Markscheme

May 2024

Chemistry

Higher level

Paper 2

17 pages

© International Baccalaureate Organization 2024

All rights reserved. No part of this product may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without the prior written permission from the IB. Additionally, the license tied with this product prohibits use of any selected files or extracts from this product. Use by third parties, including but not limited to publishers, private teachers, tutoring or study services, preparatory schools, vendors operating curriculum mapping services or teacher resource digital platforms and app developers, whether fee-covered or not, is prohibited and is a criminal offense.

More information on how to request written permission in the form of a license can be obtained from https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/.

© Organisation du Baccalauréat International 2024

Tous droits réservés. Aucune partie de ce produit ne peut être reproduite sous quelque forme ni par quelque moyen que ce soit, électronique ou mécanique, y compris des systèmes de stockage et de récupération d'informations, sans l'autorisation écrite préalable de l'IB. De plus, la licence associée à ce produit interdit toute utilisation de tout fichier ou extrait sélectionné dans ce produit. L'utilisation par des tiers, y compris, sans toutefois s'y limiter, des éditeurs, des professeurs particuliers, des services de tutorat ou d'aide aux études, des établissements de préparation à l'enseignement supérieur, des fournisseurs de services de planification des programmes d'études, des gestionnaires de plateformes pédagogiques en ligne, et des développeurs d'applications, moyennant paiement ou non, est interdite et constitue une infraction pénale.

Pour plus d'informations sur la procédure à suivre pour obtenir une autorisation écrite sous la forme d'une licence, rendez-vous à l'adresse https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/.

© Organización del Bachillerato Internacional, 2024

Todos los derechos reservados. No se podrá reproducir ninguna parte de este producto de ninguna forma ni por ningún medio electrónico o mecánico, incluidos los sistemas de almacenamiento y recuperación de información, sin la previa autorización por escrito del IB. Además, la licencia vinculada a este producto prohíbe el uso de todo archivo o fragmento seleccionado de este producto. El uso por parte de terceros —lo que incluye, a título enunciativo, editoriales, profesores particulares, servicios de apoyo académico o ayuda para el estudio, colegios preparatorios, desarrolladores de aplicaciones y entidades que presten servicios de planificación curricular u ofrezcan recursos para docentes mediante plataformas digitales—, ya sea incluido en tasas o no, está prohibido y constituye un delito.

En este enlace encontrará más información sobre cómo solicitar una autorización por escrito en forma de licencia: https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/.

Subject Details: Chemistry Higher Level Paper 2 Markscheme

Candidates are required to answer **ALL** questions. Maximum total = **[90 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.

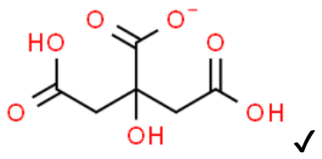
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

Question			Answers	Notes	Total
1.	**(a)**	**(i)**	mol (citric acid) = $\frac{0.45}{192.14}$ = 0.00234 ✓ mol ($NaHCO_3$) = $\frac{0.25}{84.01}$ = 0.00298 ✓ 0.00298÷3 = 0.000992 mol therefore $NaHCO_3$ is LR✓	*Award 1 mark for 2 correct masses of reactants or molar masses* *Accept sodium hydrogen carbonate for M3* *Only award M3 if it is correctly based on previous mole calculations*	**3**
1.	**(a)**	**(ii)**	1:1, so 0.00298 mol ✓ $\frac{(0.00298 \cdot 8.31 \cdot 298)}{100}$ = 0.0738 « dm^3 »✓		**2**
1.	**(a)**	**(iii)**	$100 \cdot \frac{0.043}{0.0738}$ = 58.4 % ✓		**1**
1.	**(b)**	**(i)**	three ✓		**1**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**(b)**	**(ii)**	 ✓ [Source: With permission from The Royal Society of Chemistry]		**1**
1.	**(b)**	**(iii)**	weak ***AND*** organic/carboxylic acid /has -COOH ✓	*Accept weak **AND** partially dissociated.*	**1**
1.	**(b)**	**(iv)**	salt of strong base and weak acid ***OR*** eqm removes H^+ ions «in aqueous solution» ***OR*** citrate ion reacts with water to form conjugate acid and OH^- ✓	*Accept "conjugate base of weak acid"*	**1**
1.	**(c)**		-log(0.0025) = 2.60 ✓	*Accept 2.6.*	**1**
1.	**(d)**		electrostatic attraction ✓ « between » Na^+ and $citrate^-$ ions / oppositely charged ions ✓	*Award **[1 max]** for just "ionic".*	**2**
1.	**(e)**		lattice lower ***AND*** hydration lower ✓ K^+ lower charge density / larger ion «radius with same charge » ✓	*Ignore references to atomic radii for M2*	**2**

Question			Answers	Notes	Total
2.	**(a)**	**(i)**	400.00 * 4.18 * 21.0 = 35 112 = 35 100 J ✓	*Accept 35.1 kJ*	**1**
2.	**(a)**	**(ii)**	21±1 ✓ « $100 * \frac{0.02}{400.00}$ + $100 * \frac{1.0}{21}$ = 0.005 + 4.76 = » 4.77 % ✓	*Accept 4.76 (if only temperature uncertainty used).* *Accept correct final answer for 2 marks*	**2**
2.	**(a)**	**(iii)**	repeat experiment ***AND*** take average ✓	*Accept increase amount of water* *Accept allow experiment to run longer to have greater* ΔT *Accept more precise thermometer / temperature probe / digital thermometer.* *Accept more precise balance /scale* *Do not accept more precise equipment without names.* *Do not accept references to accuracy*	**1**

(continued…)

(Question 2 continued)

2.	**(b)**	**(i)**	«36.03 + 8.08 + 16.00 = 60.11» 1.80/60.11 = 0.0299 ✓ –35100/0.0299 = –1200 kJ mol^{-1} ✓ *Assumption: (any one from)* - propan-1-ol only ingredient to release heat - gel is pure propan-1-ol - no heat loss - all heat transferred to water - no heat absorbed by copper - complete combustion ✓	*Accept –1000 to –1004 kJ mol^{-1} if 30 000 used.* *M2 can only be awarded for exothermic answer*	**3**
2.	**(b)**	**(ii)**	« $\frac{100(-1200 - -2021)}{-2021}$ = – » 40.6% ✓	*Ignore negative signs* *Accept 50% if 30 kJ used in 2bi*	**1**

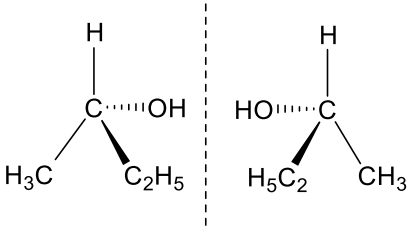
(continues...)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**(b)**	**(iii)**	heat loss ***AND*** insulate the calorimeter ✓	*Accept heat loss **AND** decrease distance between calorimeter and flame.* *Accept heat loss **AND** use screens to prevent drafts / OWTTE.* *Accept heat loss and use a closed system / food calorimeter* *Accept heat loss and use a calorimeter with a low heat capacity.* *Do not accept Styrofoam / coffee cup calorimeter* *Do not accept "add a lid"*	**1**
2.	**(c)**		ALTERNATIVE 1 «1g propan-1-ol contains $\frac{1}{60.11}$ = 0.017 mol » « 0.017(–2021) =» –33.62 «kJ» ✓ «1g e1thanol contains $\frac{1}{46.08}$ = 0.022 mol » « 0.022(–1367) =» –29.72 «kJ» ✓ second gel/ethanol less energy ✓	*Accept positive values for M1, M2* *Do not award M3 without M1 and M2.*	**3**

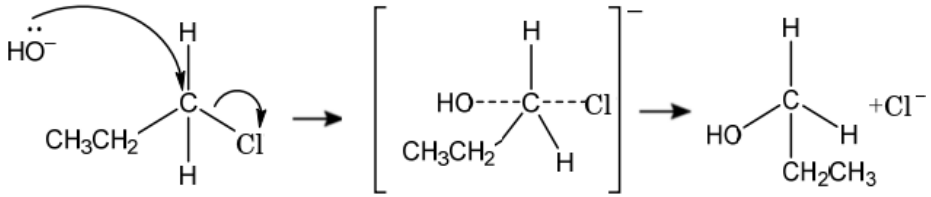
(continued…)

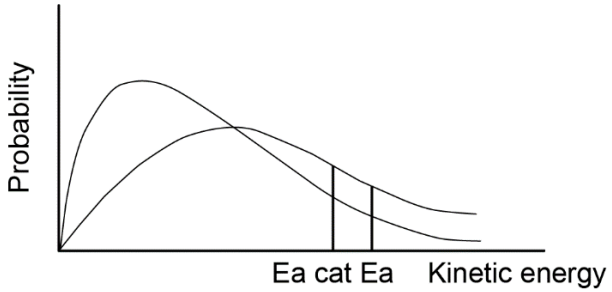
(Question 2 continued)

Question			Answers	Notes	Total
2.	**(d)**	**(i)**	alcohol ✓ hydroxyl ✓	*Award **[1 max]** for both answers, but the wrong way around.* *Accept "hydroxy", but not "hydroxide"* *Ignore references to R-OH or other formula*	**2**
2.	**(d)**	**(ii)**	hydrogen bonding ✓		**1**
2.	**(d)**	**(iii)**	London/dispersion forces ✓	*Accept instantaneous / induced dipoles.* *Do not accept van der Waals' forces*	**1**
2.	**(e)**	**(i)**	correct representation of 3D structure ✓ Enantiomeric/isomer pair clearly represented ✓ 		**2**
2.	**(e)**	**(ii)**	butanoic acid ✓ butanone ✓	*Accept butan-2-one / 2-butanone.* *Accept correct structures*	**2**

(continues...)

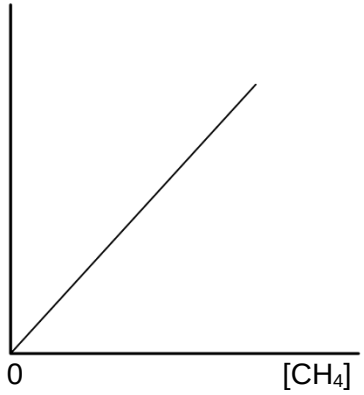
(Question 2 continued)

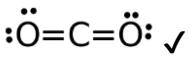
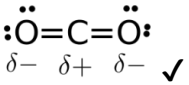
Question			Answers	Notes	Total
2.	**(f)**	**(i)**	OH^- ✓	*Accept water / H_2O* *Accept "hydroxide" / "sodium hydroxide / NaOH"*	**1**
2.	**(f)**	**(ii)**	 curly arrow from lone pair/negative charge on O in OH^- to C ✓ curly arrow originating on C–Cl bond to Cl ✓ representation of transition state showing negative charge, square brackets and partial bonds ✓	*Hydroxide must have negative charge and lone pair(s) for M1* *Do not award M3 if OH–C bond shown*	**3**
2.	**(g)**	**(i)**	« conc.» H_2SO_4/H_3PO_4 ***AND*** high temperature ***OR*** high pressure ✓	*Accept "H^+/H_3O^+/strong acid"* *Accept "heat" or "steam"*	**1**
2.	**(g)**	**(ii)**	esterification ✓	*Accept "condensation"* *Accept "addition-elimination" but not "addition" only*	**1**
2.	**(g)**	**(iii)**	H_2O ✓	*Accept water*	**1**

Question			Answers	Notes	Total
3.	**(a)**		$\frac{[CO]\,[H_2]^3}{[CH_4]\,[H_2O]}$ ✓	*Square brackets required*	**1**
3.	**(b)**		shifts right/towards products ***AND*** endothermic/$\Delta H>0$ ✓		**1**
3.	**(c)**		temp labelled appropriately (*eg*: low, high / T1, T2) ✓ Ea line ✓ more molecules with KE > Ea at higher T ✓	*Higher temperature line must be identified eg: T2 > T1*	**3**
3.	**(d)**		 two Ea lines appropriately labelled, *eg*: Ea and Ea cat ✓		**1**
3.	**(e)**	**(i)**	catalyst ***AND*** regenerated/not consumed ✓	*Accept catalyst **AND** Ni is a product*	**1**
3.	**(e)**	**(ii)**	« rate = » k $[CH_4]$ ✓		**1**
3.	**(e)**	**(iii)**	different mechanisms could give same rate equation ***OR*** mechanisms can only be disproved ***OR*** does not give information about what occurs after RDS ✓	*Accept any valid argument.*	**1**

(continues...)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**(e)**	**(iv)**	rate  ✓	*First order, ie. straight line from origin.*	**1**
3.	**(f)**		« 3(130.7) + 197.7 – 188.8 – 186 = » 215 «J K^{-1} » ✓		**1**
3.	**(g)**		« ΔG = 206 000 – (215 * 1500) = » –116 500 « J » ✓ « –116 500 = –8.31(1500) lnK » « *K*c = e^(9.35) » 1.15 x 10^4 ✓	*Accept* ΔG = *–116.5 kJ* *If 227 used* *M1 = –134500* « J » *M2 = 4.85 x10^4*	**2**
3.	**(h)**		« ΔG = » 0 ✓ « 0 = 206 – 0.215 T » « T = $\frac{206}{0.215}$ = » 958 « K » ✓	*Award **[2]** for correct final answer.* *If 227 used T= 907*	**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>4.</td><td>(a)</td><td>(i)</td><td>+2 AND +4 ✓</td><td>Accept II/2 AND IV/4
Do not accept 2+ and 4+</td><td>1</td></tr>
<tr><td>4.</td><td>(a)</td><td>(ii)</td><td><table><tr><td></td><td>CO(g)</td><td>H_2O(g)</td></tr><tr><td>Oxidising or reducing agent?</td><td>reducing</td><td>oxidising</td></tr><tr><td>Species oxidised or reduced?</td><td>oxidised</td><td>reduced</td></tr></table>
✓✓</td><td>Award [1] for every two correct.</td><td>2</td></tr>
<tr><td>4.</td><td>(b)</td><td>(i)</td><td>  ✓</td><td>Accept any combination of dots and crosses or lines.
Ignore non linear drawing of correct Lewis structure.</td><td>1</td></tr>
<tr><td>4.</td><td>(b)</td><td>(ii)</td><td>  ✓</td><td>Accept only one correct δ+ and δ-</td><td>1</td></tr>
<tr><td>4.</td><td>(b)</td><td>(iii)</td><td>linear AND two domains «repel» ✓
non-polar AND polar bonds cancel / symmetrical distribution of charge ✓</td><td>Accept OWTTE two domains
Accept non polar and no net dipole
Award [1] mark if correctly states “linear and non-polar" without correct explanations.</td><td>2</td></tr>
<tr><td>4.</td><td>(b)</td><td>(iv)</td><td>carbon monoxide: sp
AND
carbon dioxide: sp ✓</td><td></td><td>1</td></tr>
</table>

(continued…)

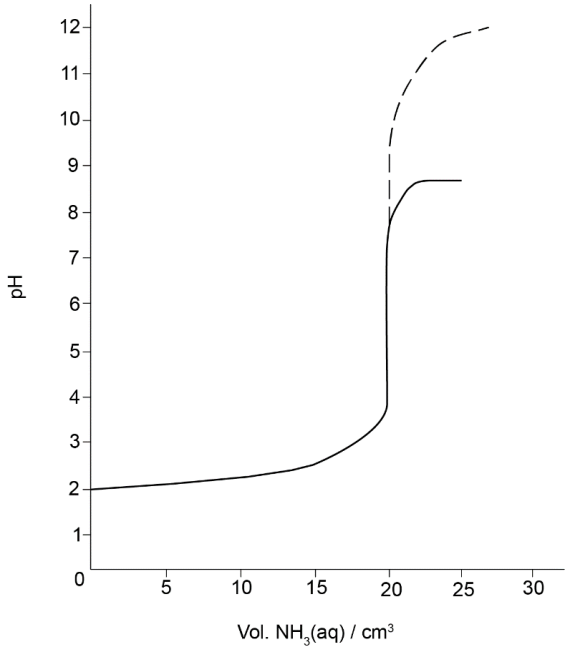
(Question 4 continued)

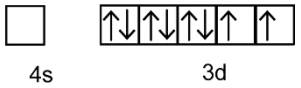
Question			Answers	Notes	Total
4.	**(b)**	**(v)**	1 σ ***AND*** 2 π ✓		**1**
4.	**(b)**	**(vi)**	CO + 2(O-H) – 2(C=O) – H-H = –41 ***OR*** *x* + 2(463) – 2(804) – 436 = –41 ✓ « *x* = –41 – 926 + 2044 = » 1077 « kJ mol^{-1} » ✓	*Award **[2]** for correct final answer.* *Award **[1]** for –1077*	**2**

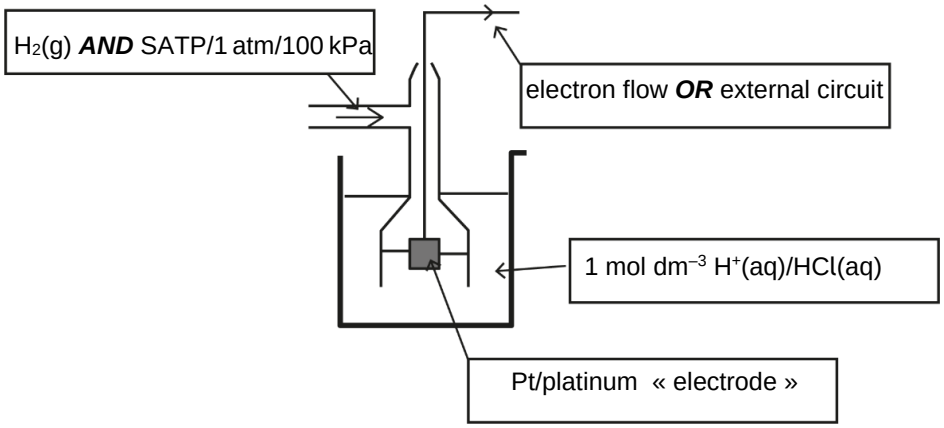
Question			Answers	Notes	Total
5.	**(a)**		16 ***AND*** 7th IE much higher ✓	*Accept VI/6*	**1**
5.	**(b)**	**(i)**	Structure 1: E «6-0-4 = » +2 2x O «6-6-1 = » –1 O «6-4-2 = » 0 ✓ Structure 2: E «6-0-6 = » 0 3x O «6-4-2 = » 0 ✓ structure 2 most likely ✓	*M1 requires two FCs for different oxygens* *accept notations on diagram for M1, M2* *Do not award M3 without explanation based on formal charge.*	**3**
5.	**(b)**	**(ii)**	$EO_3 + H_2O \rightarrow H_2EO_4$ ✓		**1**

(continues...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	**(c)**	**(i)**	methyl red ✓	*Accept bromothymol blue or bromocresol green*	**1**
5.	**(c)**	**(ii)**	 New curve added. Straight section is now from pH4 to 10, and levels off towards 12. extend vertical section at equivalence point ✓ level off at pH 11-12 ✓	*Need same equivalence volume for M1 (20 cm^3)*	**2**

Question			Answers	Notes	Total
6.	(a)		« 58 × 0.68 + 60 × 0.26 + 61 × 0.010 + 62 × 0.04 + 64 × 0.01 = » 58.77 ✓	*Do not accept 58.69 (in data booklet)*	**1**
6.	(b)	(i)	$^{58}_{28}Ni^{2+}$ ✓		**1**
6.	(b)	(ii)	 ✓	*Accept single or double headed arrows* *Do not award ECF from 6b(i)*	**1**
6.	(b)	(iii)	paramagnetic ***AND*** unpaired electrons ✓		**1**
6.	(c)	(i)	NH_3 stronger ligand/higher in spectrochemical series ✓ greater splitting of d-orbitals ***OR*** higher energy/orange/yellow absorbed « instead of red » ✓	*Accept reference to correct wavelength absorbed* *Accept converse statements for water as ligand*	**2**
6.	(c)	(ii)	Lewis base ***AND*** donates electron pair ✓		**1**
6.	(c)	(iii)	base ***AND*** accepts H^+/hydrogen ion/proton ✓ $NH_3(g) + H_2O(l) \rightleftharpoons NH_4OH(aq)$ ***OR*** $NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ ✓	*Accept either type of arrow*	**2**

Question			Answers	Notes	Total
7.	**(a)**		 *Award **[1]** for every two correctly placed answers.* H_2(g) ***AND*** SATP/1 atm/100 kPa electron flow ***OR*** external circuit 1 mol dm^{-3} H^+(aq)/HCl(aq) Pt/platinum « electrode » ✓✓	*Accept current / pd/ potential difference / voltage for external circuit* *Do not accept "electron" or "e^-" only for external circuit*	**2**
7.	**(b)**	**(i)**	$Pt\|H_2\|H^+\|\|Cu^{2+}\|Cu$ ✓	*Do not penalize missing Pt* *Accept fractions / multiples of species eg ½ H_2*	**1**
7.	**(b)**	**(ii)**	n = 2 ✓ «−2(96 500)(0.34) =» –65 620 «J mol^{-1}» / –65.6 «kJ mol^{-1}» ✓	*Answer must be negative*	**2**