M13/4/CHEMI/HP2/ENG/TZ1/XX/M

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

MARKSCHEME

May 2013

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.

SECTION A

1. (a) 0.675 (g) ± 0.002 (g);
Percentage uncertainty: 0.3 %; ***[2]***
Accept answers correct to one, two or three significant figures for percentage uncertainty.

(b) *In 25.0 cm³:* $n_{HA} = 1.21\times10^{-3}$ (mol);
In 100 cm³: $n_{HA} = 4.84\times10^{-3}$ (mol);
$M\left(=\frac{0.675}{4.84\times10^{-3}}\right) = 139\,(g\,mol^{-1})$; ***[3]***
*Award **[3]** for correct final answer.*
Accept suitable alternative methods.

(c) n_C: $\left(\frac{70.56}{12.01}=\right)5.88$ **and** n_O: $\left(\frac{23.50}{16}=\right)1.47$ **and** n_H: $\left(\frac{5.94}{1.01}=\right)5.88$;
C_4H_4O; ***[2]***
*Award **[2]** for correct final answer.*
Accept answers using integer values of molar mass.

(d) $\left(\frac{M}{\text{Mass of } C_4H_4O}=\right)\frac{139}{68.08} = 2$;
$C_8H_8O_2$; ***[2]***
*Award **[2]** for correct final answer.*

(e) weak acids partially dissociated/ionized **and** strong acids completely dissociated/ ionized (in solution/water) / *OWTTE*; ***[1]***

(f) (i) solution which resists change in pH / changes pH slightly / keeps pH constant / *OWTTE*;
when small amounts of acid or base are added; ***[2]***

(ii) less effective at higher temperatures / more effective between 24 °C and 40 °C than > 40 °C;
pH changes more if the same volume of acid is added at high(er) temperature / *OWTTE*; ***[2]***

2. (a) decreases (from left to right/across period 3);
same number of shells/energy levels / shielding remains the same;
number of protons/nuclear charge increases so attraction of nucleus on outer electrons increases / *OWTTE*; ***[3]***

(b) hypothesis is wrong since ionic radius should be smaller than atomic radius/110×10^{-12} m;
greater attraction of the nucleus on outer electrons / effective charge of nucleus greater / repulsive forces between electrons smaller; ***[2]***

3. (a) minimum energy needed to react/start a reaction / energy difference between reactants and transition state; ***[1]***

(b) *gradient of the line*: –63;
Accept –60 to –65.

$E_a (= -R \times \text{gradient}) = 0.52\,(\text{kJ mol}^{-1})$; ***[2]***
Accept 0.50 to 0.54.

(c) gradient of the line less steep (less negative); ***[1]***
Accept any position as long as gradient less steep.

4. (a) loss of electrons; ***[1]***

(b) *Carbon:*
III to IV / +3 to +4 / (+)1;

Manganese:
VII to II / +7 to +2 / –5; ***[2]***
Penalize incorrect notation such as 3+ once only in all the paper.

(c) *Oxidizing agent:* MnO_4^- **and** *Reducing agent:* $(COOH)_2$; ***[1]***
Accept correct names instead of formulas.
Do not accept Mn and C.

(d) $(COOH)_2 \rightleftharpoons 2CO_2 + 2H^+ + 2e^-$; ***[1]***
Accept either $\rightarrow$ *or* $\rightleftharpoons$.
Allow equation times 5.
Allow e instead of e^-.

(e) (i) $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l) \quad E^\ominus = 1.51\,V$;
$\Delta E^\ominus (= 1.51 + 0.49) = 2.00\,V$; ***[2]***
First mark may be implied in the calculation.
Allow e instead of e^-.
Accept either $\rightarrow$ *or* $\rightleftharpoons$.

(ii) positive sign, spontaneous reaction; ***[1]***
Allow ECF from (e) (i).

(f) negative/< 0; ***[1]***
Do not allow ECF. This mark is independent of the answer in (e)(ii).

5. (a) butan-2-ol/2-butanol; ***[1]***

(b) $CH_3CH_2CH_2CH_2OH$;
$(CH_3)_2CHCH_2OH$;
$(CH_3)_3COH$; ***[2 max]***
Accept condensed or full structural formulas.
Penalise missing H atoms or incorrect bonds (such as C–HO, C–H_2C) once only in the whole paper.

(c) (i) 1-aminopropane/propylamine/1-propanamine; ***[1]***

(ii) $CH_3CH_2CN + 2H_2 \rightarrow CH_3CH_2CH_2NH_2$; ***[1]***
Accept condensed or full structural formulas.

(iii) condensation (polymerization) / polycondensation; ***[1]***

(iv) <u>two</u> reactive/functional groups; ***[1]***

(v) production of nylon/clothes/carpets/ropes/Kevlar; ***[1]***
Accept other uses of nylon.

SECTION B

6. (a) (i) atoms of the same element/with the same number of protons/with same atomic number but different number of neutrons/mass number/mass; ***[1]***

(ii) $10x + 11(1-x) = 10.81,\ x = 0.19$;
Accept similar method.

^{10}B: 19% **and** ^{11}B: 81%; ***[2]***

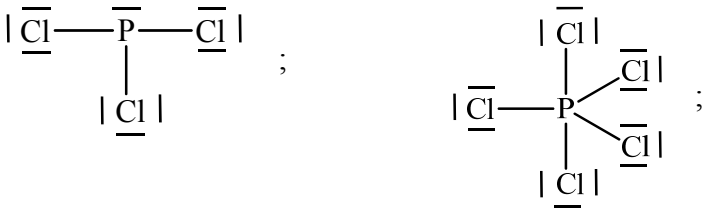
(b) (i) ***R***: acceleration **and** ***S***: deflection; ***[1]***

(ii) B^+; ***[1]***

(iii) ^{12}C/carbon-12; ***[1]***

(c) (i) $1s^2 2s^2 2p^6 3s^2 3p^3$; ***[1]***

(ii) *PCl_3* *PCl_5*



[2]

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

(iii)

	PCl_3	PCl_5
Shape	trigonal/triangular pyramidal;	trigonal/triangular bipyramidal;
Bond angles	any angle between 99° and 108°;	90° **and** 120°; *ignore* 180°

[4]

Shape and bond angle must be consistent with the number of electron domains given in the diagram in (ii).

(iv) sp^3 (hybridization); ***[1]***

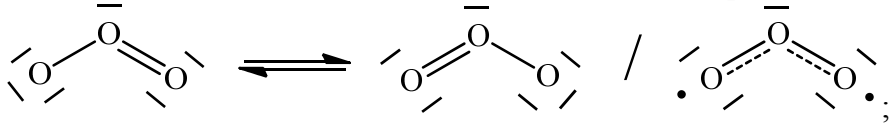
(v) PCl_5 has higher melting point than PCl_3;
PCl_5 has stronger intermolecular/London/dispersion/van der Waals' forces;
(because of) more electrons/greater mass; ***[3]***
Accept the opposite argument for PCl_3.
*Award **[1 max]** for answers suggesting PCl_3 has higher melting point because it is polar and PCl_5 is not.*

(vi) $PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$; ***[1]***
Ignore state symbols.

(d) (i) electron pair acceptor; ***[1]***

(ii) Lewis base;
has non-bonding/lone pair of electrons; ***[2]***
No ECF from (i).

(e) overlap of *p* orbitals / *p* electrons of double/π bond and non-bonding/lone pair on oxygen interact / *OWTTE*;
π electrons not localized / different resonance structures possible /



both bonds/O–O and O=O have equal length / *OWTTE*;
both bonds/O–O and O=O have equal bond energy / *OWTTE*; ***[4]***

7. (a) (i) reactivity decreases down group;
as atomic radius increases / more electron shells;
attraction of nucleus on electrons decreases / electron affinity decreases;
Accept opposite argument for "up the group". ***[3]***

(ii) no reaction with NaCl;
$Br_2(aq) + 2NaI(aq) \rightarrow 2NaBr(aq) + I_2(aq)$; ***[2]***
Accept ionic equation.
Ignore state symbols.

(b) (i) (electrostatic attraction between a) lattice of positive ions/cations **and** delocalized/sea of electrons;
Accept suitable diagram.

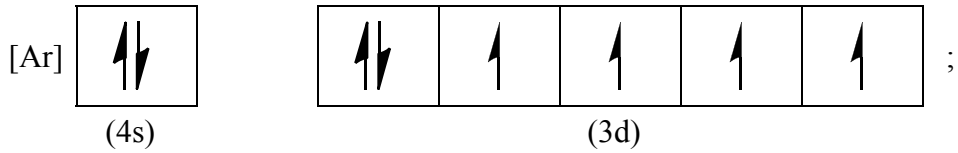
atoms/ions/layers (of positive ions) can slide over each other */ OWTTE*;
without change in the bonding forces */ OWTTE*; ***[3]***

(ii) variable oxidation numbers/valency
form complex (ions)
form coloured compounds/ions
catalytic (behaviour) ***[2]***
*Award **[2]** for any three, **[1]** for any two.*

(iii) dative (covalent)/coordinate; ***[1]***

(iv) III / +3; ***[1]***
Penalize incorrect format such as 3+ only if not penalized in 4 (b).

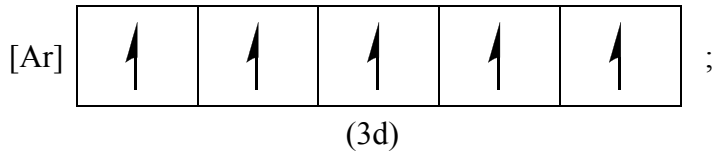
(v)



; ***[1]***

Penalise missing [Ar] only once in (v) and (vi).
Do not accept full orbital diagram; penalise only once in (v) and (vi).
Accept full or half-arrows in (v) and (vi).
Ignore absence of labels 4s and 3d.

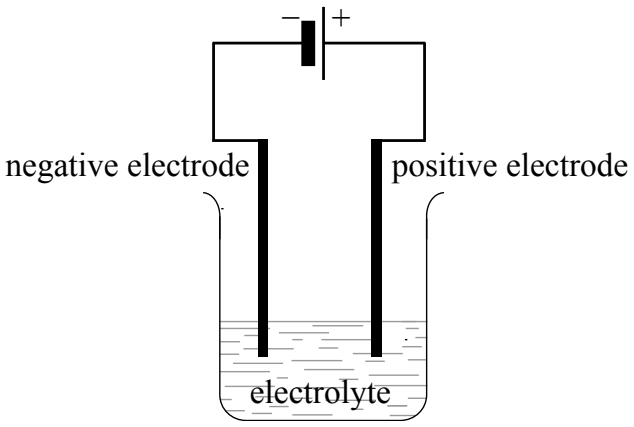
(vi)



; ***[1]***

Accept empty 4s box in (vi).
No ECF from (iv).

(c) (i)



clear diagram containing all elements (power supply, connecting wires, electrodes, container and electrolyte);
Accept power supply if shown as conventional long/short lines (as in diagram above) or clearly labelled DC power supply.

labelled positive electrode/anode **and** negative electrode/cathode;
Accept positive and negative by correct symbols near power supply.

labelled electrolyte/$FeBr_2$ (l)/$FeBr_2$(aq); ***[3]***
State must be included for $FeBr_2$.

(ii) *Electrolyte:* positive ions/cations move to negative electrode/cathode **and** negative ions/anions to positive electrode/anode;
Conductors: electrons flow from negative pole of battery to positive pole of battery / *OWTTE*; ***[2]***
Look at diagram in (i) for possible clarification of electron flow.

*Award **[1 max]** for "electrons in wire/external circuit **and** ions in solution".*

(iii) *Negative electrode/cathode*:
H_2;
$E^{\ominus}$ (H_2) is less negative than $E^{\ominus}$ (Fe) / Fe is more reactive than H_2 / H_2 is lower in reactivity series / H^+ more easily reduced than Fe^{2+} / *OWTTE*;

Positive electrode/anode:
O_2;
$E^{\ominus}$ (O_2) is less positive than $E^{\ominus}$ (Br_2) / in a dilute Br^- solution OH^-/H_2O is preferably discharged / *OWTTE*; ***[4]***
*Award **[3 max]** if electrodes reversed or omitted.*

(iv) Br_2; ***[1]***
Accept Fe.

(v) $2Br^- \rightleftharpoons Br_2 + 2e^-$ shifts to the right; ***[1]***
Accept similar reason for Fe.

8. (a) (i) $(q = mc\Delta T =)\ 0.0500 \times 4.18 \times 21.3 = 4.45$ (kJ);
Do not accept m = 0.05023 kg.

$(n\ methanol =)\ \dfrac{0.230}{32.05} = 7.18 \times 10^{-3}\ (\text{mol})$;

$\Delta H = \dfrac{4.45}{7.18 \times 10^{-3}}$;

$\Delta H = -6.20 \times 10^{2}\ \text{kJ mol}^{-1}$; ***[4]***

Accept integer values of molar mass.
Final answer must have negative sign and correct units.
*Award **[4]** for correct final answer with correct units.*

(ii) less heat is liberated than theoretically/–726 kJ mol^{-1};
probably due to heat loss/incomplete combustion;
determine heat capacity of calorimeter and take heat absorbed by calorimeter into account / any suitable insulation method / measure temperature with time and extrapolation of graph to compensate heat loss / *OWTTE*; ***[3]***
If the value calculated in (a) (i) is more exothermic than theoretically, allow ECF for M1 and for improvement if consistent.

(b) (i) $CH_3OH + \frac{3}{2}O_2 \rightarrow CO_2 + 2H_2O \quad \Delta H^{\ominus}_c = -726\ (\text{kJ mol}^{-1})$
$CO + \frac{1}{2}O_2 \rightarrow CO_2 \quad \Delta H^{\ominus}_c = -283\ (\text{kJ mol}^{-1})$
$H_2 + \frac{1}{2}O_2 \rightarrow H_2O \quad \Delta H^{\ominus}_c = -286\ (\text{kJ mol}^{-1})$
*Award **[1 max]** for three correct values.*
Mark can be implicit in calculations.

$(\Delta H^{\ominus}_R =) 2(-286) + (-283) - (-726)$;
$-129\ (\text{kJ mol}^{-1})$; ***[3]***
*Award **[3]** for correct final answer.*
*Award **[2 max]** for +129 (kJ mol^{-1}).*

(ii) $(\Delta S^{\ominus} = 240 - 198 - 2 \times 131 =) -220\ (\text{J K}^{-1}\ \text{mol}^{-1})$; ***[1]***

(iii) $(-129 - 298(-0.220) =) -63.4\ \text{kJ mol}^{-1}$; ***[2]***
*Award **[1]** for correct numerical answer and **[1]** for correct unit if the conversion has been made from J to kJ for $\Delta S^{\ominus}$.*

(iv) not spontaneous at high temperature;
$T\Delta S^{\ominus} < \Delta H^{\ominus}$ **and** $\Delta G^{\ominus}$ positive; ***[2]***

(c) (i) rate of forward reaction equals rate of backward reaction;
concentrations of reactants and products do not change / constant macroscopic properties; ***[2]***

(ii) $K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$; ***[1]***

Do not award mark if incorrect brackets are used or brackets omitted.

(iii) $n(CO) = 0.508\,(mol)$;
$n(H_2) = 2 \times 0.508\,(mol)$;
$K_c \left(= \frac{0.492}{0.508 \times (2 \times 0.508)^2} \right) = 0.938$; ***[3]***

Accept answer in range between 0.930 and 0.940.
*Award **[3]** for correct final answer.*
*Award **[2]** for $K_c = 1.066$ if (c)(ii) is correct.*

(d) (i) shifts to left/reactants;
to endothermic side / (forward) reaction is exothermic; ***[2]***

(ii) shifts to the right/products;
to the side with fewer gas molecules/moles of gas; ***[2]***

9. (a) (i) same functional group / same general formula;
difference between successive members is CH_2;
similar chemical properties;
Do not accept "same" chemical properties.

gradually changing physical properties; ***[3 max]***

(ii) adding bromine (water);
but-2-ene: brown/orange to colourless / decolourizes bromine water **and**
butane: does not change colour; ***[2]***

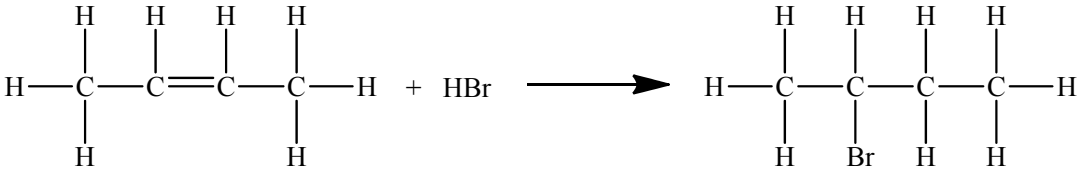
OR

adding acidified potassium permanganate solution/$KMnO_4$(aq);
but-2-ene: purple to colourless/brown **and**
butane: does not change colour;

OR

adding Baeyer's reagent;
but-2-ene: purple/pink to brown **and**
butane: does not change colour;

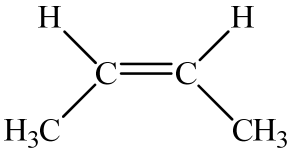
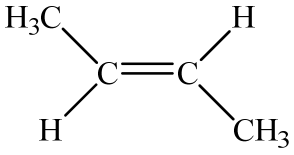
Do not accept "clear" or "transparent" for "colourless".

(iii)  ***[1]***

Accept condensed structural formula.
Penalise missing H atoms or incorrect bonds (such as C–HO, C–H_2C) once only in the whole paper.

(iv) compounds with the same structural formula but different arrangement of atoms (in space); ***[1]***

(v) (but-2-ene exists as) *cis*-but-2-ene **and** *trans*-but-2-ene /

 **and**  ;

cis *trans*

restricted rotation of C=C/double bond; ***[2]***

(b) (i) $C_4H_9Br + OH^- \rightarrow C_4H_9OH + Br^-$; ***[1]***
Accept NaOH in the equation.

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

(c) (i) *C_4H_9Br:*
$[C_4H_9Br]$ doubles **and** time halves/rate doubles/rate proportional to $[C_4H_9Br]$;
Do not accept rate increases when $[C_4H_9Br]$ increases.

NaOH:
[NaOH] doubles **and** time/rate does not change/rate independent of [NaOH];

C_4H_9Br: first order **and** *NaOH:* zero order; ***[3]***

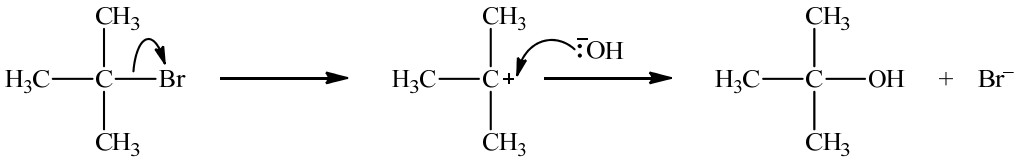
(ii) $\text{rate} = k[C_4H_9Br]$; ***[1]***
Accept ECF.

(iii) s^{-1}; ***[1]***
Accept ECF.

(iv) rate depends on $[C_4H_9Br]$ <u>only</u> / rate does not depend on $[OH^-]$ / S_N1 reaction / first order reaction / if it was primary, reaction would be S_N2;
tertiary; ***[2]***
Accept ECF.

(v) $(CH_3)_3CBr$; ***[1]***
Allow both condensed and full structural formula.
Accept ECF.

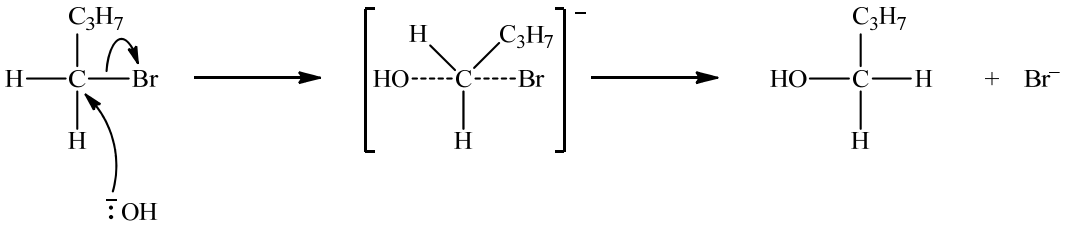
(d) (i)



curly arrow showing Br^- leaving;
representation of tertiary carbocation;
curly arrow going from lone pair/negative charge on O in ^-OH to C^+;
Do not allow arrow originating on H in ^-OH.

formation of $(CH_3)_3COH$ **and** Br^-; ***[4]***
Accept Br^- anywhere on product side in the reaction scheme.

If primary halogenoalkane has been answered in (c)(iv) apply ECF for the mechanism.



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

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

representation of transition state showing negative charge, square brackets and partial bond;
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 C_4H_9OH **and** Br^-;
Accept Br^- anywhere on product side in the reaction scheme.

(ii) greater stability of tertiary carbocation;
steric hindrance for S_N2 mechanism;
positive inductive effect (of alkyl groups); ***[1 max]***
Do not allow ECF.

(iii) the first step / Br^- leaving / formation of carbocation; ***[1]***
Do not allow ECF.