International Baccalaureate®
Baccalauréat International
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MARKSCHEME

November 2014

CHEMISTRY

Standard Level

Paper 2

12 pages

Subject Details: Chemistry SL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[30 marks]** and **ONE** question in Section B **[20 marks]**. Maximum total = **[50 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 <u>underlined</u> 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) river (water); *[1]*

(b) $\left(\frac{0.1}{5.1}\times 100 =\right) 2\%$; *[1]*

(c) recognition that values differ by 2 Ph units / calculation of **both** $[H^{+}]$ values;
(ratio) $= 1:100/10^{-2}/0.01 \;/ \frac{1}{100}$; *[2]*
*Award **[2]** for correct final answer.*
*Award **[1 max]** for 100:1/100/10^{2}.*

(d) $CO_2 + H_2O \rightleftharpoons HCO_3^{-} + H^{+} \;/\; CO_2 + 2H_2O \rightleftharpoons HCO_3^{-} + H_3O^{+} \;/\; CO_2 + H_2O \rightleftharpoons H_2CO_3$; *[1]*
Do not penalize missing reversible arrow.
Do not accept equations with the carbonate ion as a product.

2. (a) smooth curve through the data; *[1]*
*Do not accept a curve that passes through **all** of the points or an answer that joins the points using lines.*

(b) inversely proportional / $V \alpha \frac{1}{p} \;/\; P \alpha \frac{1}{V}$; *[1]*
Accept inverse/negative correlation/relationship.
Do not accept $V = \frac{1}{p}$ / $P = \frac{1}{V}$ *or descriptions like "one goes up as other goes down" / OWTTE.*

(c) $p = 21\times 10^{5}/2.1\times 10^{6}\,(\text{Pa}) \;/\; 2.1\times 10^{3}\,(\text{kPa})$ **and**
$V = 50\times 10^{-6}/5.0\times 10^{-5}\,(\text{m}^{3}) \;/\; 5.0\times 10^{-2}\,(\text{dm}^{3})$;
$\left(n = \frac{pV}{RT} =\right) \frac{2.1\times 10^{6}\times 5.0\times 10^{-5}}{8.31\times 330}$;
$n = 0.038\,(\text{mol})$; *[3]*
*Award **[3]** for correct final answer.*
For M3 apply ECF for correct computation of the equation the student has written, unless more than one mistake is made prior this point.

3. (a) (attraction within layer/between carbons) covalent bonding / sharing of electrons;
(attraction between layers) van der Waals'/vdW/London/dispersion/LDF (forces) / temporary/instantaneous/induced dipoles;
bond/attraction within the layer stronger than bond/attraction between layers; ***[3]***

(b) *Two of the following pairs:*

used as pencil (lead);
layers can flake off/slide off/break off/stick to paper / *OWTTE*;
M2 must contain concept of separation of layers, so do not award mark for phrases like "layers can slide over each other" on their own.

OR

used as carbon fibre / *OWTTE*;
bonding within layer is strong / layers are extensive / layers are strong;

OR

used as electrodes/conductor/in batteries;
has mobile/free/delocalized electrons (between layers) / electricity flows parallel to layers;

OR

used for thermal insulation;
vibrations are not easily passed between layers; ***[4 max]***

Accept other valid uses of graphite along with a suitable explanation.

4. (a) hydroxyl **and** carbonyl; ***[1]***
Accept alcohol as an alternative to hydroxyl and/or ketone as an alternative to carbonyl.
Allow hydroxy, but not hydroxide as an alternative to hydroxyl.

(b) CH_2O ; ***[1]***

(c) $C:\left(\frac{12.01}{30.03}\times 100=\right)39.99/40.0\%$

$H:\left(\frac{2.02}{30.03}\times 100=\right)6.73/6.7\%$

$O:\left(\frac{16.00}{30.03}\times 100=\right)53.28/53.3\%$;; ***[2]***

*Award **[2]** if all three are correct, and **[1]** if two are correct.*
Accept if the third value is obtained by subtracting the other two percentages from 100%.
Do not penalize if integer values of relative atomic masses are used.

(d) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
correct formulas of reactants and products;
correct balancing; ***[2]***
M2 can only be scored if M1 correct.

5. (a) concentration of products is much higher than the concentration of reactants / reaction nearly/almost goes to completion / position of equilibrium lies very far to the right / *OWTTE*; ***[1]***

Response must indicate the position of equilibrium is far to the right, but ***not*** *complete conversion.*

(b) *Temperature:* ***[2 max]***

rate of reaction/production is slow at low temperature/fast at high temperature / *OWTTE*;

forward reaction is exothermic/backward reaction is endothermic

and

high temperature shifts equilibrium to left/reactants/favours reverse reaction / low temperature shifts equilibrium to right/products/favours forward reaction / *OWTTE*;

450 °C is a compromise temperature / produces a relatively good equilibrium yield at a reasonably fast rate;

Pressure: ***[2 max]***

rate of reaction/production is slow at low pressure/fast at high pressure / *OWTTE*;

more moles of <u>gaseous</u> reactants/less moles of <u>gaseous</u> products

and

high pressure shifts equilibrium to right/products/favours forward reaction / low pressure shifts equilibrium to left/reactants/favours reverse reaction / *OWTTE*;

a high yield/good reaction rate is obtained even at low pressure;
high pressure is expensive/dangerous; ***[4 max]***

(c) (hypothesis is not valid as) equilibrium already nearly goes to completion / *OWTTE*;
(hypothesis is not valid as increase in yield may not be worth) expense of using pure oxygen / *OWTTE*;
(hypothesis is valid as pure oxygen) increases the rate of (the forward) reaction / more SO_3 produced per hour/day;
(hypothesis is valid as pure oxygen) shifts equilibrium to the right/products/SO_3 / increases the equilibrium concentration of SO_3; ***[2 max]***

Award ***[1 max]*** *if no reference to "hypothesis".*

SECTION B

6. (a) (i) $\left(\frac{(77.44\times 24)+(10.00\times 25)+(12.56\times 26)}{100}\right)$;

24.35; ***[2]***

*Award **[2]** for correct final answer.*
Two decimal places are required for M2.
Do not award any marks for 24.31 without showing method (as the value can be copied from the Data Booklet).

(ii) amount of deflection depends on mass/*m/z* of isotope / magnetic field required to deflect isotope onto detector depends on mass/ *m/z* of isotope;
(detector) current/voltage/signal is proportional to/depends on abundance of isotope/number of atoms/ions / detector produces a graph of (percent) abundance against mass/*m/z*; ***[2]***

Do not award M2 if no reference to output/signal from detector.
*Award **[1 max]** if answer relates mass to deflection and abundance to detection without satisfying requirements of M1 and M2.*

(iii) same atomic radii / 160 pm;
isotopes only differ by number of neutrons/size of nucleus / radius determined by electron shells and number of protons / *OWTTE*; ***[2]***

Accept neutrons do not affect distance of electrons / OWTTE.

(b) (lattice of) positive ions/cations **and** mobile/free/delocalized electrons;
Accept "sea of electrons" instead of "delocalized electrons".
Award M1 for a suitable diagram.
electrostatic attraction (between ions and delocalized electrons); ***[2]***

(c) $MgO + H_2O \rightarrow Mg(OH)_2$ / $Mg^{2+} + 2\ OH^-$; ***[1]***
Accept reversible arrow.

(d) (i) $P_4O_{10}: \left(\frac{5.00}{283.88}=\right)0.0176\,(\text{mol})$ **and** $H_2O: \left(\frac{1.50}{18.02}=\right)0.0832\,(\text{mol})$;

H_2O is the limiting reactant **and** reason related to stoichiometry; ***[2]***

(ii) $\frac{0.0832\times 4}{6}$ / $0.0555(\text{mol})$;

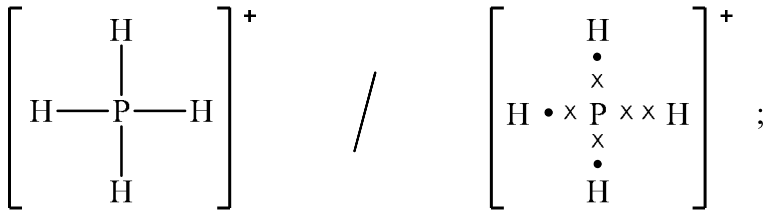
$(0.0555\times 98.00=)\,5.44\,\text{g}$; ***[2]***

The unit is needed for M2.
*Award **[2]** for correct final answer.*
Do not penalize slight numerical variations due to premature rounding.

(iii) $H_3PO_4\,(aq) + 3NaOH\,(aq) \rightarrow Na_3PO_4\,(aq) + 3H_2O\,(l)$
correct products and balancing;
correct state symbols; ***[2]***
Accept valid ionic equations.

(iv) $H_2PO_4^-$; ***[1]***

(e) (i)



[1]

Accept dots, crosses or lines for pairs of electrons.
No need to distinguish the dative covalent bond from the other bonds.
Charge is required for the mark.
Do not penalize missing square brackets.

(ii) $109^\circ 27'$ / 109.5° / 109°;
4 electron domains/pairs/(negative) charge centres (around central atom/P); ***[2]***
Accept ion is tetrahedral / electron pairs/domains repel each other.

(iii) non-polar **and** P and H have the same electronegativity / *OWTTE*; ***[1]***
Accept slightly polar as precise electronegativities of P and H are not identical / OWTTE.

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

(b) (i) same <u>molecular formula</u> but differ in arrangement of their atoms; ***[1]***
Allow "different structures/structural formulas" instead of "different arrangement of atoms".

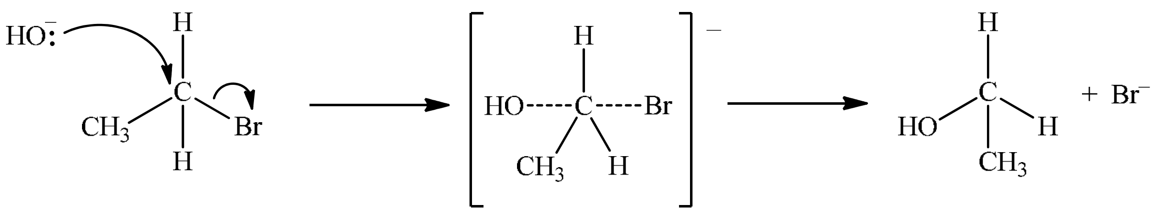
(ii) (compounds) 2 and 4 / butanone and butanal; ***[1]***

(c)

Compound	**Organic Product**
$CH_3CH_2CH(OH)CH_3$	butanone/$CH_3CH_2COCH_3$;
$CH_3CH_2COCH_3$	no reaction;
$CH_3CH_2CH_2OH$	propanoic acid/CH_3CH_2COOH;
$CH_3CH_2CH_2CHO$	butanoic acid/$CH_3CH_2CH_2COOH$;

[4]

(d)



curly arrow going from lone pair/negative charge on O in HO^- to C;
Do not allow 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 bromoethane or in the transition state.

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, but penalise wrong bonding once only.

formation of organic product CH_3CH_2OH **and** Br^-; ***[4]***
Accept "NaBr / Na^+ and Br^-" as product.

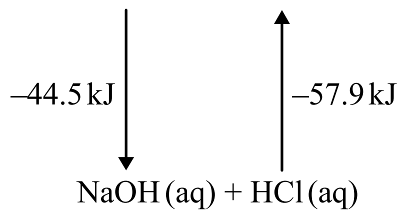
*If candidate writes an S_N1 mechanism then deduct 1 mark for this, so that it is marked out of **[3 max]**.*

(e) (i) heat transferred/absorbed/released/enthalpy/<u>potential</u> energy change when 1 mol/molar amounts of reactant(s) react (to form products) */ OWTTE*;
under standard conditions / at a pressure 100 kPa/101.3 kPa/1 atm **and** temperature 298 K/25 °C; ***[2]***
*Award **[2]** for difference between standard enthalpies of products and standard enthalpies of reactants /* $H^{\ominus}$ *(products) –* $H^{\ominus}$ *(reactants).*
*Award **[2]** for difference between standard enthalpies of formation of products and standard enthalpies of formation of reactants /* $\Sigma\Delta H_f^{\ominus}$ *(products) –* $\Sigma\Delta H_f^{\ominus}$ *(reactants).*

(ii) $(1.00 \times 0.0500 =)\ 0.0500\,(\text{mol})$;
$(0.0500 \times 57.9 =)\ 2.90\,(\text{kJ})$; ***[2]***
Ignore any negative sign.
*Award **[2]** for correct final answer.*
*Award **[1 max]** for 2900 J.*

(iii) $\left(\frac{2.50}{40.00} =\right) 0.0625\,(\text{mol NaOH})$;
$0.0500 \times 4.18 \times 13.3 = 2.78\,(\text{kJ}) / 50.0 \times 4.18 \times 13.3 = 2780\,(\text{J})$;
$\left(\frac{2.78}{0.0625}\right) = -44.5\,(\text{kJ mol}^{-1})$; ***[3]***
*Award **[3]** for correct final answer.*
Negative sign is necessary for M3.
Award M2 and M3 if 52.5 g is used to obtain an enthalpy change of –46.7.

(iv) $-44.5 - 57.9$ / correct Hess's Law cycle (as below) / correct manipulation of equations;
$NaOH(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$



$-102.4\,(\text{kJ})$; ***[2]***
*Award **[2]** for correct final answer.*

8. (a) (i) oxidation **and** (iron/Fe) loses electrons/increases in oxidation number/state; ***[1]***

(ii) $O_2(aq) + 4e^- + 2H_2O(l) \rightarrow 4OH^-(aq)$

0	I	–II	–II	I

; ***[2]***

*Award **[2]** for five correct.*
*Award **[1]** for four correct.*
Accept use of oxidation states (0, +1, –2, –2, +1) for oxidation numbers.
Penalize once for incorrect notation (eg, 2, 2–).

(iii) $O_2(aq) + 2H_2O(l) + 2Fe(s) \rightarrow 2Fe^{2+}(aq) + 4OH^-(aq)$; ***[1]***
Ignore state symbols.

(iv) Fe/iron; ***[1]***

(b) oxygen is non-polar;
needs to break strong <u>hydrogen bonds/H–bonds</u> between water molecules (to dissolve) / oxygen cannot form <u>hydrogen bonds/H–bonds</u> with water;
oxygen can only form (weak) van der Waals'/vdW/LDF/London/dispersion forces with water; ***[2 max]***

(c) (i) *Negative electrode (anode):*
$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ / $\frac{1}{2}Mg(s) \rightarrow \frac{1}{2}Mg^{2+}(aq) + e^-$ /
$Mg(s) - 2e^- \rightarrow Mg^{2+}(aq)$ / $\frac{1}{2}Mg(s) - e^- \rightarrow \frac{1}{2}Mg^{2+}(aq)$;
Accept equations for the oxidation of water/hydroxide ions.

Positive electrode (cathode):
$Ag^+(aq) + e^- \rightarrow Ag(s)$; ***[2]***
Accept Ag equation doubled so that both electrodes involve 2 electrons.

Accept e instead of e^-.
*Award **[1 max]** if both equations are correct but the state symbols are missing/incorrect.*
*Award **[1 max]** if both equations are reversed but state symbols correct.*

(ii) provides ions that flow into electrolytes/half-cells / maintains electrical neutrality of solutions/electrolytes / provides electrical continuity by providing path for migrating ions; ***[1]***
Accept completes the (electrical) circuit / allows current to flow / OWTTE.

(d) (i) atomic number / number of protons; ***[1]***
Accept number of electrons in a (neutral) <u>atom</u>.

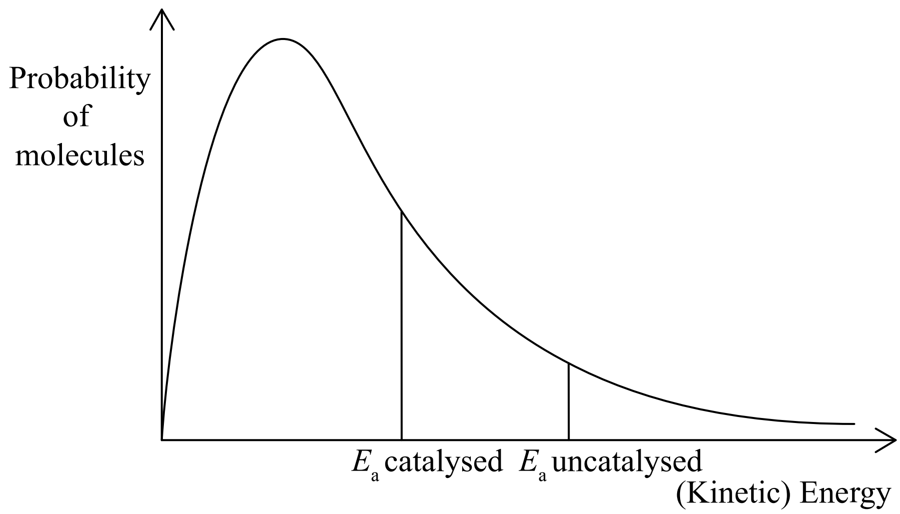
(ii) groups indicate the number of electrons in the highest energy level/outer/valence shell;
periods indicate the number of (occupied) energy levels/shells (in the atom); ***[2]***

(e) (i) steeper curve with a similar shape that reaches same maximum volume of O_2; ***[1]***

(ii) (draw a) tangent to the curve at origin/time = 0/start of reaction;
(calculate) the gradient/slope (of the tangent); ***[2]***

(iii) measure/monitor mass/pressure/[H_2O_2]; ***[1]***
Accept measure/monitor temperature of system.

(iv) *y-axis*: probability / fraction of molecules/particles / probability density
Allow "number of particles/molecules" on y-axis.
and
x-axis: (kinetic) energy;
Accept "speed/velocity" on x-axis.



correct relative position of E_a catalysed and E_a uncatalysed;
more/greater proportion of molecules/collisions have the lower/required/catalysed E_a (and can react upon collision); ***[3]***
M3 can be scored by shading and annotating the graph.
Accept a greater number/proportion of successful collisions as catalyst reduces E_a.