Chemistry marking guide and solution

External assessment

Combination response (120 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
Queensland Curriculum & Assessment Authority
For all Queensland schools

Purpose

This document consists of an EAMG.

The EAMG:

- 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.

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.

Allowing for FT error — 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 be awarded so long as it still demonstrates the correct conceptual understanding or skill in the rest of the response.

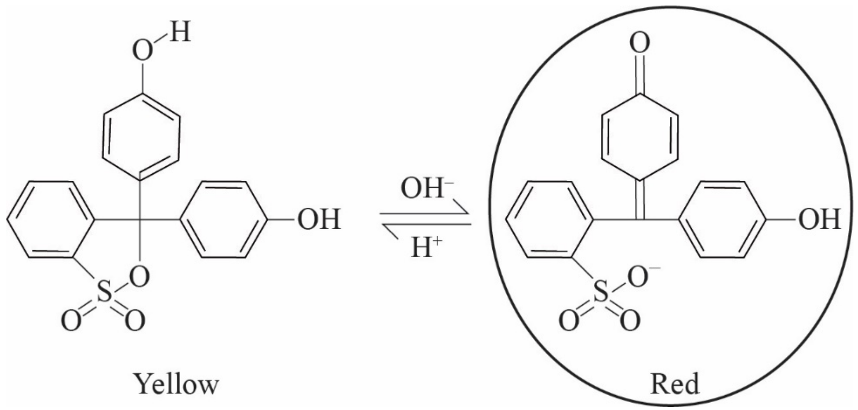
Where no response to a question has been made, a mark of ‘N’ will be recorded.

External assessment marking guide

Paper 1: Multiple choice

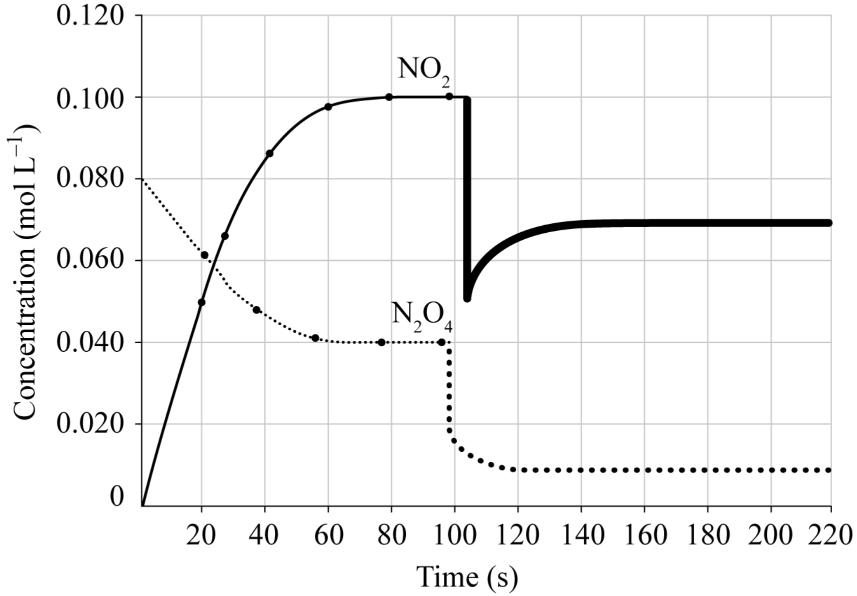
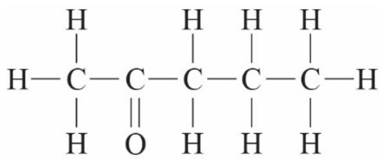
Question	Response
1	D
2	D
3	A
4	A
5	B
6	D
7	B
8	C
9	C
10	D
11	B
12	A
13	D
14	D
15	A
16	B
17	C
18	D
19	C
20	D

Paper 1: Short response

Q		Sample response	The response:	Notes
21	a)	Monosaccharide	• provides monosaccharide **[1 mark]**	Accept aldose.
	b)	Both starch and cellulose form 1-4 glycosidic links. However, starch is a polymer of α–glucose and cellulose is a polymer of β–glucose. Starch forms a linear polymer due to 1-4 α–glycosidic links (amylose) and a branched polymer due to 1-4 and 1-6 α–glycosidic links (amylopectin). Cellulose only exists as a linear polymer with 1-4, β–glycosidic links.	• identifies that both contain 1-4 links **[1 mark]** • identifies that starch is a polymer of α–glucose and cellolose is a polymer of β–glucose **[1 mark]** • indicates that starch can be linear due to 1-4 α–glycosidic links (amylose) and branched due to 1-4 and 1-6 α–glycosidic links **[1 mark]** • indicates that cellulose only exists as a linear polymer with 1-4, β–glycosidic links **[1 mark]**	
22	a)		• circles the red species **[1 mark]**	

Q		Sample response	The response:	Notes
	b)	$K_a = \frac{[2.0 \times 10^{-4}][2.0 \times 10^{-4}]}{0.034}$ $= 1.18 \times 10^{-6}$ pK_a = –log $[1.18 \times 10^{-6}] = 5.9$ pK_a = 5.9 (to two significant figures)	• demonstrates substitution correctly performed **[1 mark]** • determines K_a = 1.2×10^{-6} **[1 mark]** • determine pK_a = 5.9 **[1 mark]**	Allow FT error for K_a. Do not penalise for incorrect decimal places/ significant figures.
	c)	Phenol red changes colour over a pH range because the molecular form (HIn(aq)) and ionic form (In^-(aq)) are different colours. When [HIn(aq)] = [In^-(aq)], the pH = pK_a and phenol red changes colour. When pH < pK_a, the [HIn(aq)] > [In^-(aq)] and phenol red turns yellow. When pH > pK_a, the [HIn(aq)] < [In^-(aq)] and phenol red turns red.	• indicates pH colour range is due to molecular form and ionic form being different colours **[1 mark]** • identifies phenol red changes colour when pH = pK_a **[1 mark]** • indicates when pH < pK_a equlibrium favours the molecular form (HIn), the solution is yellow. When pH > pK_a equilbrium favours the ionic form (In^-), the solution is red **[1 mark]**	
23	a)	i) Na(l) and Cl_2(g)	• provides Na(l) and Cl_2(g) **[1 mark]**	
		ii) H_2(g) and O_2(g)	• provides H_2(g) and O_2(g) **[1 mark]**	
	b)	In a dilute solution of aqueous sodium chloride, sodium ions, chloride ions, hydrogen ions, hydroxide ions and water molecules are present. The concentration and the *E*° value of the species create competition at the electrodes and affect the products formed. Na^+ and H^+ compete to be reduced at the cathode. The E^0 value for reducing H^+ is more positive; therefore, H^+ is preferentially reduced and H_2 gas is formed rather than Na metal. Cl^- and OH^- compete to be oxidised at the anode. As the concentration of Cl^- is low in a dilute NaCl solution, OH^- is preferentially oxidised and O_2 gas is produced rather than Cl_2 gas.	• identifes that Na^+, Cl^-, OH^-, H^+, and H_2O are present **[1 mark]** • identifies that concentration and *E*° values of the species affects products **[1 mark]** • identifies that H^+ is preferentially reduced, producing H_2 gas due to a more positive *E*° value **[1 mark]** • identifies that OH^- is preferentially oxidised, producing O_2 gas due to a higher concentration of ions **[1 mark]**	For H_2O, accept OH^- and H^+.

Q		Sample response	The response:	Notes
24	a)	As the temperature increases, the $[H_3O^+]$ increases. $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ Therefore, the equilibrium shifts towards the products. Increasing temperature shifts equilibrium in the endothermic direction, therefore the self-ionisation of water is endothermic.	• identifies $[H_3O^+]$ increases as temperature increases **[1 mark]** • identifies equilibrium shifts towards the products and the endothermic direction **[1 mark]** • determines self-ionisation of water is endothermic **[1 mark]**	Allow FT error for: – equilbrium shifts to the reactants – self-ionisation of water decreases.
	b)	pH $= -\log[H^+] = 6.63$ $[H^+] = 10^{-6.63}$ $= 2.34 \times 10^{-7}$ $K_w = [H^+][OH^-]$ $= (2.34 \times 10^{-7})^2$ $K_w = 5.48 \times 10^{-14}$ (to 3 significant figures)	• determines $[H^+] = 2.34 \times 10^{-7}$ **[1 mark]** • determines consequentially correct K_w **[1 mark]**	Allow FT error from $[H^+]$. Do not penalise for incorrect decimal places/significant figures.
25	a)	$N_2O_4(g) \rightleftharpoons 2NO_2(g)$	• provides $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ **[1 mark]**	
	b)	80 seconds	• identifies time as 80 **[1 mark]**	Accept values between 70 and 90 inclusive.

Q	Sample response	The response:	Notes
c)	 	• indicates that at 100 s concentration of N_2O_4 and NO_2 would halve **[1 mark]** • indicates that after 100 s concentration of N_2O_4 would decrease to a new equilibrium at a lower concentration **[1 mark]** • indicates that after 100 s concentration of NO_2 would increase to a new equilibrium at a higher concentration **[1 mark]**	
26	The peak in the IR spectrum at $1700–1750$ corresponds to a $C=O$ bond in either an aldehyde or a ketone. There is no stretch in the IR peak at $2720–3100$, therefore, the molecule is not an aldehyde and must be a ketone Fragment at m/z = 43 is $CH_3CH_2CH_2^+$ and $COCH_3^+$ Fragment at m/z = 71 is $CH_3CH_2CH_2CO^+$ Empirical formula = 86. This corresponds to the molecular mass shown on the mass spectrum. Therefore, the molecular formula is $C_5H_{10}O$. 	• identifies IR peak at $1700–1750$ corresponds to a $C=O$ bond in aldehyde or ketone **[1 mark]** • indicates that X is a ketone **[1 mark]** • identifies mass fragment at – 43 m/z as $CH_3CH_2CH_2^+$ and $COCH_3^+$ **OR** – 71 m/z as $CH_3CH_2CH_2CO^+$ **[1 mark]** • uses mass spectrum data to show that the molecular formula for X is $C_5H_{10}O$ **[1 mark]** • provides correct structural formula for pentan-2-one **[1 mark]**	

Q		Sample response	The response:	Notes
27	a)	Z	• provides Z **[1 mark]**	
	b)	Q^{2+}	• provides Q^{2+} **[1 mark]**	For Q^{2+} accept Q in $Q(NO_3)_2$
	c)	$Z(NO_3)_2$(aq) and A(s)	• provides $Z(NO_3)_2$(aq) and A(s) **[1 mark]**	For $Z(NO_3)_2$(aq), accept Z^{2+}(aq).
	d)	$Z^{2+} + 2e^- \rightleftharpoons Z$ $A^{2+} + 2e^- \rightleftharpoons A$ $X^{2+} + 2e^- \rightleftharpoons X$ $Q^{2+} + 2e^- \rightleftharpoons Q$ Z can reduce X^{2+}, Q^{2+} and A^{2+}, therefore it is the strongest reducing agent. X can only reduce Q^{2+} therefore it is the second weakest reducing agent. Q cannot reduce any metal ions, therefore it is the weakest reducing agent.	• provides half-equations in correct order **[1 mark]** • provides reasoning for – Z as strongest reducing agent **[1 mark]** – Q as weakest reducing agent **[1 mark]** – A as stronger reducing agent than X **[1 mark]**	

Paper 2: Short response

Question		Sample response	The response:	Notes
1	a)	Zinc is oxidised when Zn changes to Zn^{2+}. Copper is reduced when Cu^{2+} changes to Cu. Therefore, the reaction can be classified as redox as Zn is oxidised and Cu^{2+} is reduced.	• identifies that – zinc is oxidised **[1 mark]** – copper is reduced **[1 mark]** – reaction is redox **[1 mark]**	Acceptable responses are: – $Zn(s) \rightarrow Zn^{2+} + 2e^-$ – oxidation number of Zn increases from 0 to +2. Acceptable responses are: – $Cu^{2+} + 2e^- \rightarrow Cu(s)$ – oxidation number of Cu decreases from +2 to 0.

Question		Sample response	The response:	Notes
	b)	i) $4H^+(aq) + 2NO_3^-(aq) + 2e^- \rightarrow 2NO_2(g) + 2H_2O(l)$	• provides $2H^+(aq) + e^- \rightarrow H_2O(l)$ **[1 mark]** • provides $NO_3^-(aq) + e^- \rightarrow NO_2(g)$ **[1 mark]**	Acceptable response is $2H^+(aq) + NO_3^-(aq) + e^- \rightarrow NO_2(g) + H_2O(l)$
		ii) E^o_{red} = 0.46 + 0.34 = +0.80 V	• determines E^o_{red} = +0.80 V **[1 mark]**	
	c)	i) For hydrochloric acid: $E^o_{cell} = E^o_{red} - E^o_{ox}$ = +0.00 – (+0.34) = –0.34 Reaction is non-spontaneous, therefore HCl cannot dissolve Cu. For nitric acid: E^o_{cell} = +0.46 (positive), therefore the reaction is spontaneous. HNO_3 can dissolve Cu.	• determines E^o_{cell} for HCl equals –0.34 and E^o_{cell} for HNO_3 equals +0.46 V **[1 mark]** • determines reaction between Cu and HCl is not spontaneous and therefore Cu will not dissolve **[1 mark]** • indicates reaction between Cu and HNO_3 is spontaneous and therefore Cu will dissolve **[1 mark]**	Acceptable response is Cl^- is more negative, therefore stronger reducing and will be oxidised in preference to Cu.

Question		Sample response	The response:	Notes
		ii) Reduction: $4H^+(aq) + 2NO_3^-(aq) + 2e^- \rightarrow 2NO_2(g) + 2H_2O(l)$, $E^o = +0.80V$ or $H^+(aq) + 2e^- \rightarrow H_2(g)$, $E^o = 0.00$ V The E^o value for NO_3^- is more positive than $H^+(aq)$, therefore NO_3^- is a stronger oxidising agent. Therefore NO_3^- reduced in preference to H^+ and NO_2(g) formed	• identifies that, in HNO_3, $H^+(aq)$ and NO_3^- compete to be reduced **[1 mark]** • indicates that NO_3^- is stronger oxiding agent **[1 mark]** • determines NO_3^- is preferentially reduced therefore NO_2(g) formed **[1 mark]**	Acceptable response is NO_3^- is more positive than Cu, therefore stronger oxidising agent and can be reduced to oxidise Cu to $Cu^{2+}(aq)$.
2	a)	Esterification	• identifies the reaction as esterification **[1 mark]**	
	b)	$K_c = \frac{[C_9H_8O_4][C_2H_4O_2]}{[C_7H_6O_3][C_4H_6O_3]}$	• provides $\frac{[C_9H_8O_4][C_2H_4O_2]}{[C_7H_6O_3][C_4H_6O_3]}$ **[1 mark]**	
	c)	$K_c < 1$ The equilibrium lies towards the reactants, therefore, the concentration of the reactants is greater than the concentration of the products.	• identifies that equilibrium lies towards the reactants **[1 mark]** • identifies that reactants > products **[1 mark]**	
	d)	Molar mass of aspirin = (12.01 x 9) + (16.00 x 4) + 8.08 = 180.17 g Moles of aspirin produced = 0.5 g / 180.17 g = 2.78×10^{-3} mol	• determines molar mass of aspirin is 180 g **[1 mark]**	Allow FT error from $n_{aspirin}$.

Question		Sample response	The response:	Notes
		Ratio 1:1 45.0% efficient Moles of salicylic acid = $\frac{2.78 \times 10^{-3}}{0.45} = 6.17 \times 10^{-3}$ mol Mass of salicylic acid = $6.17 \times 10^{-3} \times 138.13 = 0.852$ g = Mass = 852 mg (to three significant figures)	• determines $n_{aspirin}$ = 2.78×10^{-3} **[1 mark]** • determines n_{acid} **[1 mark]** • determines mass **[1 mark]**	Do not penalise for incorrect decimal places/ significant figures.
	e)	An increase in K_c means that equilibrium has shifted towards the products. An increase in temperature shifts equilibrium in the endothermic direction. Le Châtelier's principle means that when a system at equilibrium experiences an increase in temperature, the equilibrium shifts in the endothermic direction to decrease the temperature. As the forward reaction increases, the system as written must be endothermic.	• identifies that increased temperature means increased products **[1 mark]** • identifies that equilibrium has shifted in the endothermic direction **[1 mark]** • uses Le Châtelier's principle to explain a shift in equilibrium for an increase in temperature **[1 mark]** • identifies the forward reaction as endothermic **[1 mark]**	Allow FT error from an increase in temperature shifting equilbrium towards reactants.
3	a)	$C_2H_{12}O_6(aq) \xrightarrow{\text{yeast}} 2CH_3CH_2OH(aq) + 2CO_2(g)$	• provides correct reactants and products **[1 mark]** • correctly balances the equation **[1 mark]** • indicates that yeast is required as a catalyst **[1 mark]**	

Question		Sample response	The response:	Notes
	b)	Molar mass (ethanol) = 46.08 g Molar mass (glucose) = 180.18 g atom economy = $\frac{2\times46.08}{180.18}\times 100$ atom economy = $\frac{2\times46.08}{180.18}\times 100 = 51.148\ \% \approx 51\%$ Atom economy = 51%	• shows substitution correctly performed **[1 mark]** • determines atom economy **[1 mark]**	Allow FT error from incorrect molar masses. Do not penalise for incorrect decimal places/significant figures.
	c)	Hydration atom economy = 100% Fermentation atom economy = 51% Therefore, production of ethene by hydration is greener.	• determines atom economy for hydration reaction is 100% **[1 mark]** • identifies that hydration reaction is greener **[1 mark]**	
	d)	Use of renewable feedstocks Design for energy efficiency	• provides use of renewable feedstocks **[1 mark]** • provides design for energy efficiency **[1 mark]**	
4	a)	unsaturated	• provides unsaturated **[1 mark]**	
	b)	2–methylpropene	• provides 2-methylpropene **[1 mark]**	

Question		Sample response	The response:	Notes
	c)	$2(CH_3)_2C = CH_2 + 2H_2O \xrightarrow{H^+} (CH_3)_3C(OH) + (CH_3)_2CHCH_2OH$	• identifies $(CH_3)_3C(OH)$ as a product **[1 mark]** • identifies $(CH_3)_2CHCH_2OH$ as a product **[1 mark]**	Accept condensed or expanded structural formula.
	d)	Major product (Markovnikov's rule) $(CH_3)_3C(OH)$	• identifies tertiary alcohol as the major product produced **[1 mark]**	
	e)	$(CH_3)_2CHCH_2OH$ is a primary alcohol and $(CH_3)_3C(OH)$ is a tertiary alcohol. Therefore, they have different boiling points. Experimental technique: distillation The hydroxyl group of a primary alcohol is more exposed than it is in a tertiary alcohol, therefore is easier for the primary alcohol to form more hydrogen bonds. Therefore, the intermolecular forces are stronger and the boiling point higher for $(CH_3)_2CHCH_2OH$.	• identifies the products are primary and tertiary alcohols **[1 mark]** • identifies boiling point as physical property that can be used to separate the alcohols **[1 mark]** • identifies distillation as a suitable experimental technique **[1 mark]** • links the position of the hydroxyl group in the primary alcohol to increased hydrogen bonding **[1 mark]** • indicates that stronger intermolecular forces result in a higher boiling point for the primary alcohol **[1 mark]**	

Question		Sample response	The response:	Notes
5	a)	ethanamine	• provides ethanamine **[1 mark]**	
	b)	H_2O(l) $C_2H_5NH_3^+$(aq)	• provides H_2O(l) **[1 mark]** • provides $C_2H_5NH_3^+$(aq) **[1 mark]**	
	c)	The hydrochloric acid (H^+) reacts with the OH^- ions and decreases their concentration. According to Le Châtelier's principle, this will make the equilibrium position shift to the right to counteract decrease in OH^- (products). Therefore, the concentration of A will decrease.	• indicates that $[OH^-]$ will decrease **[1 mark]** • indicates that the equilibrium will shift right **[1 mark]** • indicates that A will decrease **[1 mark]**	

Question		Sample response	The response:	Notes
	d)	$[CH_3CH_2NH_2] = 2.0 - x \approx 2.0$ as $2.0 \gg K_b$ Let $x = [C_2H_5NH_3^+] = [OH^-]$ $K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[CH_3CH_2NH_2]}$ $5.6 \times 10^{-4} = \frac{[x][x]}{[2.0]} = \frac{x^2}{2.0}$ $x^2 = 1.12 \times 10^{-3}$ $x = 0.033466 = [OH^-]$ $pOH = -\log [OH^-] = 1.475 \approx 1.5$ $pH = 14 - 1.5 = 12.5$ pH = 12.5 (to 1 decimal place)	• indicates assumption to support $[CH_3CH_2NH_2] \approx 2.0$ **[1 mark]** • indicates $[C_2H_5NH_3^+] = [OH^-]$ **[1 mark]** • shows substitution correctly performed **[1 mark]** • determines $[OH^-] = 3.35 \times 10^{-2}$ **[1 mark]** • determines pOH **[1 mark]** • determines pH **[1 mark]**	Accept ICE table. Allow FT error from $[OH^-]$. Do not penalise for incorrect decimal places/significant figures.

Question		Sample response	The response:	Notes
	e)	Heat CH_3Br with KCN under reflux to produce CH_3CN and KBr $CH_3CN(aq) + 2H_2(g) \xrightarrow{\text{heat with Ni catalyst}} CH_3CH_2NH_2(aq)$	• indicates CH_3Br reacts with KCN to produce KH_3CN and KBr **[1 mark]** • identifies reaction is heated under reflux in ethanol **[1 mark]** • indicates CH_3CN reacts with $H_2(g)$ to produce $CH_3CH_2NH_2$ **[1 mark]** • indicates heat and Ni/Pt/Pd catalyst required **[1 mark]** • represents one of the reactions as a balanced chemical equation **[1 mark]**	Also accept as balanced equation: $CH_3Br(aq) \xrightarrow{\text{heat under reflux with KCN (ethanol)}} CH_3CN(aq) + KBr(aq)$