1.38 \times 10^{-3} (\text{mol dm}^{-3});$$

$$[\text{H}^+] = \sqrt{1.38 \times 10^{-3} \times 0.200};$$

$$= 0.0166 (\text{mol dm}^{-3});$$

$$\text{pH} = -\log[\text{H}^+] / -\log 0.0166 = 1.78;$$

Allow $\text{pH} = 1.77$ and 1.780 (since log. calc. involved here).

Allow $\text{pH} = 1.80$ if solved quadratically.

Correct pH scores [4].

Apply ECF throughout.

[5]

- (b) potassium bromide: C
 potassium ethanoate: D
 iron(II) chloride: B
 iron(III) chloride: A

Award [2] for all four correct.

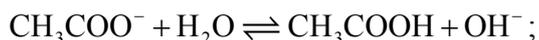
Award [1] for order D, C, B, A or C, D, A, B.

[2]

- (c) potassium bromide:
 K^+ neutral cation from a strong base and Br^- neutral anion from a strong acid;
 Accept neutral because made from strong acid and strong base.

potassium ethanoate:

alkaline because made from weak acid and strong base /



Allow reference to ethanoate/ CH_3COO^- as a stronger conjugate base.

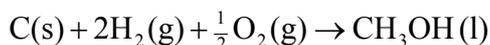
iron(II)/(III) chloride:

acidic because made from strong acid and weak base hydrate/ Fe^{2+} / Fe^{3+} ions can act as Lewis acids / OH bond polarized by positively charged/high charge density of ion;
 iron(III) chloride/ FeCl_3 very/more acidic than iron(II) chloride/ FeCl_2 because higher ionic charge / greater charge density causes greater loss of H^+ from hydrated/aqua-complex / OWTTE;

[4]

SECTION B

5. (a) the enthalpy change for the formation of 1 mol of a compound from its elements; in their standard states/conditions / at 1 atm / 101 kPa;
Allow 1 atm and 298 K/25 °C.



Award [1] for correctly balanced equation and [1] for all state symbols correct. [4]

- (b) the energy needed to break (1 mol of) a bond between two atoms / elements in the gaseous state;
averaged over several (similar) compounds;

$$\sum \text{BE (bonds broken)} = (2 \times 743) + (3 \times 436) = 2794 \text{ (kJ)};$$

$$\sum \text{BE (bonds formed)} = (3 \times 412) + 360 + (3 \times 463) = 2985 \text{ (kJ)};$$

$$\Delta H^\ominus = 2794 - 2985 = -191 \text{ (kJ)};$$

[5]

Award [2] for 191 or +191.

Apply ECF from previous two answers for bonds broken and bonds formed in the third marking point, only if sign convention is correct for bonds breaking and bonds forming.

- (c) $\Delta H^\ominus = \sum \Delta H^\ominus_f(\text{products}) - \sum \Delta H^\ominus_f(\text{reactants}) / (-487) - [(-239) + (-111)];$
 $= -137 \text{ (kJ)};$

[2]

Correct answer scores [2].

Award [1] for 137 or +137

If value of CH₃OH (g) is used, apply ECF in second marking point.

- (d) (increased temperature) shifts equilibrium position to left;
in endothermic direction / to absorb heat / *OWTTE*;
(increased pressure) shifts equilibrium position to right;
more gas moles on left / fewer gas moles on right / to reduce pressure;

[4]

- (e) standard (molar) entropy change;
negative because of decrease in disorder / increase in order / change in number of moles of gas;

[2]

- (f) $\Delta G^\ominus = (\Delta H^\ominus - T\Delta S^\ominus) = 210 - (298 \times 0.216) = (+)146 \text{ (kJ)};$

Allow calculations involving joules.

ΔG^\ominus value is positive;

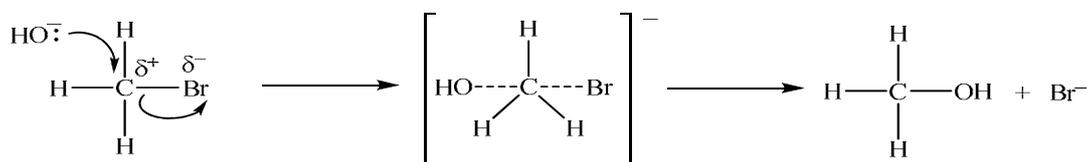
$$T = \frac{\Delta H^\ominus}{\Delta S^\ominus} = \frac{210}{0.216};$$

$$= 972 \text{ K};$$

No ECF.

[4]

- (g) nucleophilic substitution /S_N2 ;
 Allow nucleophilic displacement.
 Do not allow bimolecular.
 Do not accept S_N1 .



curly arrow showing attack by electrons of OH⁻ on C atom **and** bonding electrons moving to Br;

No penalty if lone pair is not shown.

Curly arrow coming from negative charge accepted. However, electron coming from H of OH⁻ not accepted.

Do not penalize if partial charges are not shown.

correct transition state showing partial bonds from Br and O to C **and** overall negative charge;

correct products: CH₃OH and Br⁻ ;

[4]

6. (a) tetrahedral because there are four electron pairs/negative charge centres/electron domains/density around N/the central atom;
trigonal pyramidal because there are three bonding pairs / three H atoms and one non-bonding/lone pair (of electrons);
Allow 3D representation of 3 B.P.'s and 1 L.P. without stating trigonal pyramidal for second marking point.
107° (because the tetrahedral angle of 109.5° is reduced slightly) because non-bonded electron/lone pairs repel more than bonded electron pairs; [3]
- (b) (i) tetrahedral;
V-shaped / bent / angular;
103° ; [3]
Accept answer in range 95 - 105°.
- (ii) octahedral;
square planar/coplanar; [3]
90° ;
- (c) (i) correct Lewis structure showing **all** valence shell pairs as lines or pairs of dots or crosses: [1]
-
- (ii) sigma bond forms when two s / two p / one s and one p (atomic) orbitals overlap end-on/head-on / along line between nuclei;
pi bond forms when two parallel p orbitals overlap sideways / pi bond consists of two regions of negative charge above and below sigma bond / nuclei;
First two marking points may also be obtained from diagrams illustrating both sigma and pi overlap of orbitals.

in chloroethene all bonds are sigma except C=C;
C=C consists of one sigma **and** one pi bond; [4]
- (iii) hybridization is the mixing / combining of atomic orbitals;
both carbons are sp² hybridized; [2]
- (d) CCl bond is shorter than in other/single bonded compounds / has the same bond length as the CCl bond in chlorobenzene;
non-bonding/lone pair electrons from Cl overlap with C=C / give some double bond character to CCl bond / *OWTTE*;
CC bond should have less double bond character / CC bond should be (slightly) longer than in other/double bonded compounds / intermediate between C=C and C-C value;
CC bond length predicted to be in range > 0.134 – < 0.154 (nm); [4]

- (e) ethene < chloroethene < bromoethene;
Accept alternative way of representing the same trend.

ethene has lowest bp because it has (only) van der Waals'/London/dispersion forces;
chloroethene and bromoethene have (in addition) dipole-dipole forces/attractions;
bromoethene has highest value because of largest M_r / molecular size / more
electrons;
and so has stronger London/dispersion/van der Waals' forces;

[5]



State symbols not needed.

ionic bonding **and** lattice/giant/network structure / ionic lattice;
 high melting point due to strong electrostatic attractions / strong attractions between oppositely charged ions / *OWTTE*;
 good conductivity (when molten) due to ability of ions to move (when voltage applied);

[4]

(b) covalent bonding **and** molecular structure;

*Allow simple covalent structure, **followed** by discussion of intermolecular forces for first marking point.*

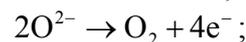
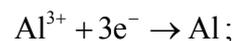
low melting point due to (relatively) weak intermolecular / van der Waals' forces (between molecules);

poor conductivity due to lack of ions;

[3]

(c) electrons flow through connecting wires/cables;

ions move to electrodes of opposite charge;



Ignore state symbols.

Electrode polarities do not have to be stated.

If two correct half-equations are given, but the wrong electrode is stated, award [1].

[4]

(d) pH with Al_2O_3 is 7;

Al_2O_3 insoluble / does not react with water;

pH with AlCl_3 is 1-5;

Accept any number within this range.

AlCl_3 hydrolyzed by water / reacts with water to form HCl;



Accept $\text{AlCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{Al}(\text{OH})_3 + 3\text{HCl}$.

[5]

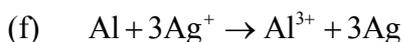
(e) $[\text{Al}^{3+}] = 1 \text{ mol dm}^{-3}$;

Do not accept 1 mol dm⁻³ aluminium sulfate solution.

Accept $[\text{Al}^{3+}] = 1 \text{ M}$.

25 °C / 298 K ;

[2]



Award [2] for correct equation.

Award [1] if equation unbalanced or balanced but reversed.

State symbols not required.

$$E^\ominus = (0.80 - (-1.66)) = 2.46 \text{ (V)};$$

[3]

- (g) (a ligand is) a species that uses a lone/non-bonding electron pair to form a coordinate/dative covalent bond with a metal ion;
(a ligand is a) Lewis base which forms coordinate/dative covalent bonds with a metal ion (which acts as a Lewis acid);
Accept either answer for first marking point.

solutions of $[\text{Zn}(\text{H}_2\text{O})_4]^{2+}$ are colourless because their d orbitals are full/complete;
solutions of $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ are coloured because their d orbitals split into two different energy levels;
and light is absorbed as electrons move between energy levels/due to d to d transitions;

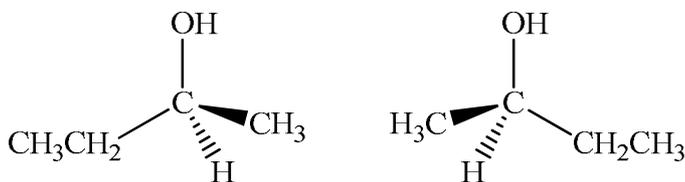
[4 max]

8. (a) butane contains two identical CH_3 /methyl groups / six hydrogens in same chemical environment;
and two identical CH_2 groups / four hydrogens in a different chemical environment; [2]
- (b) due to presence of chiral/asymmetric/stereo centre / four different groups around one carbon atom;
that rotate (the plane of polarization of) polarized light;
in opposite directions (by equal amounts); [3]
- (c) orange to green;
Both colours needed.
Allow red instead of orange.

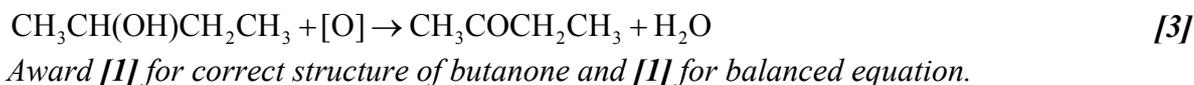
+3;
Accept 3+ and III but not 3 or Cr^{3+} . [2]

- (d) A is $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$;
B is $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$;
C is $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$;
D is $(\text{CH}_3)_3\text{COH}$; [4]
Accept more detailed formulas, showing all bonds present.
Penalize missing H atoms once only in this question.

(e)



Award [1] for both correct structures in correct 3-dimensional forms.



- (f) aldehyde;
Accept alkanal.
- distilling off product as it forms / heat only with oxidizing agent and distill; [2]
- (g) $\text{CH}_2\text{CHCH}_2\text{CH}_3$;
 $\text{CH}_3\text{CHCHCH}_3$ – cis;
 $\text{CH}_3\text{CHCHCH}_3$ – trans;
 $(\text{CH}_3)_2\text{CCH}_2$; [3 max]

Accept more detailed formulas, inclusive of double bonds.
Penalize missing H atoms once only in this question.

(h) E/F is $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$;

E/F is $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$;

infrared/IR absorption at $1000\text{--}1300\text{ cm}^{-1}$ indicates C–O bond **and** infrared/IR absorption at $3230\text{--}3550\text{ cm}^{-1}$ indicates O–H;

mass spectrometry/spectroscopy / ms;

$m/z = 45$ represents loss of CH_3 and $m/z = 31$ represents loss of C_2H_5 ;

^1H /proton NMR;

$\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ 3 peaks (in ratio 6:1:1) and $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ 4 peaks (in ratio 3:2:2:1);

oxidation;

$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ /primary alcohol will react to form an acidic product **and**

$\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ /secondary alcohol will not;

[6 max]

Allow also argument involving different boiling points, with justification in terms of intermolecular forces.
