M12/4/CHEMI/HP2/ENG/TZ2/XX/M

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

MARKSCHEME

May 2012

CHEMISTRY

Higher Level

Paper 2

16 pages

General Marking Instructions

Assistant Examiners (AEs) will be contacted by their team leader (TL) through Scoris™, by e-mail or telephone – if through Scoris™ or by e-mail, please reply to confirm that you have downloaded the markscheme from IBIS. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the markscheme and its interpretation. AEs should contact their team leader through Scoris™ or by e-mail at any time if they have any problems/queries regarding marking. For any queries regarding the use of Scoris™, please contact emarking@ibo.org.

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

Rachel Bengough
Subject Operations
IB Assessment Centre
Peterson House
Malthouse Avenue
Cardiff Gate
Cardiff CF23 8GL
GREAT BRITAIN

Tel: +(44) 29 2054 7777

Fax: +(44) 29 2054 7778

E-mail: rachel.bengough@ibo.org

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

2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.

3. 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.**

4. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases use Scoris™ annotations to support your decision. You are encouraged to write comments where it helps clarity, especially for re-marking purposes. Use a text box for these additional comments. It should be remembered that the script may be returned to the candidate.

5. Personal codes/notations are unacceptable.

6. Where an answer to a part question is worth no marks but the candidate has attempted the part question, enter a zero in the mark panel on the right-hand side of the screen. Where an answer to a part question is worth no marks because the candidate has not attempted the part question, enter an "NR" in the mark panel on the right-hand side of the screen.

7. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers. Scoris™ will only award the highest mark or marks in line with the rubric.

8. Ensure that you have viewed **every** page including any additional sheets. Please ensure that you stamp 'seen' on any page that contains no other annotation.

9. Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have got wrong. However, a mark should not be awarded where there is contradiction within an answer. Make a comment to this effect using a text box or the "CON" stamp.

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.

SECTION A

1. (a) reaction is complete / all hydrogen peroxide/reactant is used up / no more bubbles are being produced / layer of bubbles is constant / *OWTTE*; ***[1]***

(b) correctly drawn tangent to the graph at 120 s;

rate = gradient of the tangent to the graph at 120 s / $\text{rate} = \frac{6.0 - 2.0}{240 - 0}$;

$= 0.017 \text{ mm s}^{-1}$; ***[3]***

Accept answers in the range 0.014 to 0.020 mm s^{-1}.
Units required for M3.

(c) (i)

Species	Oxidation number of oxygen
H_2O_2	–1
H_2O	–2
O_2	0

[2]

*Award **[2]** for three correct.*
*Award **[1]** for two correct.*

(ii) *Oxidation*:

$H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$;

Reduction:

$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$; ***[2]***

2. (a) $Mg(s) + 2HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$; ***[1]***

(b) $n(Mg) = \left(\frac{0.0740}{24.31}\right) = 3.04 \times 10^{-3}$ (mol);

Accept range 3.04×10^{-3} to 3.08×10^{-3}.

$n(HCl) = (2.00 \times 15.0 \times 10^{-3}) = 3.00 \times 10^{-2}$ (mol);

Mg; ***[3]***

(c) (i) $n(H_2) = n(Mg) = 3.04 \times 10^{-3}$ (mol); ***[1]***

Accept same value as in 2(b).

Answer must be in range 3.04×10^{-3} to 3.08×10^{-3} and must have 2, 3 or 4 significant figures.

(ii) $V\left(= \frac{nRT}{P}\right) = \frac{3.04 \times 10^{-3} \times 8.31 \times 293 \times 10^{6}}{1.01 \times 10^{5}}$;

$= 73.4\ (cm^3)$; ***[2]***

Accept answers in the range 72.3 to 74.3 (cm^3).

(d) gas leaks from apparatus / gas escapes;
the syringe stuck;
Mg impure; ***[2 max]***

3. (a) radius of the metal/positive ion/cation increases;
attraction (between ions) is weaker; ***[2]***

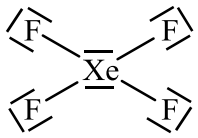
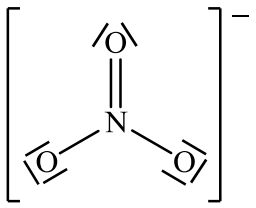
(b) higher charge (on cation);
smaller radius (of cation); ***[2]***

(c) (i) (standard enthalpy of) atomization/$\Delta H^{\ominus}_{\text{atomization}}$ / (standard enthalpy of) sublimation/$\Delta H^{\ominus}_{\text{sublimation}}$; ***[1]***

(ii) lattice enthalpy $= +1049\ \text{kJ mol}^{-1}$ (Data Booklet Table 13)
bond enthalpy F–F $= +158\ \text{kJ mol}^{-1}$ (Data Booklet Table 10)
first ionization energy (Li) $= +520\ \text{kJ mol}^{-1}$ (Data Booklet Table 7)
$\Delta H^{\ominus}_{\text{electron affinity}}$ (F) $= -328\ \text{kJ mol}^{-1}$ (Data Booklet Table 7)
$\Delta H^{\ominus}_{\text{atomization}}$ of Li $= +159\ \text{kJ mol}^{-1}$ (given)

$\Delta H_f^{\ominus} = +159 + \frac{1}{2}(158) + 520 + (-328) - (1049)$;
$= -619\ \text{kJ mol}^{-1}$; ***[2]***
Accept use of theoretical value of lattice enthalpy, +1030 kJ mol^{-1}:
$\Delta H_f^{\ominus} = +159 + \frac{1}{2}(158) + 520 + (-328) - (1030)$
$= -600\ \text{kJ mol}^{-1}$

4.

Species	Lewis structure	Shape	Bond angle
XeF_4	 ;	square planar;	90° ;
NO_3^-	 ;	trigonal/triangular planar;	120° ;

[6]

Accept any combination of lines, dots or crosses to represent electron pairs.

5. (a) (i) atoms which have same atomic number but different mass number / atoms of the same element which have different numbers of neutrons / atoms with the same number of protons but different numbers of neutrons / atom of an element with a fixed number of protons but a number of neutrons which can be variable; ***[1]***

(ii) medical tracer / used to investigate functioning of thyroid gland / to treat thyroid cancer / to treat hyperthyroidism;
produces gamma rays/ionizing radiation / destroys healthy cells / *OWTTE*; ***[2]***
Do not accept I-131 is radioactive.

(b) living organisms have ^{12}C:^{14}C ratio constant/same as atmosphere / *OWTTE*;
after death no more ^{14}C is absorbed and ^{14}C level drops / ^{12}C:^{14}C ratio changes with time / ^{14}C decays / remains become less radioactive;
rate of decay of ^{14}C is constant / half-life of ^{14}C is known;
measuring radioactivity indicates length of time since death / *OWTTE*; ***[3 max]***

6. *$Cr(NO_3)_3$*:
acidic;
high charge density of small Cr^{3+} causes it to be a Lewis acid /
$[Cr(H_2O)_6]^{3+} \rightleftharpoons [Cr(OH)(H_2O)_5]^{2+} + H^+$ / *OWTTE*;

CH_3COONH_4:
(approximately) neutral;
salt of a weak acid and weak base / K_a of NH_4^+ is approximately equal to K_b of CH_3COO^- / ions are a weak acid and a weak base / *OWTTE*; ***[4]***

SECTION B

7. (a) (i) *Empirical formula:*
simplest (whole number) ratio of atoms/moles of each element present in a compound/molecule;

Molecular formula:
actual numbers of atoms/moles of each element present in a compound/molecule / whole number multiple of empirical formula; ***[2]***

(ii) $n(\text{C}) = 4.54\,(\text{mol})$, $n(\text{H}) = 9.11\,(\text{mol})$ **and** $n(\text{O}) = 2.27\,(\text{mol})$;
$\text{C}_2\text{H}_4\text{O}$; ***[2]***
Accept other valid method for calculation.

(iii) $\text{C}_4\text{H}_8\text{O}_2$; ***[1]***

(iv) $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$; ***[1]***
Accept full or condensed structural formulas.

(v) $\text{CH}_3\text{CH}_2\text{COOCH}_3$ / $\text{CH}_3\text{COOCH}_2\text{CH}_3$ / $\text{HCOOCH}_2\text{CH}_2\text{CH}_3$ / $\text{HCOOCH}(\text{CH}_3)_2$; ***[1]***
Accept full or condensed structural formulas.

(vi) *Stronger bond:*
C=O/double bond;

Longer bond:
C–O/single bond; ***[2]***

(vii) bond length and bond strength identical for both carbon to oxygen bonds;
intermediate between single and double bond length and strength;
due to delocalization of the electrons (in the p orbitals); ***[3]***
Accept use of Data Booklet values of bond lengths and bond enthalpies.
Accept diagram of delocalization or the two resonance structures for M3.

(b) (i) mixing/joining together/combining/merging of (atomic) orbitals to form molecular/new orbitals (of equal energy); ***[1]***

(ii) sp^3;
isolated C atom electron configuration $1s^2 2s^2 2p^2$ / excited state C electron configuration is $1s^2\ 2s^1 2p^3$;
$2s^1 2p^3$ electrons blend to form four identical hybrid orbitals;
hybrid orbitals lower in total energy than atomic orbitals;
repulsion of (identical hybrid) orbitals creates a tetrahedral shape; ***[3 max]***
Accept suitably annotated diagram for M2, M3 and M4.

(iii) *diamond*:
sp^3;

graphite:
sp^2;
(p) electrons delocalized (around layer); ***[3]***

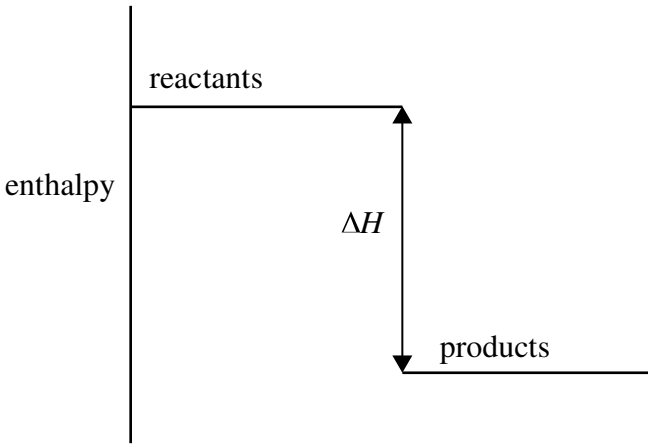
(c) (i) Al_2Cl_6:
covalent bonding / dimer/molecular structure;
no free charges when molten so not an electrical conductor;

Al_2O_3:
ionic / lattice structure;
ions free to move/mobile in molten state; ***[4]***

(ii) vigorous reaction / fizzing / fumes are seen / heat is released / *OWTTE*;
HCl(g) evolved;
$Al_2O_3/Al(OH)_3$ is formed; ***[2 max]***
Accept suitable equation for second and third marking points.

8. (a) (i) enthalpy on *y*-axis;
Do not accept energy.

reactants higher than products;
ΔH labelled; ***[3]***



Accept appropriate formulas for reactants and products.
Arrow heads not needed.
57.6 is acceptable as an alternative to ΔH .

(ii) products are more stable as they are at a lower enthalpy level / energy has been given off by the reactants / reaction is exothermic / *OWTTE*; ***[1]***

(iii) $n(\text{NaOH}) = 0.125 \text{ mol}$;
change in heat energy = $(-57.6 \times 0.125) = -7.20$ (kJ) / heat released $= (57.6 \times 0.125) = 7.20$ (kJ); ***[2]***

(b) more vigorous reaction / more gas bubbles / *OWTTE*;
more heat released;
solid decreases more quickly; ***[1 max]***

(c) $q = (mc\Delta T =) 100.0 \times 4.18 \times 3.50 / 1463 \text{ J} / 1460 \text{ J}$;
$n(\text{NH}_4\text{Cl}) = \frac{5.35}{53.5} / 0.100 \text{ mol}$;
$\Delta H = +14.6 / 14.6 \text{ (kJ mol}^{-1}\text{)}$; ***[3]***
Accept $q = 105.35 \times 4.18 \times 3.50 / 1541 \text{ J}$.
Accept $\Delta H = +15.4 / 15.4 \text{ (kJ mol}^{-1}\text{)}$.

(d) $[OH^-] = \left(\sqrt{0.500 \times 1.78 \times 10^{-5}}\right) = 2.98 \times 10^{-3}\ \text{mol dm}^{-3}$;

$\text{pOH} = -\log_{10}[OH^-] = 2.526$ / $[H^+] = \left(\frac{1.00 \times 10^{-14}}{2.98 \times 10^{-3}}\right) = 3.35 \times 10^{-12}\ \text{mol dm}^{-3}$;

$\text{pH} = 11.47$;

Accept correct answer obtained using another method.

Assumption:
$[NH_3] = 0.500\ \text{mol dm}^{-3}$ / $[NH_4^+] = [OH^-]$ / all OH^- ions come from the reaction of ammonia with water and not from the dissociation of water / temperature is 25 °C/298 K / *OWTTE*; ***[4]***

(e) (i) resists change in pH when <u>small</u> amounts of a strong base/strong acid/water are added to it; ***[1]***

(ii) $[NH_3] = 0.250\ \text{mol dm}^{-3}$;
$[NH_4^+] = 0.250\ \text{mol dm}^{-3}$; ***[2]***

(iii) $\text{pOH} = \text{p}K_b = 4.75$;
$\text{pH} = 9.25$; ***[2]***

(iv) equilibrium shifted left in buffer / *OWTTE*; ***[1]***

(v) acid neutralized by hydroxide / most of the added H^+ ions react with NH_3;
more ammonia reacts with water to replace hydroxide ions / more NH_4^+ ions form so there is little change in the pH / *OWTTE*; ***[2]***
Accept equations.

(f) (i) colours of HIn and In^- are different / *OWTTE*; ***[1]***

(ii) colour change occurs when $[HIn] = [In^-]$;
$\text{pH} = \text{p}K_a$;

OR

pH range is a range of pH values either side of pK_a value;
lower pH when acid colour is seen **and** upper pH when alkaline colour seen; ***[2]***

9. (a) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ / $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$; ***[1]***

(ii) $[Ar]\,3d^5$; ***[1]***

(iii) lone pair of electrons (on C);
CN^- acts as a Lewis base / Fe^{3+} acts as a Lewis acid;
dative covalent/coordinate bond formed (between CN^- and Fe^{3+});
ligands occupy an octahedral shape around central metal ion / coordination number of Fe^{3+} is 6; ***[4]***

(iv) d sub-level splits (into two sets of orbitals of different energy) / $\underline{\quad}\ \underline{\quad}\ \underline{\quad} \updownarrow \Delta E$;
colour due to electron transitions between (split) d orbitals; ***[2]***

(b) (i) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$; ***[1]***

(ii) Pt/platinum / V_2O_5/vanadium(V) oxide/vanadium pentoxide; ***[1]***

(iii) provides a reaction pathway with lower activation energy;
more molecules/particles have sufficient energy to react; ***[2]***

(iv) reduces energy costs (as reaction occurs at lower temperatures) / *OWTTE*;
catalyst can be reused;
increases reaction rate so more product produced in a given time / *OWTTE*; ***[2 max]***

(v) entropy decreases;
products have fewer moles of gas than reactants; ***[2]***

(vi) less spontaneous at higher temperatures;
spontaneous when $\Delta G < 0$ / $\Delta G = \Delta H - T\Delta S$;
$-T\Delta S$ always positive so spontaneous when $T\Delta S < \Delta H$ / *OWTTE*; ***[3]***

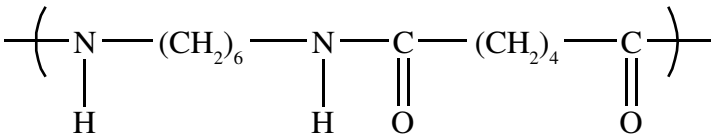
(c) (i) *k*:
rate constant;

A:
Arrhenius constant / frequency/pre-exponential factor; ***[2]***

(ii) gradient $= \frac{-E_a}{R}$ / $E_a = -\text{gradient} \times R$;
$\left(= -(-16) \times 8.31\right) = +133\ (\text{kJ mol}^{-1})$ / $1.33 \times 10^5\ (\text{J mol}^{-1})$; ***[2]***

(iii) $\ln A = (\text{intercept on } y\text{-axis} =) 23.2$;
$A = 1.190 \times 10^{10}$; ***[2]***

10. (a) (i) ethanol **and** methanoic acid/methanoic anhydride/methanoyl chloride;
H_2SO_4/H^+ **and** heat; ***[2]***

(ii) 

*Award **[1]** for the correct amide link.*
*Award **[1]** if the rest of the structure is correct.*

nylon fabric / clothing / ropes; ***[3]***

(b) (i) (concentrated) sulfuric acid/ H_2SO_4 / phosphoric acid/ H_3PO_4; ***[1]***
Acid must be named or formula given.

(ii) step **I**:
HBr/hydrogen bromide;
gaseous / anhydrous / inert/non-polar solvent;

step **II**:
sodium hydroxide/NaOH / potassium hydroxide/KOH;
aqueous (solution) / dilute / warm / heat / reflux; ***[4]***

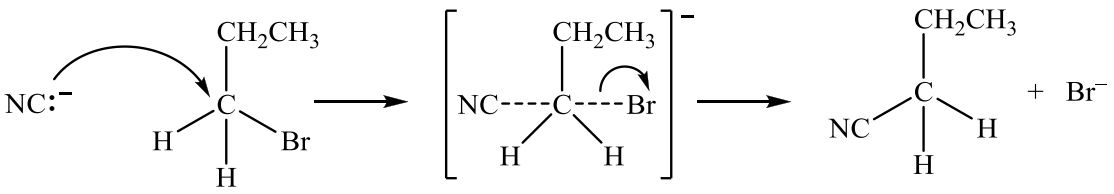
(iii) slower rate because carbon to chlorine bond stronger than carbon to bromine bond / *OWTTE*; ***[1]***

(c) (i) compounds with the same molecular formula but different arrangements of atoms / compounds with the same molecular formula but different structural formulas; ***[1]***

(ii) $CH_3CH(Br)CH_2CH_3$;
secondary/ 2°;

$CH_2(Br)CH(CH_3)CH_3$;
primary/ 1°; ***[4]***
Accept full or condensed structural formulas.

(d) (i) C has partial positive charge / C to Br bond is polar; ***[1]***

(ii) 

curly arrow going from lone pair/negative charge on C in CN^- to C;
Do not allow curly arrow originating on N in CN^-.

curly arrow showing Br leaving;
Allow curly arrow going from bond between C and Br to Br in reactant or transition state.

representation of transition state showing negative charge, square brackets and partial bonds;
Do not penalize if NC and Br are not at 180° to each other.
Do not award M3 if CN–C bond is represented.

formation of organic product **and** Br^-; ***[4]***

(iii) hydrogen/H_2;
(catalyst) nickel/Ni / palladium/Pd / platinum/Pt; ***[2]***

(e) $CH_3CH_2CH_2Br + OH^- \longrightarrow CH_3CH{=}CH_2 + H_2O + Br^-$
correct organic product;
products of H_2O and Br^-; ***[2]***