Chemistry marking guide and solution

External assessment 2021

Combination response (108 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.

Purpose

This document consists of a marking guide.

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.

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.

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

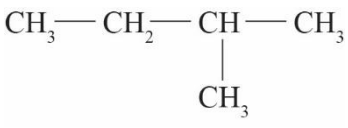
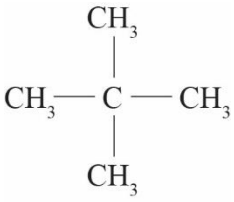
Allow FT mark/s — refers to 'follow through', where an error in the prior section of working is used later in the response, a mark (or marks) for the rest of the response can still be awarded so long as it still demonstrates the correct conceptual understanding or skill in the rest of the response.

Marking guide

Paper 1: Multiple choice

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

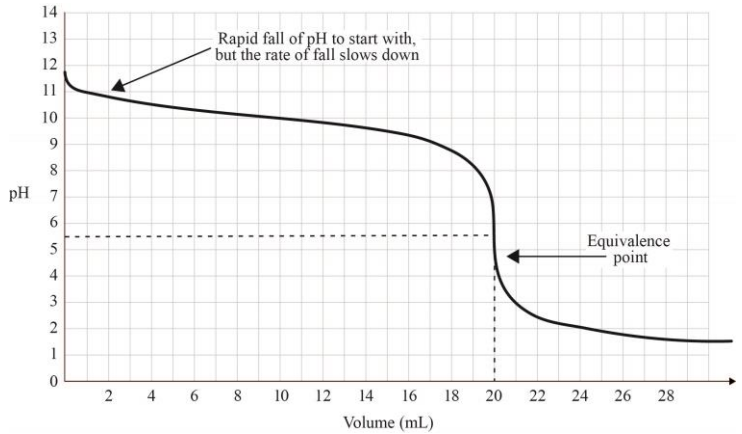
Paper 1: Short response

Q	Sample response	The response:	Notes
21	$[OH^-] = 2 \times [Ba(OH)_2] = 2 \times 0.1 = 0.2$ M $pOH = -\log[OH^-] = -\log 0.2 = 0.7$ $pH = 14 - pOH = 14 - 0.7 = 13.3$ $pH = 13.3$ (to one decimal place)	• correctly determines $[OH^-] = 0.2$ M **[1 mark]** • determines $pOH = 0.7$ **[1 mark]** • determines $pH = 13.3$ **[1 mark]**	Allow FT error for pOH and pH from $OH^- = 0.1$ M only. Do not penalise for incorrect decimal places/significant figures.
22a)	 IUPAC name: 2-methylbutane	• correctly determines structural formula for 2-methylbutane **[1 mark]** • determines name **[1 mark]**	Allow FT error for name. Isomers can be given in either order.
22b)	 IUPAC name: 2,2-dimethylpropane	• correctly determines structural formula for 2,2-dimethylpropane **[1 mark]** • determines name **[1 mark]**	Allow FT error for name.
23a)	aspartic acid and phenylalanine	• correctly identifies aspartic acid and phenylalanine **[1 mark]**	For *aspartic acid*, accept *Asp*. For *phenylalanine*, accept *Phe*. Accept correctly drawn diagrams.

Q	Sample response	The response:	Notes
23b)	Isoleucine is a non-polar amino acid. The distance travelled by Spot A is similar to the distance travelled by isoleucine; therefore, Spot A is also non-polar. Spot A is phenylalanine because it is a non-polar amino acid.	• indicates that isoleucine is non-polar **[1 mark]** • indicates that Spot A is non-polar and travels a similar distance to isoleucine **[1 mark]** • determines that Spot A is phenylalanine **[1 mark]**	Acceptable response indicates Spot A has a similar R_f value (distance travelled) as isoleucine and is therefore non-polar.
23c)	To allow the distance travelled by the separated amino acids to be compared to control amino acids.	• indicates that separated amino acids can be compared to control amino acids **[1 mark]**	Acceptable response indicates R_f value for separated amino acids can be compared to R_f values for control amino acids.
24a)	MnO_4^- (aq) (+1.51 V) is a stronger oxidising agent than Cu^{2+}(aq) (+0.34 V) because it has a more positive standard potential. MnO_4^- (aq) is preferentially reduced and gains electrons from Cu(s), which is oxidised. Therefore, electrons flow from Cu electrode to Pt electrode.	• correctly identifies MnO_4^- as the stronger oxidising agent **[1 mark]** • correctly identifies that MnO_4^- gains electrons **[1 mark]** • determines that electrons flow from Cu to Pt electrode **[1 mark]**	Acceptable responses are: – MnO_4^- is reduced – Cu is oxidised – Cu loses electrons. Acceptable responses are that electrons flow from: – Cu electrode to Pt electrode – Cu(s) to MnO_4^- (aq).
24b)	$E^o_{cell} = E^o_{red} - E^o_{ox} = +1.51 - (+0.34) =$ 1.17 V	• determines that the standard reduction potential is 1.17 **[1 mark]**	Do not penalise for incorrect decimal places/significant figures.

Q	Sample response	The response:	Notes
24c)	Cu^{2+}(aq) concentration will increase and the solution will become darker. MnO_4^-(aq) concentration will decrease and the solution will become lighter.	• predicts that the Cu^{2+}(aq) solution will become darker **[1 mark]** • predicts that the MnO_4^-(aq) solution will become lighter **[1 mark]**	Acceptable responses are: – Cu electrode will become smaller – Cu^{2+} solution will become darker – MnO_4^- solution will become lighter – MnO_4^- solution will become colourless. Allow FT error from 24a).
25a)	Adding $AgNO_3$ produces Ag^+ ions, which react with Cl^- ions to form insoluble $AgCl$, therefore decreasing the concentration of Cl^- ions. Equilibrium shifts to reactants (left) to counteract the decrease by increasing the concentration of Cl^- ions. The blue solution will become lighter (pinker).	• correctly identifies that Cl^- decreases **[1 mark]** • identifies that equilibrium shifts to left (reactants) to counteract the change **[1 mark]** • identifies that the blue solution becomes lighter **[1 mark]**	Allow FT error for equilibrium shift and change in solution from Cl^- increases. Acceptable responses may be: – solution becomes pinker – solution decreases in intensity – or other responses consistent with a reasonable understanding. Do not penalise students who mention the formation of a white precipitate, i.e. AgCl.
25b)	Adding heat shifts equilibrium towards the endothermic direction and produces $CoCl_4^{2-}$ ions, which are blue. Therefore, the forward reaction is endothermic.	• identifies that the forward reaction has been favoured **[1 mark]** • determines that the forward reaction is endothermic **[1 mark]**	

Q	Sample response	The response:	Notes
26a)	XY is the product.	• identifies XY as the product **[1 mark]**	
26b)	$K_c = \frac{[XY]^2}{[X][Y]} = \frac{3^2}{2 \times 2.5} = 1.8$ (to two significant figures)	• indicates correct substitution **[1 mark]** • determines K_c = 1.8 **[1 mark]**	Allow FT error for K_c. Do not penalise for incorrect decimal places/significant figures.
26c)	$K_c > 1$. Therefore, equilibrium favours the products.	• identifies $K_c > 1$ **[1 mark]** • concludes that equilibrium favours products **[1 mark]**	Allow FT error for K_c.
27a)	3 × (+1) + As + 3 × (–2) = 0 3 + As – 6 = 0 As – 3 = 0 As = +3	• provides +3 **[1 mark]**	Do not accept 3 or 3+. Do not penalise for incorrect decimal places/significant figures.
27b)	Balanced oxidation half-equation: $H_3AsO_3 + H_2O \rightarrow H_3AsO_4 + 2H^+ + 2e^-$ Balanced reduction half-equation: $NO_3^- + 2H^+ + e^- \rightarrow NO_2 + H_2O$ Multiply by 2: $2NO_3^- + 4H^+ + 2e^- \rightarrow 2NO_2 + 2H_2O$ Balanced redox equation: $H_3AsO_3 + 2NO_3^- + 2H^+ \rightarrow H_3AsO_4 + 2NO_2 + H_2O$	• provides balanced oxidation half-equation **[1 mark]** • provides balanced reduction half-equation **[1 mark]** • uses multiplication factor to balance electrons **[1 mark]** • determines balanced redox equation **[1 mark]**	Allow FT error for multiplication factor and balanced equation. Award full marks for correctly balanced equation without full working.

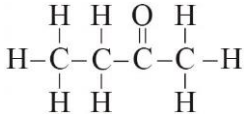
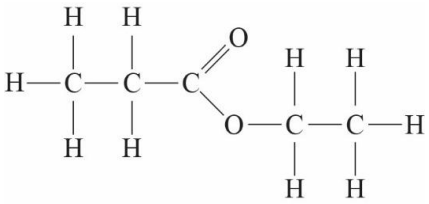
Q	Sample response	The response:	Notes
27c)	NO_3^-	• provides NO_3^- **[1 mark]**	Acceptable responses are: – nitrogen – N
28		• sketches an S-shaped curve with – the half equivalence point at pH 10 and 10 mL **[1 mark]** – the equivalence point < pH 7 at 20 mL **[1 mark]** – initial pH between 10 and 12, and the final pH between 3 and 1 (but not below 1) **[1 mark]**	

Paper 2: Short response

Q	Sample response	The response:	Notes
1a)	Acid: H_3PO_4(aq) Conjugate base: $H_2PO_4^-$(aq) Reasoning: H_3PO_4 is the strongest Brønsted-Lowry acid because it has the largest K_a value. H_3PO_4(aq) donates a proton and $H_2PO_4^-$(aq) accepts a proton.	• identifies H_3PO_4 as the acid and $H_2PO_4^-$ as the conjugate base **[1 mark]** • identifies H_3PO_4 as the strongest acid due to having the largest K_a **[1 mark]** • identifies acid as the H^+ donor and base as the H^+ acceptor **[1 mark]**	For H^+, accept *proton*. Do not accept *hydrogen donor* or *acceptor*.
1b)	$H_2PO_4^-$(aq) is amphiprotic, because it can donate or accept a proton and therefore act as a Brønsted-Lowry acid or a base.	• identifies an amphiprotic species **[1 mark]** • identifies that this species can accept or donate protons **[1 mark]**	Acceptable amphiprotic species are: – $H_2PO_4^-$ – HPO_4^{2-}
1c)	$K_w = K_a \times K_b$ $K_b = \frac{K_w}{K_a} = \frac{10^{-14}}{4.5 \times 10^{-13}} = 2.2 \times 10^{-2}$	• correctly substitutes into formula **[1 mark]** • determines $K_b = 2.2 \times 10^{-2}$ **[1 mark]**	Allow FT error from substitution. Do not penalise for incorrect decimal places/significant figures.

Q	Sample response	The response:	Notes
1d)	As K_a is very small, the dissociation of $H_2PO_4^- \rightarrow HPO_4^{2-}$ is very very small. Assume $0.05 >> x$, therefore $0.05 - x \approx 0.05$ At equilibrium $[H_2PO_4^-] = 0.05 - x = 0.05$ Let $x = [H^+] = [HPO_4^{2-}]$ $6.5 \times 10^{-8} = \frac{[x][x]}{[0.05-x]} \approx \frac{x^2}{0.05}$ $x^2 = 0.05 \times 6.5 \times 10^{-8}$ $x = \sqrt{3.25 \times 10^{-9}}$ $x = 5.70 \times 10^{-5}$ mol $L^{-1} = [H^+]$ pH = –log 5.70×10^{-5} pH = 4.2 (to one decimal place)	• indicates assumption $0.05 - x \approx 0.05$ **[1 mark]** • shows substitution correctly performed **[1 mark]** • correctly determines $[H^+] = 5.70 \times 10^{-5}$ **[1 mark]** • determines pH = 4.2 **[1 mark]**	Allow FT error from incorrect substitution of K_a. Accept ICE table or other valid working. Allow FT error from $[H^+]$. Do not penalise for incorrect decimal places/significant figures.
2a)	i) carboxylic acid monomer  ii) alcohol monomer $HO-CH_2-CH_2-OH$	• provides the correct structural formula for – benzene-1,4-dicarboxylic acid (terephthalic acid) **[1 mark]** – ethane-1,2-diol (ethylene glycol) **[1 mark]**	
2b)	condensation	• determines polymerisation as condensation **[1 mark]**	For *condensation*, accept: – *elimination* – *esterification*.
2c)	Ester	• identifies ester as the functional group **[1 mark]**	Also accept: – RCOOR[1] - carboalkoxy.
2d)	addition	• determines polymerisation as addition **[1 mark]**	

Q	Sample response	The response:	Notes
2e)	Structural features Isotactic and syntactic — both have regular arrangement methyl groups. Syntactic has methyl groups on the opposite side of the polymer chain, while isotactic has methyl groups on the same side of the chain. Properties Isotactic — chains can pack closer together, resulting in greater intermolecular forces. Isotactic PP is therefore stronger than syntactic PP.	• identifies regular arrangement methyl groups **[1 mark]** • identifies methyl groups on the opposite side of the chain for syntactic and same side of the chain for isotactic PP **[1 mark]** • indicates that isotactic chains can pack closer together **[1 mark]** • indicates increased intermolecular forces for isotactic PP **[1 mark]** • indicates increased strength for isotactic PP **[1 mark]**	For *intermolecular forces*, accept *dispersion forces*.

Q	Sample response	The response:	Notes
3a)	Compound D is 1-butene. Undergoes addition reaction with Br_2(aq).	• identifies Compound D as 1-butene **[1 mark]** • indicates that Compound D undergoes addition **[1 mark]**	For *1-butene*, accept *but-1-ene*.
3b)	$CH_2CHCH_2CH_3 + Br_2 \rightarrow CH_2(Br)CH(Br)CH_2CH_3$ IUPAC name: 1,2-dibromobutane	• indicates balanced equation with the correct structural formula for reactants and products **[1 mark]** • correctly names 1,2-dibromobutane **[1 mark]**	Allow FT error from equation.
3c)	Compound C is butane. It can't be oxidised by potassium manganate(VII) or undergo an addition reaction with bromine water. Therefore, Compound C is unreactive because it's saturated.	• identifies Compound C as butane **[1 mark]** • identifies that Compound C cannot be oxidised **[1 mark]** • concludes that Compound C is unreactive and saturated **[1 mark]**	For *saturated*, accept *contains only single bonds*. Acceptable response is to identify that Compound C cannot undergo an addition reaction.
3d)		• provides correct structural formula for butanone for Compound Y **[1 mark]**	Acceptable response is Compound Y = $CH_3COCH_2CH_3$
3e)	2-butanol	• identifies Compound B as 2-butanol **[1 mark]**	For *2-butanol*, accept *butan-2-ol*.
3f)		• provides correct structural formula for ethyl propanoate for Compound Z **[1 mark]**	Acceptable response is Compound Z = $CH_3CH_2COOCH_2CH_3$
3g)	IUPAC name: ethyl propanoate	• correctly names ethyl propanoate **[1 mark]**	

Q	Sample response	The response:	Notes
4a)	$K_c = \frac{[HI]^2}{[H_2]\times[I_2]}$	• provides $K_c = \frac{[HI]^2}{[H_2]\times[I_2]}$ **[1 mark]**	
4b)	Change in $[H_2]$= $[I_2]$ = $\frac{9.30\times10^{-4}\text{ mol}}{\text{L}} \times \frac{1\text{ mol H}^2}{2\text{ mol HI}} = 4.65 \times 10^{-4}$ M $[H_2]_{eq} = 5.00 \times 10^{-4} - 4.65 \times 10^{-4} = 3.50 \times 10^{-5}$ M $[I_2]_{eq} = 1.0 \times 10^{-3} - 4.65 \times 10^{-4} = 5.35 \times 10^{-4}$ M $K_c = \frac{(9.30\times10^{-4})^2}{3.50\times10^{-5}\times5.35\times10^{-4}}$ = 46.2 K_c = 46.2 (to three significant figures)	• correctly determines change in $[H_2]$ = $[I_2]$ = 4.65×10^{-4} **[1 mark]** • determines $[H_2]_{eq} = 3.50 \times 10^{-5}$ **[1 mark]** • determines $[I_2]_{eq} = 5.35 \times 10^{-4}$ **[1 mark]** • shows substitution correctly performed **[1 mark]** • determines K_c = 46.2 **[1 mark]**	Allow FT error for $[H_2]_{eq}$. Allow FT error for $[I_2]_{eq}$. Allow FT error from Question 1a). Do not penalise for incorrect decimal places/significant figures.
4c)	A catalyst will speed up both the forward and the reverse reactions. Therefore, the position of the equilibrium will not change. Therefore, there will be no change in the value of the equilibrium constant, K_c.	• identifies that a catalyst speeds up both the forward and reverse reactions **[1 mark]** • identifies that a catalyst has no effect on the position of the equilibrium **[1 mark]** • determines that a catalyst has no effect on the K_c value **[1 mark]**	

Q	Sample response	The response:	Notes
5a)	$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$	• correctly identifies the balanced equation **[1 mark]**	
5b)	Fe (iron). Fe loses two electrons to form Fe^{2+}(aq).	• correctly identifies that Fe (iron) is oxidised **[1 mark]** • indicates that Fe loses electrons to form Fe^{2+} **[1 mark]**	Acceptable responses are: – iron – Fe. Acceptable response is oxidation number of Fe increases from 0 to +2.
5c)	$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$	• correctly balances $8H^+ + 4H_2O$ in equation **[1 mark]** • correctly balances $5Fe^{2+} + 5Fe^{3+}$ in equation **[1 mark]**	
5d)	Moles MnO_4^-(aq) reacted = $0.01640 \times 0.05 = 8.2 \times 10^{-4}$ $MnO_4^- : 5Fe^{2+}$ Moles of Fe^{2+} in 25.00 mL = $5 \times (8.2 \times 10^{-4}) = 4.1 \times 10^{-3}$ mol Moles of Fe^{2+} in 500.0 mL = moles Fe in sample $= 4.1 \times 10^{-3} \times 0.5000 \div 0.025 = 0.082 = 8.2 \times 10^{-2}$ mol Mass Fe dissolved = 0.082×55.85 = 4.6 g (4.5797) % Fe in iron ore = $4.6 \div 8.00$ = 57.2% (57.24625) Percentage Fe in ore sample = 57.2% (to one decimal place)	• correctly determines $n MnO_4^- = 8.2 \times 10^{-4}$ **[1 mark]** • determines $n Fe^{2+} = 4.1 \times 10^{-3}$ **[1 mark]** • determines $n Fe = 8.2 \times 10^{-2}$ **[1 mark]** • determines mass Fe = 4.6 g **[1 mark]** • determines Fe = 57.2% **[1 mark]**	Allow FT error from incorrect mole ratio. Acceptable response is mass Fe = 4.5797 g. Acceptable responses are: – % Fe = 57.2 – % Fe = 57.3