

# Markscheme

**May 2016**

**Chemistry**

**Standard level**

**Paper 2**

12 pages

This markscheme is the property of the International Baccalaureate and must **not** be reproduced or distributed to any other person without the authorization of the IB Assessment Centre.

## Subject Details: Chemistry SL Paper 2 Markscheme

### Mark Allocation

Candidates are required to answer **ALL** questions. Maximum total = **[50 marks]**.

1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “**max**” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. An alternative word is indicated in the “Answers” column by a slash (/). Either word can be accepted.
6. An alternative answer is indicated in the “Answers” column by “**OR**”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading **ALTERNATIVE 1** etc. Either alternative can be accepted.
8. Words inside chevrons « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. 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 “Answers” column 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) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
13. 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.

14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.
15. 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 “Notes” column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the “Notes” column.
16. 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 “Notes” column.
17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

Question			Answers	Notes	Total
1.	a	i	$\begin{array}{c} \text{H} - \overset{\ominus}{\text{P}} - \text{H} \\   \\ \text{H} \end{array} \quad \checkmark$	Accept structures using dots and/or crosses to indicate bonds and/or lone pair.	1
1.	a	ii	non-polar <b>AND</b> P and H have the same electronegativity ✓	Accept "similar electronegativities". Accept "polar" if there is a reference to a small difference in electronegativity and apply <b>ECF</b> in 1 a (iv).	1
1.	a	iii	4 electron domains/pairs/negative charge centres «around the central atom» <b>OR</b> a lone/non-bonding pair «and three bonding pairs around the central atom» ✓ repulsion between electron domains/pairs/negative charge centres «produces non-planar shape» <b>OR</b> «repulsion causes» tetrahedral orientation/pyramidal shape ✓		2
1.	a	iv	PH <sub>3</sub> has London «dispersion» forces ✓  NH <sub>3</sub> forms H-bonds ✓  H-bonds are stronger <b>OR</b> London forces are weaker ✓	Accept van der Waals' forces, dispersion forces and instantaneous dipole – induced dipole forces. Accept "dipole-dipole forces" as molecule is polar. H-bonds in NH <sub>3</sub> (only) must be mentioned to score <b>[2]</b> . Do <b>not</b> award M2 or M3 if: <ul style="list-style-type: none"> <li>• implies covalent bond is the H-bond</li> <li>• implies covalent bonds break.</li> </ul> Accept "dipole-dipole forces are weaker".	2 max

(continued)

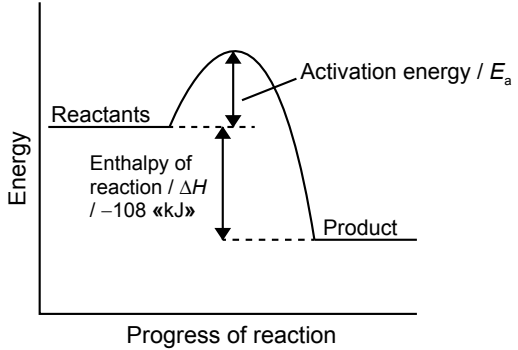
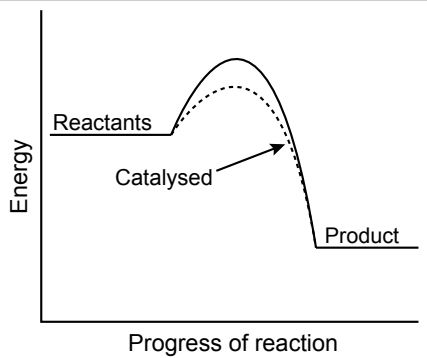
Question			Answers	Notes	Total
1.	b	i	<p><b>Element</b> carbon/C ✓</p> <p><b>Allotropes</b> Award [1] for two of: diamond graphite graphene C<sub>60</sub> / buckminsterfullerene ✓</p> <p><b>OR</b> oxygen/O/O<sub>2</sub> ✓ ozone/O<sub>3</sub> <b>AND</b> «diatomic/molecular» oxygen/O<sub>2</sub> ✓</p>	<p>Accept <b>two</b> correctly named allotropes of any other named element (S, Se, Sn, As, etc.).</p> <p>Accept fullerene, “buckyballs” etc. instead of buckminsterfullerene.</p>	2
1.	b	ii	<p>P<sub>4</sub> is a molecule «comprising 4P atoms» <b>AND</b> 4P is four/separate «P» atoms <b>OR</b> P<sub>4</sub> represents «4P» atoms bonded together <b>AND</b> 4P represents «4» separate/non-bonded «P» atoms ✓</p>		1
1.	b	iii	<p>can act as both a «Brønsted–Lowry» acid and a «Brønsted–Lowry» base <b>OR</b> can accept and/or donate a hydrogen ion/proton/H<sup>+</sup> ✓</p> <p>HPO<sub>2</sub><sup>2-</sup> <b>AND</b> H<sub>3</sub>PO<sub>2</sub> ✓</p>		2
1.	b	iv	<p>P<sub>4</sub>:                    0                    ✓ H<sub>2</sub>PO<sub>2</sub><sup>-</sup>:            +1                    ✓</p>	Do not accept 1 or 1+ for H <sub>2</sub> PO <sub>2</sub> <sup>-</sup> .	2
1.	b	v	<p>oxygen gained, so could be oxidation ✓</p> <p>hydrogen gained, so could be reduction <b>OR</b> negative charge «on product/H<sub>2</sub>PO<sub>2</sub><sup>-</sup>» /gain of electrons so could be reduction ✓</p> <p>oxidation number increases so must be oxidation ✓</p>	<p>Award [1 max] for M1 and M2 if candidate displays knowledge of at least two of these definitions but does not apply them to the reaction.</p> <p>Do not award M3 for “oxidation number changes”.</p>	3

(continued)

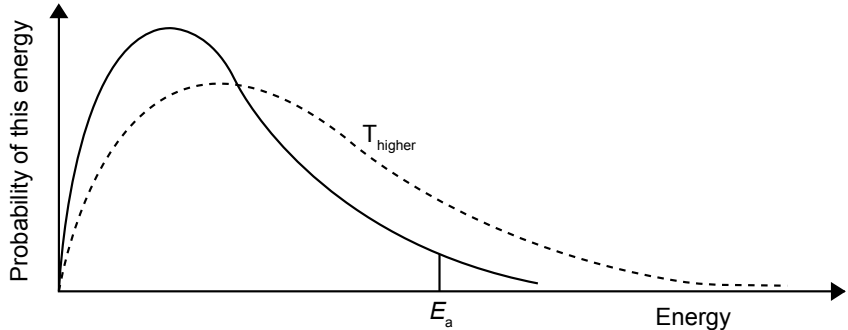
Question			Answers	Notes	Total
1.	c	i	$\left\langle \frac{2.478}{4 \times 30.97} \right\rangle = 0.02000 \text{ «mol» } \checkmark$		1
1.	c	ii	$n(\text{NaOH}) = \text{«}0.1000 \times 5.00 \Rightarrow 0.500 \text{ «mol» AND } P_4/\text{phosphorus is limiting reagent } \checkmark$	<i>Accept <math>n(\text{H}_2\text{O}) = \frac{100}{18} = 5.50</math> AND <math>P_4</math> is limiting reagent.</i>	1
1.	c	iii	amount in excess $\text{«} = 0.500 - (3 \times 0.02000) \text{»} = 0.440 \text{ «mol» } \checkmark$		1
1.	c	iv	$\text{«}22.7 \times 1000 \times 0.02000 \text{»} = 454 \text{ «cm}^3 \text{» } \checkmark$	<i>Accept methods employing <math>pV = nRT</math>, with <math>p</math> as either 100 (454 cm<sup>3</sup>) or 101.3 kPa (448 cm<sup>3</sup>).  Do not accept answers in dm<sup>3</sup>.</i>	1

Question			Answers	Notes	Total
2.	a	i	temperature rise $\llcorner = \frac{750 \times 1.00}{0.2000 \times 1.00} \llcorner = 3750 \llcorner \text{°C/K} \llcorner \checkmark$	<i>Do not accept -3750.</i>	1
2.	a	ii	$n(\text{P}) \llcorner = \frac{43.6}{30.97} \llcorner = 1.41 \llcorner \text{mol} \llcorner \checkmark$ $n(\text{O}) \llcorner = \frac{100 - 43.6}{16.00} \llcorner = 3.53 \llcorner \text{mol} \llcorner \checkmark$ $\llcorner \frac{n(\text{O})}{n(\text{P})} = \frac{3.53}{1.41} = 2.50 \llcorner \text{ so empirical formula is} \llcorner \text{P}_2\text{O}_5 \llcorner \checkmark$	<i>Accept other methods where the working is shown.</i>	3
2.	a	iii	$\llcorner \frac{285}{141.9} = 2.00 \llcorner \text{ , so molecular formula} = 2 \times \text{P}_2\text{O}_5 \Rightarrow \text{P}_4\text{O}_{10} \llcorner \checkmark$		1
2.	b	i	$\text{P}_4\text{O}_{10}(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{H}_3\text{PO}_4(\text{aq}) \llcorner \checkmark$	<i>Accept <math>\text{P}_4\text{O}_{10}(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{HPO}_3(\text{aq})</math>                      (initial reaction)                      Accept <math>\text{P}_2\text{O}_5(\text{s}) + 3\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{H}_3\text{PO}_4(\text{aq})</math>                      Accept equations for <math>\text{P}_4\text{O}_6/\text{P}_2\text{O}_3</math> if given in a (iii).                      Accept any ionized form of the acids as the products.</i>	1
2.	b	ii	<i>pH: decreases AND electrical conductivity: increases. <math>\checkmark</math></i>		1
2.	b	iii	phosphorus not commonly found in fuels <b>OR</b> no common pathways for phosphorus oxides to enter the air <b>OR</b> amount of phosphorus-containing organic matter undergoing anaerobic decomposition is small $\checkmark$	<i>Accept "phosphorus oxides are solids so are not easily distributed in the atmosphere".                      Accept "low levels of phosphorus oxide in the air".                      Do not accept "<math>\text{H}_3\text{PO}_4</math> is a weak acid".</i>	1
2.	b	iv	<i>Pre-combustion:</i> remove sulfur/S/sulfur containing compounds $\checkmark$  <i>Post-combustion:</i> remove it/SO <sub>2</sub> by neutralization/reaction with alkali/base $\checkmark$	<i>Accept "lime injection fluidised bed combustion" for either, but not both.</i>	2



Question			Answers	Notes	Total
3.	a	i	$K_c = \frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]} \checkmark$		1
3.	a	ii	no effect $\checkmark$		1
3.	b	i	 <p>products lower than reactants <b>AND</b> enthalpy of reaction correctly marked and labelled with name or value <math>\checkmark</math></p> <p>activation energy correctly marked and labelled with name or value <math>\checkmark</math></p>	Accept other clear ways of indicating energy/enthalpy changes.	2
3.	b	ii	 <p>lower dotted curve, between same reactants and product levels, labelled "Catalysed" <math>\checkmark</math></p>		1



(continued)

Question			Answers	Notes	Total
3.	b	iii	 <p>second curve at a higher temperature is correctly drawn (maximum lower and to right of original) ✓</p>		1
3.	b	iv	<p>greater proportion of molecules have <math>E \geq E_a</math> or <math>E &gt; E_a</math>  <b>OR</b>                      greater area under curve to the right of the <math>E_a</math> ✓</p> <p>greater frequency of collisions «between molecules»  <b>OR</b>                      more collisions per unit time/second ✓</p>	<p><i>Do not accept just particles have greater kinetic energy.</i>  <i>Do not accept just "more collisions".</i></p>	2

(continued)

Question			Answers	Notes	Total
4.	a	i	methylpropene ✓		1
4.	a	ii	$-\text{CH}_2-\text{C}(\text{CH}_3)_2-\text{CH}_2-\text{C}(\text{CH}_3)_2-\text{CH}_2-\text{C}(\text{CH}_3)_2-$ ✓	Must have continuation bonds at both ends.  Accept any orientation of the monomers, which could give methyl side-chains on neighbouring atoms etc.	1
4.	a	iii	$\text{C}_4\text{H}_8(\text{g}) + 6\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l})$ ✓		1
4.	b	i	«structural/functional group» isomer«s» ✓		1
4.	b	ii	Test: «react with» bromine/ $\text{Br}_2$ «in the dark» <b>OR</b> «react with» bromine water/ $\text{Br}_2(\text{aq})$ «in the dark» ✓  A: from yellow/orange/brown to colourless <b>AND</b> B: colour remains/slowly decolourized ✓	Accept other correct reagents, such as manganate(VII) or iodine solutions, and descriptions of the corresponding changes observed.  Accept “decolourized” for A and “not decolourized/unchanged” for B. Do <b>not</b> accept “clear/transparent” instead of “colourless”.	2
4.	b	iii	IR: <b>A</b> would absorb at $1620\text{--}1680\text{ cm}^{-1}$ <b>AND B</b> would not ✓  $^1\text{H NMR}$ : <b>A</b> would have 2 signals <b>AND B</b> would have 1 signal <b>OR</b> <b>A</b> would have a signal at $4.5\text{--}6.0\text{ ppm}$ <b>AND B</b> would not <b>OR</b> <b>A</b> would have a signal at $0.9\text{--}1.0\text{ ppm}$ <b>AND B</b> would not <b>OR</b> <b>B</b> would have a signal at $1.3\text{--}1.4\text{ ppm}$ <b>AND A</b> would not ✓	Accept “peak” for “signal”.  Award [1 max] if students have a correct assignment of a signal, but no comparison, for <b>both</b> IR and NMR. Accept “B would have a signal at $2.0\text{ ppm}$ ” as shown in its $^1\text{H NMR}$ spectrum.	2

(continued)

Question			Answers	Notes	Total
4.	c	i	«molecular ion» peak at «m/z => 57 , «not 56» <b>OR</b> «molecular ion» peak at one «m/z» higher <b>OR</b> will not have a «large» peak at 56 ✓	Accept a peak at m/z one greater than the <sup>12</sup> C one for any likely fragment.	1
4.	c	ii	protons: 6 <b>AND</b> neutrons: 7 ✓  <div style="display: flex; justify-content: center; align-items: center; gap: 20px;"> <div style="text-align: center;"> <div style="border: 1px solid black; padding: 5px;">1↓</div> <p>1s</p> </div> <div style="text-align: center;"> <div style="border: 1px solid black; padding: 5px;">1↓</div> <p>2s</p> </div> <div style="text-align: center;"> <div style="border: 1px solid black; padding: 5px;">1</div> </div> <div style="text-align: center;"> <div style="border: 1px solid black; padding: 5px;">1</div> <p>2p</p> </div> <div style="text-align: center;"> <div style="border: 1px solid black; padding: 5px; width: 20px; height: 20px;"></div> </div> </div>	Accept full arrows.	2
4.	d		1s:  <b>AND</b> 2p:  ✓	Accept p orbitals aligned on y- and z-axes, or diagrams correctly showing all three p-orbitals. Do <b>not</b> accept p-orbitals without a node.	1