N08/4/CHEMI/HP2/ENG/TZ0/XX/M+

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

MARKSCHEME

November 2008

CHEMISTRY

Higher Level

Paper 2

14 pages

General Marking Instructions

Assistant Examiners (AEs) will be contacted by their team leader (TL) by e-mail (or telephone) – if by e-mail, please reply to confirm that you have downloaded the markscheme from EXAMNET. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the mark scheme and its interpretation. AEs should contact their team leader by e-mail at any time if they have any problems/queries during the marking process.

Note:

The DHL courier service must be used to send assessment material to your team leader/senior moderator and to IB Cardiff. (However, this service is not available in every country.) The cost is met directly by the IBO. It is vitally important that the correct DHL account number is used.

If you have any queries on **administration** please contact:

Barry Evans
Examinations Administration Department (EAD)
IB Cardiff
Peterson House
Malthouse Avenue
Cardiff Gate
Cardiff CF23 8GL
GREAT BRITAIN

Tel: +(44) 29 2054 7777

Fax: +(44) 29 2054 7778

Email: barry.evans@ibo.org

1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**

3. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases write a brief annotation to explain your decision. You are encouraged to write comments where it helps clarity, especially for moderation and re-marking. It should be remembered that the script may be returned to the candidate.

4. Unexplained symbols or personal codes/notations are unacceptable.

5. Record marks in the right-hand margin, against each mark allocation shown in square brackets *e.g.* ***[2]***. The total mark for a question must equal the number of ticks for the question.

6. Do **not** circle sub-totals. **Circle the total mark** for the question in the right-hand margin **at the end of the question.**

7. Where an answer to a part question is worth no marks, put a zero in the right-hand margin next to the square bracket.

8. Where work is submitted on additional sheets the marks awarded should be shown as ticks and a note made to show that these marks have been transferred to the appropriate square bracket in the body of the script.

9. For each option: Add the total for each question in the option and write it in the Examiner column on the front cover.
Total: Add up the marks awarded and enter this in the box marked TOTAL in the Examiner column on the cover sheet.

10. After entering the marks on the front cover check your addition to ensure that you have not made an error. Check also that you have transferred the marks correctly to the cover sheet. **All scripts are checked and a note of all clerical errors will be given in feedback to examiners.**

11. If an answer extends over more than one page and no marks have been awarded on a section draw a diagonal line through that section to indicate that it has been marked.

12. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers and use the marks of those answers that have the highest mark, **unless the candidate has indicated the question(s) to be marked on the front cover**.

13. A mark should not be awarded where there is contradiction within an answer. Make a comment to this effect in the left hand margin.

Subject Details: Chemistry HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[40 marks]** and **TWO** questions in Section B **[2 × 25 marks]**. Maximum total = **[90 marks]**.

1. A markscheme often has more marking points than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/) – either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are underlined are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover page.

11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

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

12. If a question specifically asks for the name of a substance, do not award a mark for a correct formula, similarly, if the formula is specifically asked for, do not award a mark for a correct name.

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

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

SECTION A

1. (a) (i) gas/carbon dioxide/CO_2 is given off/evolves/escapes/formed; ***[1]***

(ii) $n(CaCO_3)\left(=\frac{5.00}{100.09}\right)=0.0500$;

$n(HCl)\left(=\frac{1.00\times 50.0}{1000}\right)=0.0500$; ***[2]***

Do not penalize significant figures.
No penalty for using 100 instead of 100.09.

(iii) $CaCO_3$ because twice as much acid needed / *OWTTE*; ***[1]***
Allow HCl is limiting.
Allow HCl in excess as correct deduction from wrong values in (a)(ii).

(iv) (line 2) steeper;
levels off at same mass as Experiment 1;
Apply ECF from part (ii).

(line 3) steeper;
levels off halfway between zero and Experiment 1; ***[4]***

Allow ECF for lines on graph from HCl in excess in (a)(iii). This means that the lines are the same but numbered the other way round.
If lines are unlabelled allow ***[2 max]****.*

(b) (i) order wrt A is zero because increasing/doubling [A] has no effect on rate / *OWTTE*;
order wrt B is 2 because doubling [B] quadruples rate/halving [B] quarters rate / *OWTTE*; ***[2]***
If explanations missing or incorrect but both orders correct, award ***[1]*** *mark.*
Accept other mathematical explanations.

(ii) $\text{rate}=k[B]^2$ / $\text{rate}=k[A]^0[B]^2$; ***[1]***
ECF from (b)(i)

(iii) $k=\frac{8.8\times 10^{-4}}{\left(7.8\times 10^{-2}\right)^2}=0.14$;

$mol^{-1}\,dm^3\,min^{-1}$; ***[2]***
ECF from (b)(ii)

2. (a) (atoms of the) same element / atoms with same number of protons/atomic number/Z;
Do not award mark if no mention of atom or element.

(but) different numbers of neutrons/mass number/A; ***[2]***

(b) (i) $(82\times0.1580)+(84\times0.6540)+(86\times0.1880)$ / other working;
84.06; ***[2]***
Consider ECF for final answer if correct method is used but transcription or arithmetic error is present in the first stage.
*Award **[2]** for correct final answer with or without working.*

(ii) 36 protons **and** 36 electrons;
48 neutrons; ***[2]***

(c) (i) $(1s^2 2s^2 2p^6)3s^2 3p^6 3d^{10} 4s^2 4p^6$; ***[1]***
Accept $3d^{10}$ and $4s^2$ in reverse order.

(ii) 20; ***[1]***

3. (a) (i) proton / H^+ / hydrogen ion donor; ***[1]***

(ii) NH_3 **and** NH_4^+ / H_2O **and** OH^-; ***[1]***

(iii) NH_3 / OH^-;
covalent / dative / co-ordinate; ***[2]***

(b) (i) $CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$; ***[1]***
Do not accept $\rightarrow$ *in place of* $\rightleftharpoons$
Ignore state symbols.

(ii) $[OH^-] = \sqrt{K_b}\,[CH_3NH_2] / \sqrt{(4.37\times10^{-4})\times0.0500}$;
$[OH^-] = 4.67\times10^{-3}\,(\text{mol dm}^{-3})$;
$pOH = 2.33$;
Correct final answer scores ***[3]*** *marks*

$[CH_3NH_2]$ does not change / *OWTTE* / appropriate mathematical abbreviation; ***[4]***
If quadratic equation used award final mark.

(iii) n $CH_3NH_3^+$ at eq (= n HCl added) =0.010;
n CH_3NH_2 at eq $(=0.025-0.010)$ =0.015;
$[OH^-] = \dfrac{K_b\times[CH_3NH_2]}{[CH_3NH_3^+]} / \dfrac{4.37\times10^{-4}\times0.015}{0.010} / = 6.6\times10^{-4}$ (mol dm^{-3});
$pOH = 3.2 / [H^+] = 1.5\times10^{-11}$;
$pH = 10.8$; ***[5]***
Correct final answer scores full marks.

4. (a) (i) (methane) 0.50 (mol)
(steam) 1.5 (mol)
(hydrogen) 1.5 (mol) ***[2]***
Three correct award ***[2]****, two correct award* ***[1]****, one or zero correct award* ***[0]****.*

(ii) $K_c = \dfrac{[CO][H_2]^3}{[CH_4][H_2O]}$; ***[1]***

(iii) $K_c = \dfrac{(0.50\div20)\times(1.5\div20)^3}{(0.50\div20)\times(1.5\div20)} = 5.6\times10^{-3}$;
mol^2 dm^{-6} / equilibrium constants have no units; ***[2]***
Apply ECF from (a)(i) and (ii).

SECTION B

5. (a) (i) energy change to break/make (one mole) of bonds (in molecule) in gaseous state; averaged over similar compounds; ***[2]***

(ii) H–H bond is only present in one molecule/*OWTTE*; ***[1]***

(b) (i) bonds broken: 2 C=O and 4 H–H / 1486 + 1744 / 3230;
bonds formed: 4 C–H and 4 O–H / 1648 + 1852 / 3500;
$\Delta H\ (= 3230 - 3500) = -270\ (\text{kJ/kJ mol}^{-1})$; ***[3]***
ECF from bonds broken and formed.
*Correct final answer scores **[3]** marks.*
*270 kJ/kJ mol^{-1} or +270 kJ/kJ mol^{-1} scores **[2]** marks.*

(ii) reactants entropy $= 214 + (4 \times 131) = 738$;
products entropy $= 186 + (2 \times 189) = 564$;
$\Delta S^{\ominus}\ (= 564 - 738) = -174\ (\text{J K}^{-1}\ \text{mol}^{-1})$; ***[3]***
ECF from reactants and products entropy.
*Correct final answer scores **[3]** marks.*
*174 J K^{-1} mol^{-1} or +174 J K^{-1} mol^{-1} scores **[2]** marks.*

(iii) sign should be negative because of increase in order/decrease in disorder;
fewer moles of gas on right; ***[2]***

(iv) $\Delta G^{\ominus} = -270 - (298 \times -0.174)$;
Mark is for correct use of $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ and unit conversion.

$= -218\ \text{kJ mol}^{-1}$ / kJ;

spontaneous because $\Delta G^{\ominus}$ negative; ***[3]***

(c) *for first equation* $8 \times -394 / -3152$;
for second equation $9 \times -286 / -2574$;
for third equation $+5512$;
$\Delta H^{\ominus} = -214\ (\text{kJ or kJ mol}^{-1})$; ***[4]***
*No penalty for missing units, but penalize wrong units by **–1(U)**.*
*Correct final answer award **[4]** marks.*
All marks can be scored from enthalpy cycle.
Consider ECF for final mark.

(d) atomization / sublimation / vaporization **and** $\text{K(s)} \rightarrow \text{K(g)}$;
ionization / first ionization energy **and** $\text{K(g)} \rightarrow \text{K}^{+}\text{(g)} + \text{e}^{-}$;
atomization / $\frac{1}{2}$ bond enthalpy **and** $\frac{1}{2}\ \text{F}_2\text{(g)} \rightarrow \text{F(g)}$;
electron affinity **and** $\text{F(g)} + \text{e}^{-} \rightarrow \text{F}^{-}\text{(g)}$; ***[4]***
No penalty for using e instead of e^{-}.
Penalize missing state symbols every time.

(e) (i) Na^+ smaller (ion/radius) / greater charge density than K^+; ***[1]***

(ii) Ca^{2+} larger ionic charge / greater charge density (compared to K^+);
stronger electrostatic attraction / stronger attraction between ions; ***[2]***
Allow second marking point in (e)(i) if not given in (e)(ii).

6. (a) (oxidation is) loss of electron(s);
Br^- / bromide (ion); ***[2]***

(b) Ti +4 and +4;
Cl 0 and –1;
C 0 and +4; ***[3]***
Penalize missing +, or answers written as 4+ once only.
*If no marks scored allow **[1]** if all oxidation numbers for reactants or for products are correct.*

(c) (i) Cr oxidation number +6/same on both sides/does not change;
neither oxidation nor reduction occur; ***[2]***
No ECF

(ii) Cl oxidation number 0 on left and –1 and +1 on right;
both oxidation and reduction occur / disproportionation; ***[2]***
No ECF

(d) (i) W > Z > Y > X;
*Award **[1]** mark for correct order.*

X below Y because of reaction 2/because X will not displace Y;
X below Z because of reaction 4/because X displaced by Z;
X below W because of reaction 1/because Z displaced by W **and** Z displaces X;
Y below Z because of reaction 3/because Y will not displace Z; ***[4 max]***
Give credit for OWTTE in this part.
*Any three of last four score **[1]** each.*

(ii) $2V + 3XO \rightarrow V_2O_3 + 3X$; ***[1]***

(e) (i) Fe^{2+} / Ag;
$2Fe^{2+} + Br_2 \rightarrow 2Fe^{3+} + 2Br^-$ / $2Ag + Br_2 \rightarrow 2Ag^+ + 2Br^-$ /
$2Ag + Br_2 \rightarrow 2AgBr$; ***[2]***
Ignore state symbols.

(ii) $(E^\ominus = +0.80 - (-1.66) =) (+)2.46$ V; ***[1]***

(iii) $(E^\ominus = +0.48 - 0.76 =) - 0.28$ V; ***[1]***

(f) (i) water has a non-bonding pair of electrons;
donates to metal ion / forms co-ordinate / dative bond with metal ion / acts as Lewis base;

octahedral; ***[3]***
Allow square bipyramidal.

(ii) in transition metal complexes the d orbitals/levels are split (into two levels of different energy);
in cobalt the d levels are partially filled **and** in zinc they are completely filled;
visible light absorbed when electrons move from lower to higher energy levels / d – d transitions (in cobalt);
transmitted light is complementary colour / *OWTTE*; ***[4]***

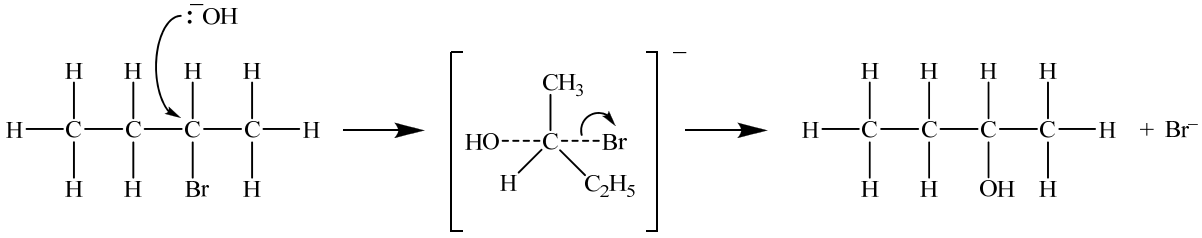
7. (a) (i) $CH_3CH_2CH_2COOH$ / $CH_3CH_2CH_2CO_2H$;
butanoic acid; ***[2]***

(ii) ester; ***[1]***

(b) (i) Br• = bromine (free) radical/atom **and** Br^- is bromide (ion);
Br• homolytic fission / involves equal division of electron pair / *OWTTE*;
Br^- heterolytic fission / involves electron pair remaining with one species / *OWTTE;* ***[3]***

(ii) S = substitution
N = nucleophilic
2 = molecularity of 2 / reaction is bimolecular ***[2]***
*Three correct award **[2]**, two correct award **[1]**, one or none correct award **[0]**.*

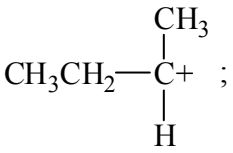
(iii)



curly arrow from O or negative charge on OH^- to C of C–Br bond;
structure of transition state showing charge **and** partial bonds;
Do not penalise missing square brackets.

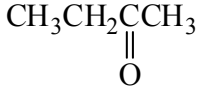
curly arrow from C–Br bond to Br (on reactant or on transition state);
structure of butan-2-ol **and** Br^-; ***[4]***
If mechanism shown for 1-bromobutene, then all marks except the last can be awarded.

(iv)



; ***[1]***

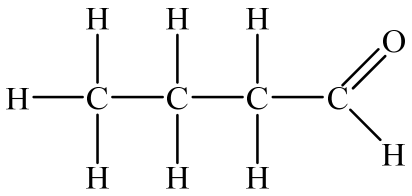
(v)



;

dichromate / $Cr_2O_7^{2-}$ / potassium dichromate / $K_2Cr_2O_7$ / sodium dichromate / $Na_2Cr_2O_7$;
acidified/sulfuric acid/ H_2SO_4/H^+; ***[3]***

(vi)



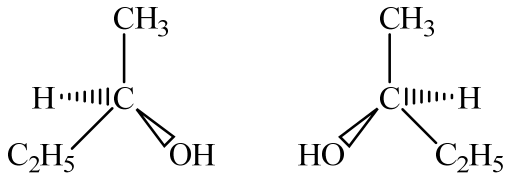
; ***[1]***

Accept condensed structural formula

(c) (i) F / butan-2-ol;
hydrogen bonding; ***[2]***

(ii) E / 2-bromobutane;
cannot hydrogen bond with water; ***[2]***

(d) chiral/asymmetric carbon atom / carbon atom joined to 4 different groups;



correct 3-D structure of either isomer;
other correct 3-D structure clearly showing relationship;

planes <u>rotated</u> in opposite directions; ***[4]***

8. (a) electron moves from 2s to 2p;
(one) (2)s and (one) (2)p orbital hybridize / mix / combine;
sp (hybrid) orbital forms sigma bonds with C and H / C and C;
two electrons in (unhybridized) (2)p orbitals overlap sideways;
*If 2 not mentioned, award **[3 max]** for above marks.*

to form (two) pi bonds; ***[4 max]***
*Any four for **[1]** each.*
*If no marks scored, award **[1]** for sp hybridization.*

(b) sp^2;
120˚;
sp^3;
109(.5)˚; ***[4]***

(c) if benzene had 3 C=C bonds enthalpy of reaction should be –360 kJ;
(real) benzene is (152 kJ) more stable than structure with 3 C=C bonds suggests;
circle-in-hexagon symbol represents delocalized electrons / resonance hybrids; ***[3]***

(d) benzene with alternate single and double bonds should have two different carbon to carbon bond lengths / carbon to carbon bond lengths of 0.154 and 0.134 nm / *OWTTE*;
(all) bonds in benzene are same length / all 0.139 nm; ***[2]***

(e) (i) electrons in p-orbitals overlap to form delocalized orbital extending over three atoms; ***[1]***

(ii) (in COOH) two different bond lengths / C=O shorter than C–O;
(in COO^-) both the same / intermediate between the values for C–O and C=O in COOH; ***[2]***

(f) I is substitution **and** II is addition;
II loses delocalization **and** decreases stability / I keeps delocalization / II needs more energy to overcome delocalization; ***[2]***

(g) (i) $K_a (= 10^{-4.20}) = 6.31 \times 10^{-5}$ (mol dm^{-3}); ***[1]***

(ii) $C_6H_5COOH + NaOH \rightarrow C_6H_5COONa + H_2O$; ***[1]***

(iii) phenolphthalein;
Accept phenol red.

weak acid-strong base titration / *OWTTE*; ***[2]***

(iv) n NaOH $= 0.0300 \times 0.0170 = 5.10 \times 10^{-4}$ (mol) = n benzoic acid;

$[HA] = \frac{5.10 \times 10^{-4}}{0.0250}$;

$= 0.0204$ (mol dm^{-3}); ***[3]***

*Correct final answer scores **[3]** marks.*