Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/04**

Paper 4 A Level Structured Questions **For examination from 2022**

MARK SCHEME

Maximum Mark: 100

Specimen

This document has **16** pages. Blank pages are indicated.

Generic Marking Principles

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct / valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6: Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
3	Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
4	The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
5	<u>'List rule' guidance</u> (see examples below) For questions that require ***n*** responses (e.g. State **two** reasons …): • The response should be read as continuous prose, even when numbered answer spaces are provided • Any response marked *ignore* in the mark scheme should not count towards ***n*** • Incorrect responses should not be awarded credit but will still count towards ***n*** • Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response • Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

6	<u>Calculation specific guidance</u> Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'. For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values. For answers given in standard form, (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme. Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.
7	<u>Guidance for chemical equations</u> Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme. State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Mark scheme abbreviations:

;	separates marking points
/	separates alternatives within a marking point
R	reject
I	ignore mark as if this material was not present
A	accept (a less than ideal answer which should be marked)
COND	indicates mark is conditional on previous marking point
OWTTE	or words to that effect (accept other ways of expressing the same idea)
AW	alternative wording (where responses vary more than usual)
<u>underline</u>	actual word given must be used by candidate (grammatical variants accepted)
max	indicates the maximum number of marks that can be awarded
ECF	credit a correct statement that follows a previous wrong answer
( )	the word / phrase in brackets is not required, but sets the context
ORA	or reverse argument

Examples of how to apply the list rule

State **three** reasons ... [3]

A

1. Correct	✓	**2**
2. Correct	✓	
3. Wrong	×	

B (4 responses)

1. Correct, Correct	✓, ✓	**3**
2. Correct	✓	
3. Wrong	ignore	

C (4 responses)

1. Correct	✓	**2**
2. Correct, Wrong	✓, ×	
3. Correct	ignore	

D (4 responses)

1. Correct	✓	**2**
2. Correct, CON (of 2.)	×, (discount 2)	
3. Correct	✓	

E (4 responses)

1. Correct	✓	**3**
2. Correct	✓	
3. Correct, Wrong	✓	

F (4 responses)

1. Correct	✓	**2**
2. Correct	✓	
3. Correct CON (of 3.)	× (discount 3)	

G (5 responses)

1. Correct	✓	**3**
2. Correct	✓	
3. Correct Correct CON (of 4.)	✓ ignore ignore	

H (4 responses)

1. Correct	✓	**2**
2. Correct	×	
3. CON (of 2.) Correct	(discount 2) ✓	

I (4 responses)

1. Correct	✓	**2**
2. Correct	×	
3. Correct CON (of 2.)	✓ (discount 2)	

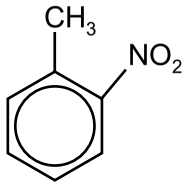
Question	Answer	Marks	Guidance
1(a)(i)	the ratio of the concentrations of a solute in two (immiscible) solvents ; at equilibrium ;	**2**	
1(a)(ii)	$[NH_3]_{aq} = 0.1 \times 12.5 / 10 = 0.125$ mol dm^{-3} **AND** $[NH_3]_{CHCl_3} = 0.1 \times 13 / 25 = 0.052$ mol dm^{-3} ; ratio = $K_{pc} = 0.052 / 0.125 = 0.416$ (allow ratio = $K_{pc} = 0.125 / 0.052 = 2.40$) ;	**2**	
1(a)(iii)	To be marked based on the ratio given for **1(a)(ii)** K_{pc} will be larger for butylamine than for ammonia (allow K_{pc} will be smaller for butylamine than for ammonia) ; butylamine contains a hydrophobic / non-polar (C_4) chain, so will be more soluble in the non-polar solvent than ammonia ;	**2**	
1(b)	presence of electron-withdrawing oxygen / carbonyl group means lone pair is not available to accept a proton	**1**	

Question	Answer	Marks	Guidance
2(a)(i)	(entropy) increases **AND** (H_2) gas is formed	**1**	
2(a)(ii)	(entropy) increases **AND** the ordered solid lattice goes to a solution with (free) moving ions	**1**	
2(a)(iii)	(entropy) decreases **AND** decrease in moles of gas as more ordered liquid formed	**1**	
2(b)(i)	$\Delta S^\ominus = 26.9 + 214 - 65.7 = (+)175.2$ (J K^{-1} mol^{-1}) ; $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$ **OR** $117 - (298 \times 175.2 / 1000)$; $\Delta G^\ominus$ = **+64.8** ; **ECF** min 3 sf	**3**	
2(b)(ii)	(at high temperature) $T\Delta S^\ominus$ is more positive than $\Delta H^\ominus$ so $\Delta G^\ominus$ is negative	**1**	
2(c)	it / solubility decreases down the group **AND** K_{sp} decreases / comparing K_{sp} data	**1**	

Question	Answer	Marks	Guidance
2(d)(i)	$MgCO_3(s) + (aq) \rightleftharpoons Mg^{2+}(aq) + CO_3^{2-}(aq)$	**1**	
2(d)(ii)	(white) solid appears / precipitation (of $MgCO_3$) ; as $[CO_3^{2-}]$ increases shifting equilibrium to the left (precipitating out $MgCO_3$) ;	**2**	
2(e)	solubility in mol dm^{-3} = $\sqrt{1.0 \times 10^{-5}} = 3.2 \times 10^{-3}$ mol dm^{-3} ; solubility in g dm^{-3} = $3.2 \times 10^{-3} \times 84.3 = 0.27$ g dm^{-3} ; **ECF**	**2**	
2(f)	Award 1 mark for 2 points. Award 2 marks for 3 points. Award 3 marks for 4 points. • the thermal stability increases / more energy required down the group ; • ionic radius of the cation increases ; • less distortion / polarisation **OR** less weakening of (C–O / C=O) bonds ; • of the anion / the CO_3^{2-} ion ;	**3**	

Question	Answer	Marks	Guidance
3(a)(i)	the power to which a concentration is raised in the rate equation	**1**	
3(a)(ii)	k = 3.7 ; $mol^{-1}\ dm^3\ s^{-1}$;	**2**	
3(a)(iii)	initial rate = 5.50×10^{-3}	**1**	**ECF** from k in **(a)(ii)**
3(a)(iv)	$[ClO_2] = 0.048$	**1**	**ECF** from **(a)(ii)**
3(b)(i)	slowest step (in a multi-step reaction)	**1**	

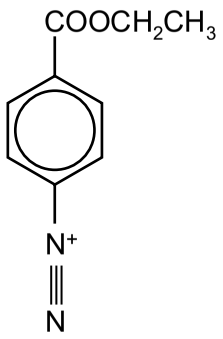
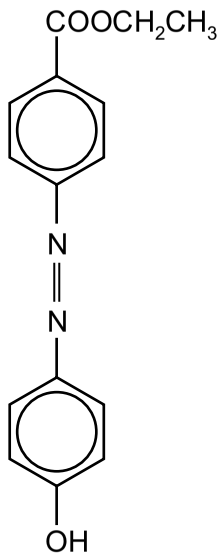
Question	Answer	Marks	Guidance
3(b)(ii)	Step 1: $ClO_2 + F_2 \rightarrow ClO_2F_2$ Step 2: $ClO_2 + ClO_2F_2 \rightarrow 2ClO_2F$ **OR** Step 1: $ClO_2 + F_2 \rightarrow ClO_2F + F$ Step 2: $ClO_2 + F \rightarrow ClO_2F$	**1**	
3(b)(iii)	rate-determining step = step 1 **AND** 1 mole of F_2 and 1 mole of ClO_2 are reacting / consistent with the rate equation	**1**	
3(c)	as temperature increases rate increases thus increasing *k*	**1**	

Question	Answer	Marks	Guidance
4(a)(i)		**1**	
4(a)(ii)	$HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + NO_2^+ + 2HSO_4^-$	**1**	
4(a)(iii)	Any **three** from: Point 1: delocalised / π system / bonding extends over only five carbons in **T** ; Point 2: only four π-electrons in (the delocalised system of) **T** ; Point 3: one carbon is sp^3 hybridised in **T OR** only five carbon are sp^2 hybridised in **T** ; Point 4: one carbon has a bond angle of 109.5° / tetrahedral in **T OR** not all the bond angles are 120° in **T** ; **ORA**	**3**	

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>4(b)(i)</td><td>4-aminobenzoic acid</td><td>1</td><td></td></tr>
<tr><td>4(b)(ii)</td><td>Sn + HCl ; concentrated AND heat</td><td>2</td><td></td></tr>
<tr><td>4(b)(iii)</td><td>CH_3COCl</td><td>1</td><td></td></tr>
<tr><td>4(b)(iv)</td><td>step 3 MnO_4^- (acidified / alkaline) AND heat ;

step 4 H^+(aq) AND heat ;</td><td>2</td><td></td></tr>
<tr><td>4(c)(i)</td><td>7 peaks</td><td>1</td><td></td></tr>
<tr><td>4(c)(ii)</td><td>
<table>
<tr><th>δ / ppm</th><th>environment of proton</th><th>number of ^1H atoms responsible for the peak</th><th>splitting pattern</th></tr>
<tr><td>1.2</td><td>alkane / alkyl / $CH_{(3)}$</td><td>3</td><td>triplet</td></tr>
<tr><td>3.5</td><td>alkyl next to electronegative atom / oxygen or $CH_{(2)}O$</td><td>2</td><td>quartet</td></tr>
<tr><td>5.5</td><td>(aryl) amine or $RNH_{(2)}$ or NH_2</td><td>2</td><td>singlet</td></tr>
</table>
Award 1 mark for each row.</td><td>3</td><td></td></tr>
<tr><td>4(c)(iii)</td><td>neighbouring / adjacent (carbon) atom has two protons (attached to it)

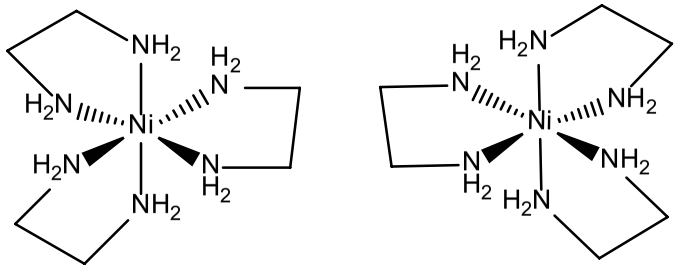
OR there is an adjacent CH_2(O) group</td><td>1</td><td></td></tr>
<tr><td>4(d)(i)</td><td>$NaNO_2$ + HCl OR HNO_2</td><td>1</td><td></td></tr>
</table>

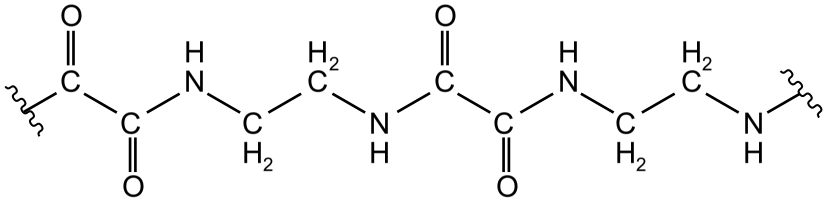
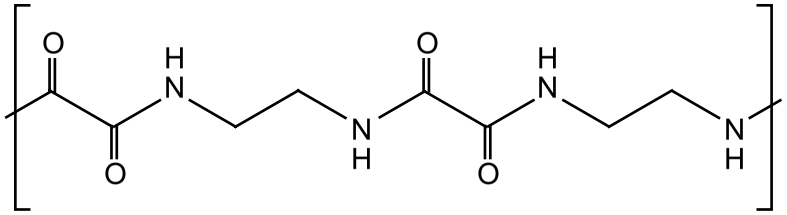
Question	Answer	Marks	Guidance
4(d)(ii)	**R**  **S**  structure of diazonium salt **R** ; structure of azo dye **S** ; **ECF**	**2**	

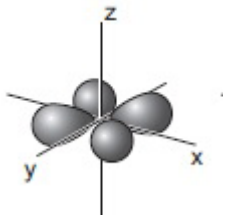
Question	Answer	Marks	Guidance
5(a)(i)	(energy change) when **1 mole** of an ionic compound is formed ; from **gaseous ions** (under standard conditions) ;	**2**	
5(a)(ii)	**forming** an ionic bond	**1**	

Question	Answer	Marks	Guidance
5(b)(i)	extraction of relevant data –361, –141, 89, 418, 496, 798 ; correct multipliers 2 × (89); 2 × (418); 0.5 × (496) ; correct sum and answer: LE= –361 – 2(89) – 2(418) – 496 / 2 – (–141 + 798) = **–2280** ;	**3**	
5(b)(ii)	tick only in box 3 (more negative) **AND** as sodium has a smaller ionic radius **AND** so greater attraction between the ions	**1**	

Question	Answer	Marks	Guidance
6(a)	(an element) forming / having (one or more stable) ions with incomplete d subshell	**1**	
6(b)(i)	(a species that) forms **one** dative / coordinate bond ; that uses a lone pair of electrons to form a dative / coordinate bond to a (metal) atom / ion ;	**2**	
6(b)(ii)	$[Ag(NH_3)_2]^+$	**1**	
6(c)(i)	cis-trans **OR** geometrical	**1**	
6(c)(ii)	the **d orbitals** are split into 2 / different levels ; (colour is due to) **absorption** of light / photon (in visible region) ; **electron** promotion / excited ; the energy gap is different for the two complexes ;	**4**	

Question	Answer	Marks	Guidance
6(d)	3D correct for octahedral **AND** one correct structure with 3D ; second correct with 3D ;  correct use of *en* as a bidentate ligand (instead of $H_2NCH_2CH_2NH_2$) is acceptable  	**2**	
6(e)(i)	nitrogen lone pair ; accepts a proton ;	**2**	
6(e)(ii)	$H_2NCH_2CH_2NH_2 + 2HCl \rightarrow ClH_3NCH_2CH_2NH_3Cl$ (or ionic)	**1**	

Question	Answer	Marks	Guidance
6(f)(i)	amide bond ; rest of the molecule with continuation bonds ;  **OR** 	**2**	
6(f)(ii)	condensation	**1**	

Question	Answer	Marks	Guidance
7(a)		**1**	
7(b)(i)	Transition elements have more than one stable oxidation state ; vacant orbitals that are energetically accessible **OR** can form dative bonds with ligands ;	**2**	

Question	Answer	Marks	Guidance
7(b)(ii)	<table><tr><td rowspan="2">reaction</td><td colspan="2">type of catalysis</td></tr><tr><td>heterogeneous</td><td>homogeneous</td></tr><tr><td>Fe in the Haber process</td><td>✓</td><td></td></tr><tr><td>Fe^{2+} in the $I^- / S_2O_8^{2-}$ reaction</td><td></td><td>✓</td></tr><tr><td>NO_2 in the oxidation of SO_2</td><td></td><td>✓</td></tr></table> All correct.	**1**	
7(c)(i)	$Sn^{2+} + 2Fe^{3+} \rightarrow Sn^{4+} + 2Fe^{2+}$	**1**	
7(c)(ii)	$E^{\ominus}_{cell} = 0.62$ (V)	**1**	**ECF** from **(c)(i)**
7(d)(i)	K_{stab} $[Fe(H_2O)_5F]^{2+} > [Fe(H_2O)_5SCN]^{2+}$ or K_{stab} for eqm 1 is greater than eqm 2 ; Award 1 mark for 2 observations. Award 2 marks for 3 observations. Award 3 marks for 4 observations. Experiment 1 (violet) → deep-red (deep-red) → colourless Experiment 2 (violet) → colourless which stays colourless / does not change	**4**	
7(d)(ii)	**ligand** displacement / exchange / substitution	**1**	
7(e)	$[H^+]^2 = 8.9 \times 10^{-4} \times 0.25$ $[H^+] = 0.0149$; pH = –log(0.0149) = 1.8 ; **ECF**	**2**	

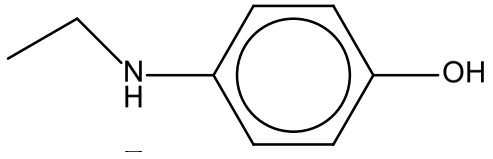
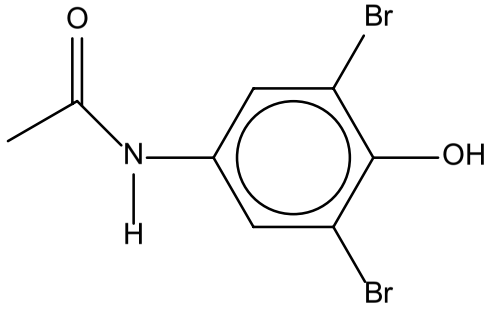
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>8(a)</td><td>Award 1 mark for 2 functional groups.
Award 2 marks for 3 functional groups.

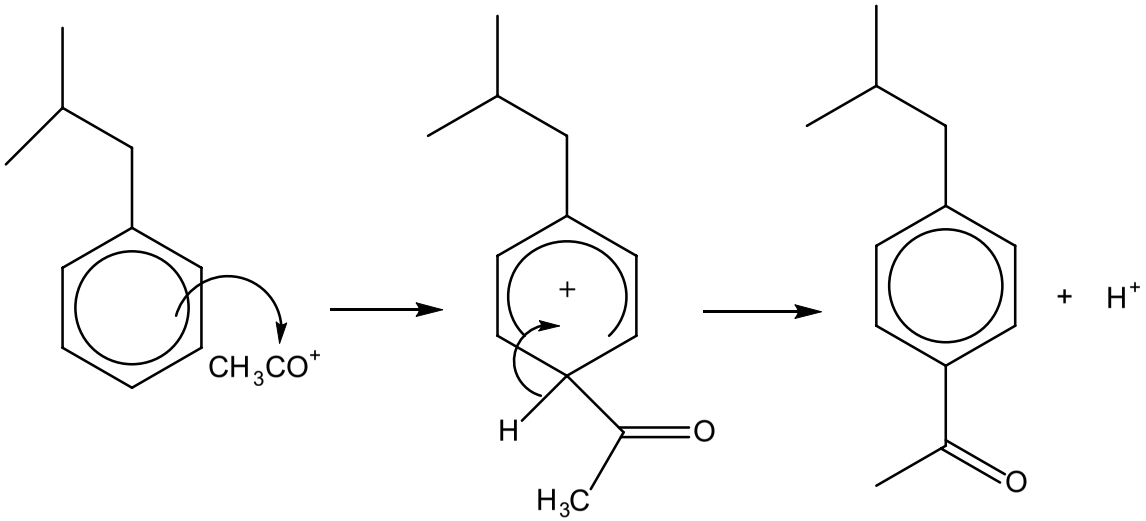
ibuprofen: carboxylic acid

paracetamol: phenol and amide</td><td>2</td><td></td></tr>
<tr><td>8(b)(i)</td><td>identical physical and chemical properties AND

ability to rotate plane polarised light OR potential biological activity</td><td>1</td><td></td></tr>
<tr><td>8(b)(ii)</td><td>a mixture containing equal amounts of each enantiomer</td><td>1</td><td></td></tr>
<tr><td>8(c)</td><td>Award 1 mark for each organic structure.

Award 1 mark for both types of reaction.

<table>
<tr><th>reagent</th><th>organic product structure</th><th>type of reaction</th></tr>
<tr><td>$LiAlH_4$</td><td>  </td><td>reduction</td></tr>
<tr><td>an excess of $Br_2(aq)$</td><td>  </td><td>electrophilic substitution</td></tr>
</table></td><td>3</td><td></td></tr>
<tr><td>8(d)(i)</td><td>$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$</td><td>1</td><td></td></tr>
</table>

Question	Answer	Marks	Guidance
8(d)(ii)	 curly arrow from ring system to CH_3CO^+ (arrow to positively charged carbon atom) ; correct intermediate ; curly arrow from C–H bond into ring and loss of H^+ ;	**3**	
8(d)(iii)	$H^+ + AlCl_4^- \rightarrow HCl + AlCl_3$	**1**	