M18/4/CHEMI/HP2/ENG/TZ1/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

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Chemistry

Higher level

Paper 2

20 pages

International Baccalaureate
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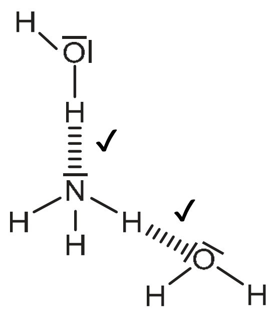
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>1.</td><td>a</td><td>i</td><td>molar mass of urea «$= 4 \times 1.01 + 2 \times 14.01 + 12.01 + 16.00$» $= 60.07$ «$g\ mol^{-1}$» ✓
«% nitrogen $= \frac{2 \times 14.01}{60.07} \times 100 =$» 46.65 «%» ✓</td><td>Award [2] for correct final answer.
Award [1 max] for final answer not to two decimal places.</td><td>2</td></tr>
<tr><td>1.</td><td>a</td><td>ii</td><td>«cost» increases AND lower N % «means higher cost of transportation per unit of nitrogen»
OR
«cost» increases AND inefficient/too much/about half mass not nitrogen ✓</td><td>Accept other reasonable explanations.
Do not accept answers referring to safety/explosions.</td><td>1</td></tr>
<tr><td>1.</td><td>b</td><td></td><td><table><tr><th></th><th>Electron geometry</th><th>Molecular geometry</th></tr><tr><td>Nitrogen</td><td>tetrahedral ✓</td><td>trigonal pyramidal ✓</td></tr><tr><td>Carbon</td><td>trigonal planar ✓</td><td>trigonal planar</td></tr></table></td><td>Note: Urea’s structure is more complex than that predicted from VSEPR theory.</td><td>3</td></tr>
<tr><td>1.</td><td>c</td><td></td><td>n(KNCO) «$= 0.0500\ dm^3 \times 0.100\ mol\ dm^{-3}$» $= 5.00 \times 10^{-3}$ «mol» ✓
«mass of urea $= 5.00 \times 10^{-3}\ mol \times 60.07\ g\ mol^{-1}$» $= 0.300$ «g» ✓</td><td>Award [2] for correct final answer.</td><td>2</td></tr>
<tr><td>1.</td><td>d</td><td>i</td><td>$K_c = \frac{[(H_2N)_2CO] \times [H_2O]}{[NH_3]^2 \times [CO_2]}$ ✓</td><td></td><td>1</td></tr>
<tr><td>1.</td><td>d</td><td>ii</td><td>«K_c» decreases AND reaction is exothermic
OR
«K_c» decreases AND ΔH is negative
OR
«K_c» decreases AND reverse/endothermic reaction is favoured ✓</td><td></td><td>1</td></tr>
</table>

(continued…)

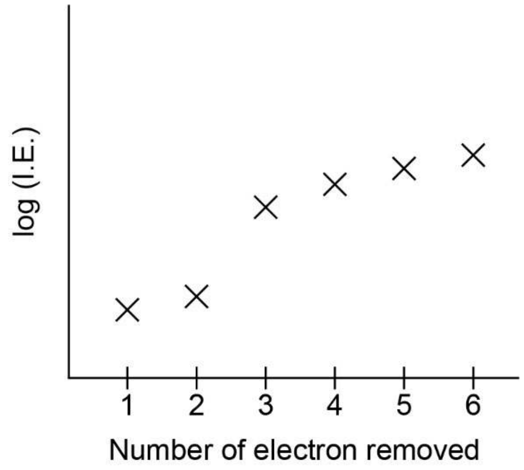
(Question 1d continued)

Question			Answers	Notes	Total
1.	**d**	**iii**	$\ln K$ « $= \frac{-\Delta G^{\ominus}}{RT} = \frac{-50 \times 10^{3}\ \text{J}}{8.31\ \text{J K}^{-1}\text{mol}^{-1} \times 298\ \text{K}}$ » $= -20$ ✓ «$K_c =$» 2×10^{-9} ***OR*** 1.69×10^{-9} ***OR*** 10^{-9} ✓	*Accept range of 20-20.2 for M1.* *Award **[2]** for correct final answer.*	**2**
1.	**e**	**i**	*Any one of:* urea has greater molar mass ✓ urea has greater electron density/greater London/dispersion ✓ urea has more hydrogen bonding ✓ urea is more polar/has greater dipole moment ✓	*Accept "urea has larger size/greater van der Waals forces".* *Do **not** accept "urea has greater intermolecular forces/IMF".*	**1**
1.	**e**	**ii**		*Award **[1]** for each correct interaction.* *If lone pairs are shown on N or O, then the lone pair on N or one of the lone pairs on O **MUST** be involved in the H-bond.* *Penalize solid line to represent H-bonding only once.*	**2**

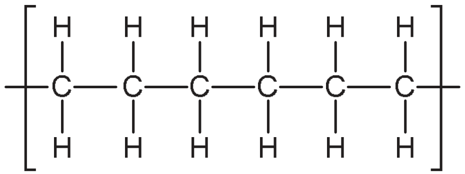
Question			Answers	Notes	Total
1.	f		$2(H_2N)_2CO\ (s) + 3O_2\ (g) \rightarrow 4H_2O\ (l) + 2CO_2\ (g) + 2N_2\ (g)$ correct coefficients on LHS ✓ correct coefficients on RHS ✓	*Accept* $(H_2N)_2CO\ (s) + \frac{3}{2}O_2\ (g) \rightarrow 2H_2O\ (l) + CO_2\ (g) + N_2\ (g)$. *Accept any correct ratio.*	**2**
1.	g		«$V = \frac{0.600\ g}{60.07\ g\ mol^{-1}} \times 22700\ cm^3\ mol^{-1} =$» 227 «$cm^3$» ✓		**1**
1.	h		lone/non-bonding electron pairs «on nitrogen/oxygen/ligand» given to/shared with metal ion ✓ co-ordinate/dative/covalent bonds ✓		**2**
1.	i		lone pairs on nitrogen atoms can be donated to/shared with C–N bond ***OR*** C–N bond partial double bond character ***OR*** delocalization «of electrons occurs across molecule» ***OR*** slight positive charge on C due to C=O polarity reduces C–N bond length ✓		**1**
1.	j		*60:* $CON_2H_4^+$ ✓ *44:* $CONH_2^+$ ✓	*Accept "molecular ion".*	**2**

Question			Answers	Notes	Total
1.	**k**		*3450 cm^{-1}:* N–H ✓ *1700 cm^{-1}:* C=O ✓	*Do **not** accept "O–H" for 3450 cm^{-1}.*	**2**
1.	**l**	**i**	1 ✓		**1**
1.	**l**	**ii**	singlet ✓	*Accept "no splitting".*	**1**
1.	**l**	**iii**	acts as internal standard ***OR*** acts as reference point ✓ one strong signal ***OR*** 12 H atoms in same environment ***OR*** signal is well away from other absorptions ✓	*Accept "inert" or "readily removed" or "non-toxic" for M1.*	**2**

Question			Answers	Notes	Total
2.	a		electrostatic attraction ***AND*** oppositely charged ions ✓		**1**
2.	b		multiply relative intensity by «*m*/*z*» value of isotope ***OR*** find the frequency of each isotope ✓ sum of the values of products/multiplication «from each isotope» ***OR*** find/calculate the weighted average ✓	*Award **[1 max]** for stating "m/z values of isotopes **AND** relative abundance/intensity" but not stating these need to be multiplied.*	**2**
2.	c		«promoted» electrons fall back to lower energy level ✓ energy difference between levels is different ✓	*Accept "Na and Ca have different nuclear charge" for M2.*	**2**
2.	d	i	*Any two of:* stronger metallic bonding ✓ smaller ionic/atomic radius ✓ two electrons per atom are delocalized ***OR*** greater ionic charge ✓ greater atomic mass ✓	*Do **not** accept just "heavier" or "more massive" without reference to atomic mass.*	**2**
2.	d	ii	delocalized/mobile electrons «free to move» ✓		**1**

Question			Answers	Notes	Total
2.	e		 general increase ✓ only one discontinuity between "IE2" and "IE3" ✓		2
2.	f		pH > 7 ✓	*Accept any specific pH value or range of values above 7 and below 14.*	1

Question			Answers	Notes	Total
2.	**g**	**i**	*sigma* (σ) *:* overlap «of atomic orbitals» along the axial/internuclear axis ***OR*** head-on/end-to-end overlap «of atomic orbitals» ✓ *pi* (π) *:* overlap «of p-orbitals» above and below the internuclear axis ***OR*** sideways overlap «of p-orbitals» ✓	*Award marks for suitable diagrams.*	**2**
2.	**g**	**ii**	*sigma* (σ) *:* 3 ***AND*** *pi* (π) *:* 2 ✓		**1**

Question			Answers	Notes	Total
3.	a	i	nickel/Ni «catalyst» ✓ high pressure ***OR*** heat ✓	*Accept these other catalysts: Pt, Pd, Ir, Rh, Co, Ti.* *Accept "high temperature" or a stated temperature such as "150 °C".*	2
3.	a	ii	 ✓	*Ignore square brackets and "n".* *Connecting line at end of carbons must be shown.*	1
3.	b		*ethyne:* $C_2H_2 + Cl_2 \rightarrow CHClCHCl$ ✓ *benzene:* $C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$ ✓	*Accept "$C_2H_2Cl_2$".*	2
3.	c	i	$\Delta H^{\ominus}$ = bonds broken – bonds formed ✓ «$\Delta H^{\ominus} = 3(C{\equiv}C) - 6(C{-\!\!-}C)_{benzene}$ / 3 × 839 – 6 × 507 / 2517 – 3042 =» –525 «kJ» ✓	*Award **[2]** for correct final answer.* *Award **[1 max]** for "+525 «kJ»".* *Award **[1 max]** for:* *«$\Delta H^{\ominus} = 3(C{\equiv}C) - 3(C{-}C) - 3(C{=}C)$ / 3 × 839 – 3 × 346 – 3 × 614 / 2517 – 2880 =» –363 «kJ».*	2

(continued…)

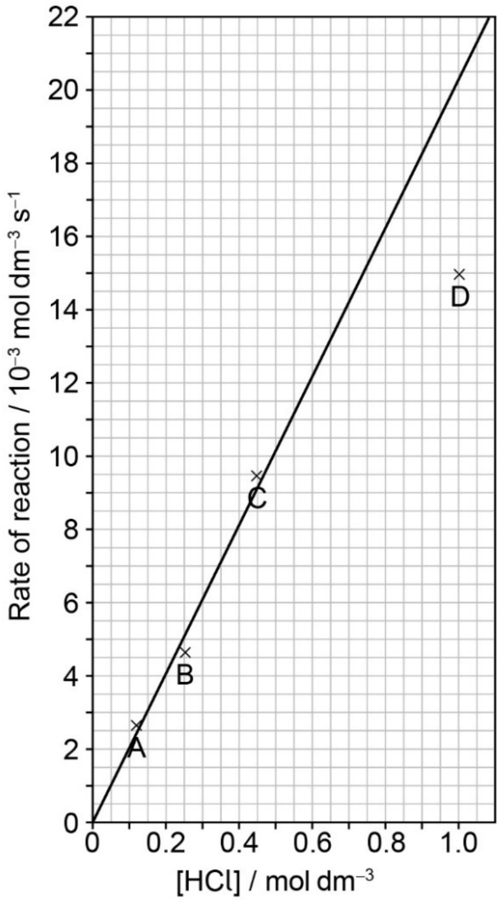
(Question 3c continued)

Question			Answers	Notes	Total
3.	**c**	**ii**	$\Delta H^{\ominus} = \Sigma\Delta H_f$ (products) – $\Sigma\Delta H_f$ (reactants) ✓ «$\Delta H^{\ominus}$ = 49 kJ – 3 × 228 kJ =» –635 «kJ» ✓	*Award **[2]** for correct final answer.* *Award **[1 max]** for "+635 «kJ»".*	**2**
3.	**c**	**iii**	ΔH_f values are specific to the compound ***OR*** bond enthalpy values are averages «from many different compounds» ✓ condensation from gas to liquid is exothermic ✓	*Accept "benzene is in two different states «one liquid the other gas»" for M2.*	**2**
3.	**c**	**iv**	«$\Delta S^{\ominus}$ = 173 – 3 × 201 = » –430 «J K^{-1}» ✓		**1**
3.	**c**	**v**	T = «25 + 273 =» 298 «K» ✓ $\Delta G^{\ominus}$ « = –635 kJ – 298 K × (–0.430 kJ K^{-1})» = –507 kJ ✓ $\Delta G^{\ominus} < 0$ ***AND*** spontaneous ✓	*$\Delta G^{\ominus} < 0$ may be inferred from the calculation.*	**3**
3.	**d**		equal C–C bond «lengths/strengths» ***OR*** regular hexagon ***OR*** «all» C–C have bond order of 1.5 ***OR*** «all» C–C intermediate between single and double bonds ✓	*Accept "all C–C–C bond angles are equal".*	**1**

Question			Answers	Notes	Total
4.	a		*Any two of:* loss of mass «of reaction mixture/CO_2» ✓ «increase in» volume of gas produced ✓ change of conductivity ✓ change of pH ✓ change in temperature ✓	*Do **not** accept "disappearance of calcium carbonate".* *Do **not** accept "gas bubbles".* *Do **not** accept "colour change" or "indicator".*	**2**
4.	b	i	reaction is fast at high concentration ***AND*** may be difficult to measure accurately ***OR*** so many bubbles of CO_2 produced that inhibit contact of HCl (aq) with $CaCO_3$ (s) ***OR*** insufficient change in conductivity/pH at high concentrations ***OR*** calcium carbonate has been used up/is limiting reagent/ there is not enough calcium carbonate «to react with the high concentration of HCl» ***OR*** HCl is in excess ***OR*** so many bubbles of CO_2 produced that inhibit contact of HCl (aq) with $CaCO_3$ (s) ✓		**1**

(continued…)

(Question 4b continued)

Question			Answers	Notes	Total
4.	b	ii	 straight line going through the origin ***AND*** as close to A, B, C as is reasonably possible ✓		1

(continued…)

(Question 4b continued)

Question			Answers	Notes	Total
4.	**b**	**iii**	«directly» proportional ✓	*Accept "first order" or "linear".* *Do **not** accept "rate increases as concentration increases" or "positive correlation".*	**1**
4.	**b**	**iv**	rate = *k* $[H^+]$ ✓	*Accept "rate = k [HCl]".*	**1**
4	**b**	**v**	0.02 ✓ s^{-1} ✓		**2**
4.	**c**		20.5×10^{-3} «$mol\,dm^{-3}\,s^{-1}$»	*Accept any answer in the range 19.5–21.5.*	**1**

Question			Answers	Notes	Total
4.	d		***ALTERNATIVE 1:*** carry out reaction at several temperatures ✓ plot $\frac{1}{T}$ against log rate constant ✓ E_a = – gradient × R ✓ ***ALTERNATIVE 2:*** carry out reaction at two temperatures ✓ determine two rate constants ***OR*** determine the temperature coefficient of the rate ✓ use the formula $\ln\frac{k_1}{k_2}=\frac{E_a}{R}\left(\frac{1}{T_2}-\frac{1}{T_1}\right)$ ✓	*Accept "gradient* $=\frac{-E_a}{R}$ *" for M3.* *Award both M2 and M3 for the formula* $\ln\frac{rate_1}{rate_2}=\frac{E_a}{R}\left(\frac{1}{T_2}-\frac{1}{T_1}\right)$. *Accept any variation of the formula, such as* $\frac{rate_1}{rate_2}=e^{-\frac{E_a}{R}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}$.	3

Question			Answers	Notes	Total
5.	a		slower rate with ethanoic acid ***OR*** smaller temperature rise with ethanoic acid ✓ $[H^+]$ lower ***OR*** ethanoic acid is weak ***OR*** ethanoic acid is partially dissociated ✓	*Accept experimental observations such as "slower bubbling" or "feels less warm".*	**2**
5.	b		*Any one of:* corrosion of materials/metals/carbonate materials ✓ destruction of plant/aquatic life ✓ «indirect» effect on human health ✓	*Accept "lowering pH of oceans/lakes/waterways".*	**1**
5.	c		*Brønsted–Lowry base:* $NH_3 + H^+ \rightarrow NH_4^+$ ✓ *Lewis base:* $NH_3 + BF_3 \rightarrow H_3NBF_3$ ✓	*Accept "$AlCl_3$ as an example of Lewis acid".* *Accept other valid equations such as $Cu^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+}$.*	**2**
5.	d		$[H^+]$ «$= \sqrt{K_a \times [C_5H_{10}O_2]} = \sqrt{9.333 \times 10^{-6} \times 0.010}$» $= 3.055 \times 10^{-4}$ «$mol\ dm^{-3}$» ✓ «pH =» 3.51 ✓	*Accept "pH = 3.52".* *Award **[2]** for correct final answer.* *Accept other calculation methods.*	**2**

Question			Answers	Notes	Total
5.	e		$(CH_3)_3CCOOH$ (aq) + OH^- (aq) → $(CH_3)_3CCOO^-$ (aq) + H_2O (l) ***OR*** $(CH_3)_3CCOOH$ (aq) + OH^- (aq) ⇌ $(CH_3)_3CCOO^-$ (aq) + H_2O (l) ***AND*** addition of alkali causes equilibrium to move to right ✓ $(CH_3)_3CCOO^-$ (aq) + H^+ (aq) → $(CH_3)_3CCOOH$ (aq) ***OR*** $(CH_3)_3CCOO^-$ (aq) + H^+ (aq) ⇌ $(CH_3)_3CCOOH$ (aq) ***AND*** addition of acid causes equilibrium to move to right ✓	*Accept "HA" for the acid.* *Award **[1 max]** for correct explanations of buffering with addition of acid **AND** base **without** equilibrium equations.*	**2**

Question			Answers	Notes	Total
6.	a		salt bridge ✓ movement of ions ***OR*** balance charge ✓	*Do **not** accept "to complete circuit" unless ion movement is mentioned for M2.*	**2**
6.	b		*Positive electrode (cathode):* Ag^{+} (aq) + e^{-} → Ag (s) ✓ *Negative electrode (anode):* Mg (s) → Mg^{2+} (aq) + $2e^{-}$ ✓	*Award **[1 max]** if correct equations given at wrong electrodes.*	**2**
6.	c		in external wire from left to right ✓		**1**
6.	d		«$E = +0.80\text{ V} - (-2.37\text{ V}) = +$» 3.17 «V» ✓		**1**
6.	e		«moles of silver $= \frac{0.10\text{ g}}{107.87\text{ g mol}^{-1}}$» moles of magnesium $= \frac{0.5 \times 0.10\text{ «g»}}{107.87\text{ «g mol}^{-1}\text{»}}$ ✓ «loss in mass of magnesium $= \frac{24.31\text{ g mol} \times 0.5 \times 0.10\text{ g}}{107.87\text{ g mol}^{-1}} =$ » 0.011 «g» ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
7.	a		*Any two similarities:* heterolytic bond breaking ***OR*** chloride ions leave ✓ nucleophilic/OH^- substitution ✓ both first order with regard to [halogenoalkane] ✓ *One difference:* $CH_3CH_2CH_2CH_2Cl$ is second order/bimolecular/S_N2 ***AND*** $(CH_3)_3CCl$ is first order/unimolecular/S_N1 ***OR*** $CH_3CH_2CH_2CH_2Cl$ rate depends on $[OH^-]$ ***AND*** $(CH_3)_3CCl$ does not ***OR*** $CH_3CH_2CH_2CH_2Cl$ is one step ***AND*** $(CH_3)_3CCl$ is two steps ***OR*** $(CH_3)_3CCl$ involves an intermediate ***AND*** $CH_3CH_2CH_2CH_2Cl$ does not ***OR*** $CH_3CH_2CH_2CH_2Cl$ has inversion of configuration ***AND*** $(CH_3)_3CCl$ has c. 50 : 50 retention and inversion ✓	*Do **not** accept "produces alcohol" or "produces NaCl".* *Accept "substitution in 1-chlorobutane and **«**some**»** elimination in 2-chloro-2-methylpropane".*	**3**
7.	b		C–Br bond weaker than C–Cl bond ✓	*Accept "Br^- is a better leaving group".* *Do **not** accept "bromine is more reactive".* *Do **not** accept "C–Br bond is longer than C–Cl" alone.*	**1**

Question			Answers	Notes	Total
7.	**c**	**i**	butan-1-ol/$CH_3CH_2CH_2CH_2OH$ ✓	*Do **not** accept "butanol" for "butan-1-ol".* *Accept "1-butanol".* *Do **not** penalize for name if correct formula is drawn.*	**1**
7.	**c**	**ii**	«reduction with» lithium aluminium hydride/$LiAlH_4$ ✓	*Do **not** accept "sodium borohydride/$NaBH_4$".*	**1**
7.	**c**	**iii**	ester ✓		**1**