Chemistry marking guide and response

External assessment 2025

Combination response (110 marks)

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

1. describe and explain chemical equilibrium systems, oxidation and reduction, properties and structure of organic materials, and chemical synthesis and design
2. apply understanding of chemical equilibrium systems, oxidation and reduction, properties and structure of organic materials, and chemical synthesis and design
3. analyse evidence about chemical equilibrium systems, oxidation and reduction, properties and structure of organic materials, and chemical synthesis and design to identify trends, patterns, relationships, limitations or uncertainty
4. interpret evidence about chemical equilibrium systems, oxidation and reduction, properties and structure of organic materials, and chemical synthesis and design to draw conclusions based on analysis.

Note: Objectives 5, 6 and 7 are not assessed in this instrument.

Queensland Government
QCAA Queensland Curriculum & Assessment Authority

Purpose

This document consists of a marking guide and a sample response.

The marking guide:

- provides a tool for calibrating external assessment markers to ensure reliability of results
- indicates the correlation, for each question, between mark allocation and qualities at each level of the mark range
- informs schools and students about how marks are matched to qualities in student responses.

The sample response demonstrates the qualities of a high-level response.

Mark allocation

Where a response does not meet any of the descriptors for a question or a criterion, a mark of ‘0’ will be recorded.

Allow FT mark/s — refers to ‘follow through’, where an error in the prior section of working is used later in the response, a mark (or marks) for the rest of the response can still be awarded so long as it still demonstrates the correct conceptual understanding or skill in the rest of the response.

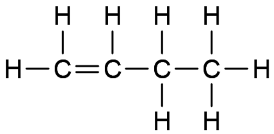
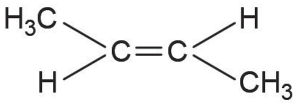
Marking guide

Multiple choice

Question	Response
1	A
2	C
3	D
4	C
5	C
6	D
7	C
8	C
9	D
10	B
11	A
12	B
13	B
14	D
15	C
16	B
17	B
18	A
19	A
20	D

Short response: Paper 1

Q	Sample response	The response:
21a)	HA is a weak acid.	• classifies HA as a weak acid **[1 mark]**
21b)	HA is a monoprotic acid because it donates one hydrogen ion.	• explains that HA is a monoprotic acid because it donates one hydrogen ion **[1 mark]**
22	Oxidation state (Mn): +3 Name of ionic compound (Mn_2O_3): manganese(III) oxide	• determines oxidation state is +3 **[1 mark]** • determines ionic name is manganese(III) oxide **[1 mark]**
23	1: All solutions are 1.0 mol L^{-1}. 2: Temperature is 25 °C (298 K).	• identifies one limitation **[1 mark]** • identifies a second limitation **[1 mark]**
24a)	Unsaturated because it contains a double bond	• classifies citronellol as unsaturated **[1 mark]** • explains that it contains a double bond **[1 mark]**
24b)	Bromine water could be used to confirm that citronellol is unsaturated. When added to citronellol, bromine water will change from brown/orange to colourless because the molecule is unsaturated.	• identifies a suitable chemical test **[1 mark]** • describes a suitable chemical test **[1 mark]**

<table>
<tr><th>Q</th><th>Sample response</th><th>The response:</th></tr>
<tr><td>25a)</td><td>
IUPAC name: but-1-ene</td><td>• draws the structural formula of a structural isomer [1 mark]
• identifies IUPAC name of the structural isomer [1 mark]</td></tr>
<tr><td>25b)</td><td>
IUPAC name: (E)-but-2-ene</td><td>• draws the structural formula of a geometric isomer [1 mark]
• identifies IUPAC name of the geometric isomer [1 mark]</td></tr>
<tr><td>26a)</td><td>The forward reaction is exothermic.</td><td>• determines that forward reaction is exothermic [1 mark]</td></tr>
<tr><td>26b)</td><td>Increasing pressure would shift equilibrium to the products to produce more $SO_3(g)$. The reaction would shift towards the products to reduce pressure because there are fewer gas molecules as products (2 molecules) than reactants (3 molecules).</td><td>• determines that increasing pressure increases production of $SO_3(g)$ [1 mark]
• explains that equilibrium shifts to the side with fewer molecules to reduce pressure [1 mark]</td></tr>
<tr><td>27</td><td><table>
<tr><th>Electrolyte</th><th>Cathode product</th><th>Oxidation half-equation</th></tr>
<tr><td>concentrated (25%) NaCl (aq)</td><td>$H_2(g)$</td><td>$2Cl^-(aq) \rightleftharpoons Cl_2(g) + 2e^-$</td></tr>
<tr><td>molten NaCl(l)</td><td>Na(l)</td><td>$2Cl^-(l) \rightleftharpoons Cl_2(g) + 2e^-$</td></tr>
</table></td><td>• determines $H_2(g)$ as product at cathode for concentrated (25%) NaCl(aq) [1 mark]
• determines oxidation half-equation for concentrated (25%) NaCl(aq) [1 mark]
• determines Na(l) as product at cathode for molten NaCl(l) [1 mark]
• determines oxidation half-equation for molten NaCl(l) [1 mark]</td></tr>
</table>

Q	Sample response	The response:
28a)	$pK_w = pK_a + pK_b$ $pK_b = 14 - 9 = 5$	• determines that pK_b equals 5 **[1 mark]**
28b)	Moles of BOH in 25.0 mL aliquot of diluted base = moles HCl at equivalence point	• determines moles of base in aliquot equals moles of HCl at equivalence point **[1 mark]**
	$\text{moles of BOH} = 0.1 \times 0.020 = 2.0 \times 10^{-3}$ moles $[\text{diluted BOH}] = \frac{2.0 \times 10^{-3}}{0.025} = 0.08 \text{ mol L}^{-1}$	• calculates concentration of BOH in aliquot **[1 mark]**
	$[\text{BOH}] = 0.08 \times 5$ $= 0.40 \text{ mol L}^{-1}$	• calculates concentration of BOH **[1 mark]**
28c)	The pH of the equivalence point: would increase to pH 7 because NaOH is a strong base. The volume of HCl required to reach the equivalence point: would remain the same, as the moles of base being neutralised has not changed.	• determines that the pH at the equivalence point is 7 **[1 mark]** • explains that the pH at the equivalence point would increase when a strong base is titrated with a strong acid **[1 mark]** • determines that the volume of HCl required to reach the equivalence point would not change **[1 mark]** • explains that the moles of base to be neutralised remains the same **[1 mark]**

Q	Sample response	The response:
29a)	Another principle of green chemistry used in the production of benzaldehyde is prevention, because it is better to prevent waste than to treat or clean it up after it has been created.	• identifies prevention as a green chemistry principle **[1 mark]** • explains that it is better to prevent waste than treat or clean it up after it has been created **[1 mark]**
29b)	The Na-MnO$_x$ catalyst reaction pathway has the best atom economy, as it maximises the conversion of reactants into benzaldehyde. $AE = \frac{\text{MW of desired product}}{\text{MW of reactants}}$ $AE = \frac{212.26\ \text{g mol}^{-1}}{230.3\ \ \text{g mol}^{-1}} = 0.92$ Meanwhile, the Criegee oxidation reaction pathway has the lowest E-factor, indicating that it has the least environmental impact because it produces the least waste (3.2 kg) per kg of benzaldehyde produced.	• concludes that the Na-MnO$_x$ catalyst pathway has best atom economy **[1 mark]** • provides evidence to support atom economy claim **[1 mark]** • concludes that the Criegee oxidation pathway has the lowest environmental impact **[1 mark]** • provides E-factor evidence to support environmental impact claim **[1 mark]**

Short response: Paper 2

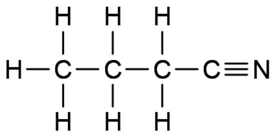
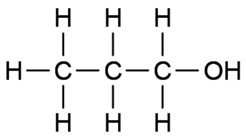
Q	Sample response	The response:
1a)	$Mg(s) \rightleftharpoons Mg^{2+}(aq) + 2e^-$	• determines the oxidation half-equation for the Mg | $Mg(NO_3)_2$ half-cell **[1 mark]**
1b)	Electrons flow from the magnesium electrode to the copper electrode via the wire, while anions move through the salt bridge towards the magnesium half-cell.	• identifies that electrons flow from the magnesium electrode to the copper electrode through the wire **[1 mark]** • identifies that anions move through the salt bridge towards the magnesium half-cell **[1 mark]**
1c)	The copper electrode would increase in mass, and the copper nitrate solution would become lighter in colour.	• describes a change observed in the cell **[1 mark]** • describes a second change observed in the cell **[1 mark]**
1d)	A voltage will be produced because Al is a more reactive metal than Cu. Therefore Al will be oxidised and Cu^{2+} will be reduced.	• predicts that a voltage would be produced **[1 mark]** • identifies that Al is more reactive than Cu **[1 mark]** • explains that Al would be oxidised and Cu^{2+} would be reduced **[1 mark]**
2a)	Hexanal would produce a CHO^+ fragment, while hexan-2-one would produce a CH_3CO^+ fragment.	• describes that hexanal would produce a CHO^+ fragment **[1 mark]** • describes that hexan-2-one would produce a CH_3CO^+ fragment **[1 mark]**
2b)	IR spectrum for hexanoic acid would have an OH^- broad peak around 2500–3000 cm^{-1} while hexanal would not.	• explains that hexanoic acid would also have a peak at 2500–3000 cm^{-1} for OH group **[1 mark]**

Q	Sample response	The response:
3a)	Indicators are weak acids, therefore, $K_a\text{(alizarin yellow R)} = \frac{[H_3O^+][In^-]}{[HIn]} = 7.9 \times 10^{-12}$ $pH = -\log[H_3O^+] = -\log[7.9 \times 10^{-12}]$ $pK_a = -\log[7.9 \times 10^{-12}] = 11.1$	• determines the pKa is 11.1 **[1 mark]**
3b)	When [H+] is 10 times greater than the K_a value of alizarin yellow R the In^- form dominates and the indicator is yellow. When [H+] is 10 times less than the K_a value of alizarin yellow R the HIn form dominates, and the indicator is red. As indicators change colour at the pH at which the $[HIn]=[In^-]$, the pH range of the colour change for alizarin yellow R is its $pK_a \pm 1$.	• explains when $[HIn]:[In^-]$ > 10 the solution is yellow and when $[In^-]:[HIn]$ > 10 the solution is red **[1 mark]** • explains that indicators change colour when $[HIn]=[In^-]$ **[1 mark]** • identifies that the pH range of colour change is $pK_a \pm 1$ **[1 mark]**
3c)	Alizarin yellow R would be a suitable indicator for a weak acid–strong base titration.	• identifies weak acid–strong base titration **[1 mark]**

Q	Sample response	The response:
4a)	$HOCl(aq) \rightleftharpoons H^{+}(aq) + OCl^{-}(aq)$ $HCl(aq) \rightarrow H^{+}(aq) + Cl^{-}(aq)$	• describes that HOCl partially dissociates using reversible arrow **[1 mark]** • describes that HCl fully dissociates using forward arrow **[1 mark]**
4b)	$K_a = \frac{[H^{+}][OCl^{-}]}{[HOCl]}$ $x = [OCl^{-}] = [H^{+}]$ $2.8 \times 10^{-8} = \frac{x^2}{2.50}$	• identifies that $[H^{+}] = [OCl^{-}]$ **[1 mark]**
	$x = [H^{+}] = 2.6 \times 10^{-4}$	• determines that $[H^{+}]$ is 2.6×10^{-4} **[1 mark]**
	$pH = -\log[H^{+}] = 3.6$	• calculates pH **[1 mark]**

Q	Sample response	The response:
5a)	Spot P is glutamic acid (Glu), Q is cysteine (Cys) and R is arginine (Arg). At pH 5, Glu is negatively charged and so would move towards the positively charged electrode. This is because the buffer's pH is higher than the pH of Glu's isoelectric point. At pH 5, Arg is positively charged and so would move to the negative electrode. This is because the buffer's pH is much less than the pH of Arg's isoelectric point. Cys has little charge due to the pH of the buffer and isoelectric point being similar. This means that the molecule would not move very far towards the negative electrode.	• determines that spot P is Glu, spot Q is Cys and spot R is Arg **[1 mark]** • explains link between the buffer's pH and the pH of the isoelectric point of Arg and Glu **[1 mark]** • explains link between the charge of Arg or Glu and their positions in the gel **[1 mark]** • explains link between the buffer's pH and the pH of the isoelectric point of Cys and its position in the gel **[1 mark]**
5b)	Spot X is between spot Q and R, so it must be from an amino acid with an isoelectric point between 5 and 10.7. Spot X is closer to spot R; therefore its isoelectric point is close to 10.7. Therefore, spot X is lysine, with a pH of 9.7 at its isoelectric point.	• identifies spot X as Lys **[1 mark]** • explains link beyween the pH of the isoelectric point of the amino acid chosen with reference to the isoelectric point of Cys or Glu or Arg **[1 mark]**

<table>
<tr><th>Q</th><th>Sample response</th><th>The response:</th></tr>
<tr><td>6a)</td><td>Hexane has a higher boiling point than pentane because a longer carbon chain has a larger molar mass, which increases dispersion forces.</td><td>• predicts that hexane has a higher boiling point [1 mark]
• explains that increasing chain length increases dispersion forces [1 mark]</td></tr>
<tr><td>6b)</td><td>Butanal is polar, and pentane is non-polar. Butanal forms dipole–dipole interactions that are stronger than the dispersion forces in pentane; therefore, butanal has a higher boiling point.</td><td>• identifies that butanal is polar and/or has dipole-dipole forces [1 mark]
• identifies that pentane is non-polar and/or only has dispersion forces [1 mark]
• explains that butanal has a higher melting point due to stronger intermolecular forces [1 mark]</td></tr>
<tr><td>6c)</td><td>Propanoic acid and butanol are highly soluble in water because the polar COOH and OH groups can form hydrogen bonds with water.</td><td>• identifies that propanoic acid and butanol are highly soluble in water [1 mark]
• explains that solubility is due to hydrogen bonding with water [1 mark]</td></tr>
<tr><td>6d)</td><td>Primary alcohol. The OH group is attached to a carbon that is attached to one carbon atom.</td><td>• identifies primary alcohol [1 mark]
• explains that the OH group is attached to a carbon that is attached to one carbon atom [1 mark]</td></tr>
<tr><td>6e)</td><td>ethyl methanoate</td><td>• names ester as ethyl methanoate [1 mark]</td></tr>
<tr><td>7</td><td><table>
<tr><th rowspan="2">Contrast</th><th colspan="2">Hydrogen fuel cell</th></tr>
<tr><th>Acidic conditions</th><th>Alkaline conditions</th></tr>
<tr><td>Electrolyte used</td><td>H^+</td><td>KOH</td></tr>
<tr><td>Movement of ions</td><td>H^+ ions move through the proton membrane towards the cathode</td><td>OH^- ions move through the membrane towards the anode</td></tr>
</table></td><td>• identifies that an alkaline fuel cell has an alkaline (KOH) electrolyte [1 mark]
• identifies that an acidic fuel cell has an acidic (H^+) electrolyte [1 mark]
• identifies that OH^- ions move through the membrane towards the anode [1 mark]
• identifies that H^+ ions move through the proton membrane towards the cathode [1 mark]</td></tr>
</table>

Q	Sample response	The response:
8a)	Compound A Structural formula  IUPAC name: butanenitrile Compound D Structural formula  IUPAC name: 1-propanol	• determines structural formula for compound A **[1 mark]** • determines that the IUPAC name for compound A is butanenitrile **[1 mark]** • determines structural formula for compound D **[1 mark]** • determines that the IUPAC name for compound D is propanol **[1 mark]**
8b)	propene	• determines that the IUPAC name for the alkene is propene **[1 mark]**
8c)	addition reaction	• identifies addition reaction **[1 mark]**
8d)	$CH_3CH_2CH_2CN + 2H_2 \xrightarrow[\text{Ni}]{\text{heat}} CH_3CH_2CH_2CH_2NH_2$	• provides a balanced chemical equation for converting butanenitrile to butanamine **[1 mark]** • identifies an appropriate catalyst **[1 mark]**
8e)	Amine B: butanamine; Amine C: propanamine. Amine B has one extra carbon in its carbon chain.	• identifies that amine B has an extra carbon in its chain **[1 mark]**

Q	Sample response	The response:
9a)	K_c is greater than 1; therefore, the equilibrium lies towards the product, so the solution will be orange.	• explains K_c is greater than 1; therefore, equilibrium lies towards the product **[1 mark]** • deduces that the solution will be orange **[1 mark]**
9b)	$\text{Let } [H^+] = x$ $K_c = \frac{[Cr_2O_7^{2-}]}{[CrO_4^-]^2[H^+]^2}$ $4.2\times10^{14} = \frac{6.0\times10^{-2}}{(1.2\times10^{-3})^2(x)^2}$	• provides appropriate substitution **[1 mark]**
	$x^2 = 1.0\times10^{-10}$ $x = 1.0\times10^{-5}$	• determines $[H^+]$ **[1 mark]**
	$pH = -\log(10^{-5}) = 5$	• calculates pH is 5 **[1 mark]**