2023 ASSESSMENT REPORT

CHM415115 CHEMISTRY

Section A

Criterion 5

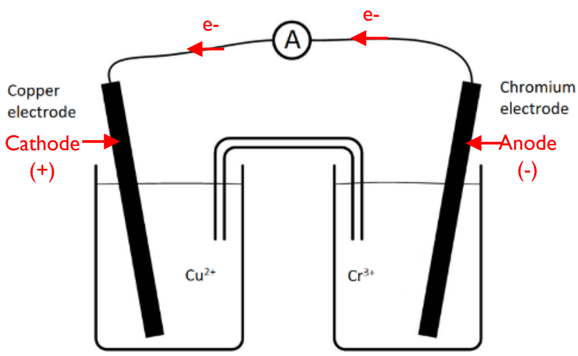
This section was straightforward for most students and potentially a little short.

It is noted that spontaneity can be explained using relative oxidising and reducing strengths of species present, not just a positive E°_{cell} value.

Half-equations are beneficial in any explanatory response to support reasoning, even if they are not specifically requested.

Question	Sample answer	Marks	Comments / considerations for 2023 exam
1 a)	V^{3+} : +3 VO_2^+ : +5 V_2O_4 : +4 NH_4VO_3 : +5	1 1 1 1	-1 if + sign was omitted
1 b)	V^{3+} is the strongest reducing agent. V^{3+} has the lowest/least positive oxidation number and therefore the greatest capacity to be oxidised and increase its oxidation state.	0.5 1.5	
1 c)	Vanadium is oxidized. Vanadium increases its oxidation state from +4 in V_2O_4 to +5 in V_2O_5.	1 1	
1 d)	$V^{3+}_{(aq)} + H_2O_{(l)} \rightarrow VO^{2+}_{(aq)} + 2H^+_{(aq)} + e^-$ (x3) $NO_3^-{}_{(aq)} + 4H^+_{(aq} + 3e^- \rightarrow NO_{(g)} + 2H_2O_{(l)}$ Total: $3V^{3+}_{(aq)} + H_2O_{(l)} + NO_3^-{}_{(aq)} \rightarrow 3VO^{2+}_{(aq)} + 2H^+_{(aq)} + NO_{(g)}$	1 1 1 1	Mark 3 allocated for x3 multiplier

TASMANIAN ASSESSMENT, STANDARDS & CERTIFICATION

Question	Sample answer	Marks	Comments / considerations for 2023 exam
2 a)		1 (e-) 1 (electrodes) 1 (polarity)	
2 b)	At the anode, the chromium metal would start oxidising, producing more Cr^{3+} ions in solution, in accordance with the equation $Cr_{(s)} \longrightarrow Cr^{3+}_{(aq)} + 3e^-$. Therefore, the intensity of the green solution increased and pitting of the anode observed. At the cathode, the reduction of copper(II) ions to copper metal occurred: $Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$. As $[Cu^{2+}]$ decreased, the saturation of the blue coloured solution would decrease and additional copper would form on the electrode.	2 (half-equations x2) 2 (descriptions of observation in each half-cell x 2)	Change in colour saturation for both half-cells had to be mentioned for full marks
2 c)	+0.74 + 0.34 = 1.08 V	1	
2 d)	Potassium nitrate	1	Other reasonable answers acceptable
2 e)	Copper metal is the stronger reducer and hence, becomes the anode and oxidises to copper(II) ions according to $Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$ E^0 = -0.34 V. The platinum electrode hence becomes the cathode where the reduction of iron(III) ions to iron(II) ions ocurrs in accordance with Fe3+⟶Fe2++e- E0 = +0.77 V The initial cell emf decreases to 0.43 V.	2 (explanation of new anode and cathode) 1 (new cell EMF)	

<table>
<tr><th>Question</th><th>Sample answer</th><th>Marks</th><th>Comments / considerations for 2023 exam</th></tr>
<tr><td>3 a)</td><td>
<table>
<tr><th rowspan="2">Solid metal</th><th colspan="3">Aqueous solutions</th></tr>
<tr><th>Tin(II) nitrate</th><th>Iron(III) nitrate</th><th>Zinc nitrate</th></tr>
<tr><td>Nickel</td><td>Y</td><td>Y</td><td>N</td></tr>
<tr><td>Copper</td><td>N</td><td>Y</td><td>N</td></tr>
<tr><td>Lead</td><td>N</td><td>Y</td><td>N</td></tr>
</table>
</td><td>1 mark per column</td><td></td></tr>
<tr><td>3 b)</td><td>As the zinc is the stronger reducer, the zinc metal is oxidised to aqueous Zn^{2+} ions by Fe^{3+} ions, which are reduced to green Fe^{2+}. Therefore, there is an initial colour change of the solution from orange (Fe^{3+}) to green as [Fe^{2+}] increases.

Assuming zinc is in excess, as the Fe^{3+} concentration decreases, over time the Fe^{2+} becomes the strongest oxidiser present and would continue to oxidise zinc. Solid Fe is eventually produced: $Fe^{2+} + 2e^- \rightarrow Fe$.</td><td>2 (explanation of reaction & colour observation)

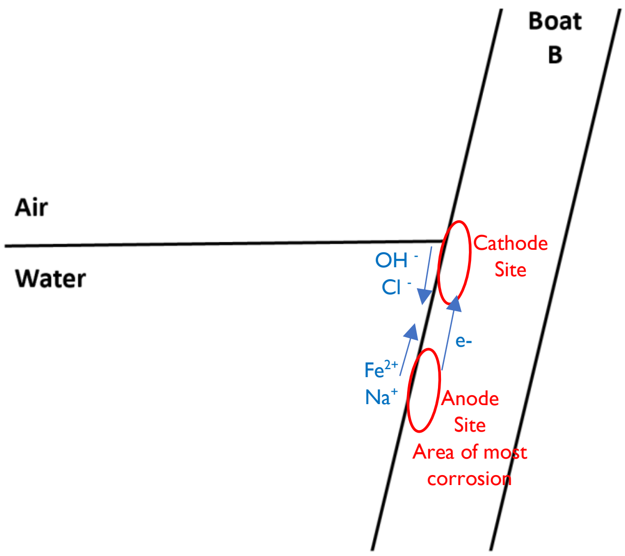
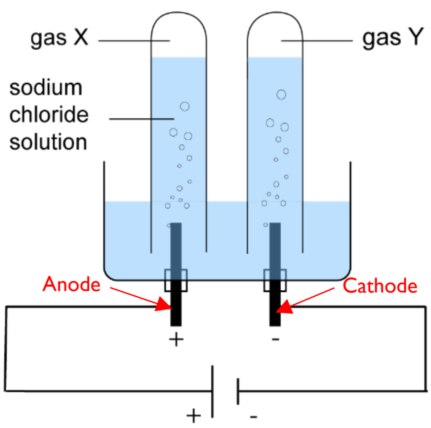
1</td><td></td></tr>
<tr><td>4 a) i.</td><td>B, A, C</td><td>1</td><td></td></tr>
<tr><td>4 a) ii.</td><td>Boat B would corrode / oxidise ($Fe_{(s)} \longrightarrow Fe^{2+} + e^-$) fastest. At the water line, the reduction of oxygen in the presence of water can happen at the cathode, $O_{2(g)} + 2H_2O_{(l)} + 4e^- \longrightarrow 4OH^-_{(aq)}$.

The saltwater has a high ion concentration, acting as an electrolyte to carry charge in the water to complete the circuit, accelerating corrosion.

Boat A would corrode next fastest since there is the same availability of oxygen, but freshwater has lower ion concentration. Boat C would be the slowest due to the limited concentration of oxygen underwater for the reaction at the cathode.</td><td>1 (Explanation of order)

1 (Explanation of salt in increased corrosion rate)

1 (Role of oxygen in the presence of water in reduction ½ equation)</td><td>½ equations required</td></tr>
</table>

Question	Sample answer	Marks	Comments / considerations for 2023 exam
4 b)		1 (correct location of cathode and anode site) 1 (correct flow of electrons and ions)	-0.5 if Fe^{2+} and OH^- were not specified
4 c)	The zinc metal is a strongest reducer than iron and therefore acts as a sacrificial anode and is preferentially oxidised: $Zn_{(s)} \rightarrow Zn^{2+} + 2e^-$. The iron therefore becomes the cathode where $O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$ occurs, preventing the hull from corroding.	1.5 (explanation) 0.5 (stating Fe becomes the cathode)	For full marks Zn being a sacrificial anode must be included. Include ½ equations
5 a)		1	
5 b)	Gas X is chlorine gas produced through the half-equation: $2Cl^-_{(aq)} \longrightarrow Cl_{2(g)} + 2e^-$ Gas Y is hydrogen gas produced through the half-equation: $2H_2O_{(l)} + 2e^- \longrightarrow 2OH^-_{(aq)} + H_{2(g)}$	1 1	Half-equation and the gaseous product named for full marks

Question	Sample answer	Marks	Comments / considerations for 2023 exam
5 c)	The reaction at the cathode will remain the same. Rather than producing chlorine gas at the anode, oxygen gas and hydrogen ions will be produced in accordance with $2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$	0.5 1.5	Half-equation required here. New E° value not required for full marks
5 d)	Solid copper would be the strongest reducer and thus would be oxidised at the anode, $Cu_{(s)} \rightarrow Cu^{2+} + 2e^-$, producing blue Cu^{2+} ions. No change would be observed at the cathode.	1 (explanation of anodic product) 0.5 (colour change) 0.5 (no change to cathodic products)	With half-equation

Section B

Criterion 6

This section was well answered by the vast majority of students with dozens achieving scores of 40 or more marks out of a possible 45.

Question 6 feedback

a. Most students recognised that the rate of the reaction decreased over time and attributed this to a decrease in the collision frequency as reactants were used up. A significant number of students incorrectly assumed that the reaction went to equilibrium when the volume levelled out. Relatively few recognised that the Mg powder was all used up.

   Markers were concerned with the number of answers that described the variation in the concentration of magnesium as if it was in solution. Another common error was to assume that the excess reagent had all been used up.

b. Students were expected to outline at least two changes to conditions. Possible answers included decreasing the mass of magnesium to half of a gram, reducing the concentration of hydrochloric acid, using a lower temperature, or chunks of magnesium instead of the powder.

   They also needed to relate at least one of these changes to shape of the Reaction 2 graph which showed that about half as much product was made and the lower gradient indicated a slower initial reaction rate even though the reaction finished slightly earlier than Reaction 1.

   A few students thought that as the time was shorter the rate was faster so did not understand the concept of reaction rate.

Question 7 feedback

a. Most students drew successful curves which included reactants on the left and products on the right of the curve with arrows indicating the activation energy and change in enthalpy with appropriate units.

   Students shouldn't be starting with reactants at H = 0 kJ despite this being common practice in the past.

b. Most students correctly identified the bonds broken and the bonds made but only half showed correct working to get the correct answer.

   Frequent errors included getting the signs wrong for energy consumed or released or missing the change in enthalpy from calculations.

c.

   i) Almost half of the students drew curves corresponding to a higher temperature instead of a lower activation energy.

   ii) Then went on to explain how a catalyst lowers the activation energy.

   Students should note that the frequency of collisions was unchanged but the frequency of effective collisions increased. Note: MBD is not an accepted abbreviation.

Question 8 feedback

a. Less than half of students identified that water in beaker 1 would cool and beaker 2 would warm.

   Often the question was mis-read and endothermic / exothermic were given as answers.

b. Most students correctly identified which reaction was endothermic and which exothermic but a minority commented on the relative strength of bonds in the reactants and products. Those who discussed bond energies rather than bond strength received part marks.

Question 9 feedback

a. Most students used LCP to explain that an increase in [CO_2] resulted in an increase in the concentration of [H_2CO_3] but relatively few explained how the acid dissociated to produce $H^+_{(aq)}$ increasing the acidity of the ocean.

b. Nil.

c. Nil.

d. Most students correctly described Bronsted-Lowry (BL) theory but less than half could show how bicarbonate ions acted as both a BL acid or a BL base. A few students suggested that $CO_3^{2-}{}_{(aq)}$ could contribute protons.

Question 10 feedback

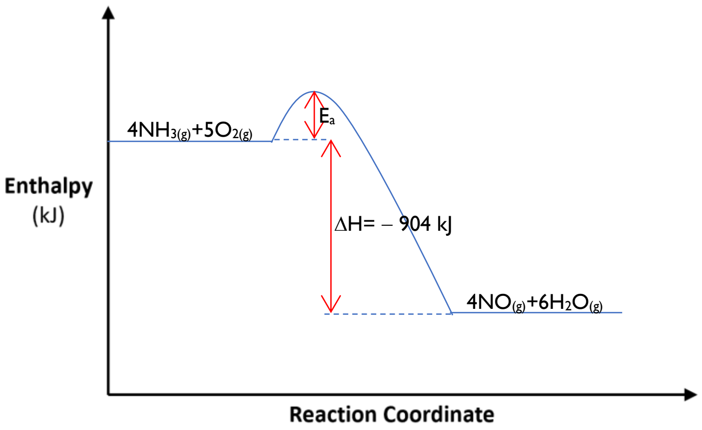
a. Nil.

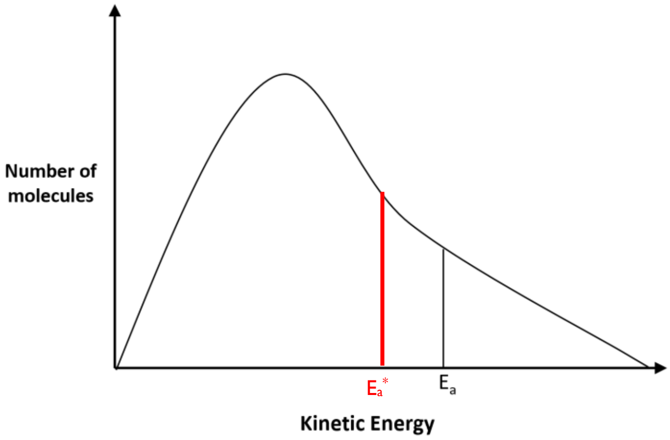
b. Nil.

c. Very few students got all six boxes correct.

d. Most students recognised that the temperature would need to decrease and the pressure increase to get the maximum yield. A significant number recognised that if the temperature was too low that the reaction might stop altogether and that a compromise might be needed to produce the yield in a reasonable time.

Question	Sample answer	Marks	Comments / considerations for 2023 exam
6 a)	At the start of the reaction the reaction is fast as there is a high concentration of H^+ ions and Mg atoms and therefore there are frequent collisions, resulting in a high rate of effective collisions. As the reactions proceeds the concentrations of the reactants decreases, resulting in less frequent collisions and a slower reaction rate. Eventually, the magnesium is used up and the reaction stops.	1 1 1	- ½ mark for not referring to frequency OR collisions per unit time
6 b)	Reaction 2 involves 1 g of magnesium as it only produces half as much hydrogen. It also proceeds more slowly, suggesting the reactants are	1 1	- ½ for not referencing reaction 1

Question	Sample answer	Marks	Comments / considerations for 2023 exam
	less concentrated, so the hydrochloric acid could have a concentration lower than 0.5 mol L^{-1}.		
7 a)		1 (correct shape) 1 (ΔH correct) 1 (E_a correct) 1 (specific products and reactants labelled)	- ½ for sloppy diagrams where arrows were much shorter or longer than they needed to be - ½ for lack of coefficients for reactants or products - ½ without ΔH value or scale
7 b)	$4NH_{3\,(g)} + 5O_{2\,(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}$ $\Delta H = -904$ kJ mol^{-1} Bonds broken: 4 x 3 x 389 + 5 x 498 = 7158 kJ Bonds formed: - 5568 - $4x$ -($4x$+ 6 x 2 x 464)= - 5568 - $4x$ 7158 + (-5568 - $4x$) = -904 x = 624 kJ NO bond energy is 624 kJ	 1 1 1 1	Various calculation methods were accepted -1 correct value with no working - ½ no units - ½ negative answer

Question	Sample answer	Marks	Comments / considerations for 2023 exam
7 c) i)		1	Line position to the left of E_a Shading of effective collisions portion not required
7 c ii)	A catalyst speeds up a reaction by lowering the activation energy by providing an alternate reaction pathway or mechanism.	1	Shaded region in diagram not required for full marks but did improve answers
	This increased the number of molecules with $E_k > E_a$.	1	
	This means that a greater proportion of collisions have sufficient energy to be successful/effective collisions and have a greater reaction rate.	1	-½ if collision frequency was used
8 a)	Reaction 1 will decrease in temperature. Reaction 2 will increase in temperature.	1	
8 b)	Reaction 1 is endothermic which means that the reactants have a higher enthalpy than the products and energy is taken in from the environment. The bonds in the reactants are stronger than the bonds in the products so more energy is required to break the bonds in the reactants (lattice energy) than is released in making bonds in the products (hydration energy).	1 (enthalpy comparison) 1 (bond strength comparison)	Stating 'endothermic' or 'exothermic' only gained ½ mark for enthalpy comparison
	In contrast, Reaction 2 is exothermic which means that the reactants have a lower enthalpy than the products and energy is released from the environment. The bonds in the reactants are weaker than the bonds in the products so less energy is required to break the bonds in the reactants (lattice energy) than is released in making bonds in the products (hydration energy).	1 (enthalpy comparison) 1 (bond strength comparison)	Terms 'lattice' and 'hydration' energies were not required for full marks

Question	Sample answer	Marks	Comments / considerations for 2023 exam
9 a)	Increased carbon dioxide concentrations in the atmosphere cause the equilibrium reaction to shift to the right in accordance with Le Chatielier's Principle (LCP), which states that an equilibrium will shift to try to oppose the change which created it. As a result, this results in greater amounts of carbonic acid in the ocean. H_2CO_3 dissociating H^+, making the ocean more acidic.	1 (shift to right) 1 (more H_2CO_3 formation) 1	'L.C.P' was not explicitly required to gain full marks: however, is recommended
9 b)	Rising temperatures will cause the reaction to shift to the right to absorb heat to counter the change in accordance with LCP and thus will increase the acidity of the ocean.	1 (shift) 1 (acidity increase)	
9 c)	H_2CO_3 is a stronger acid as it has a higher K_a value which means the equibrium position is furthur to the right and more of it dissociates into HCO_3^- and H^+ ions.	1 (identity) ½ K_a size ½ relate to dissociation	
9 d)	HCO_3^- acts as both a Bronsted Lowry acid and base in the two reactions. In Step 1 HCO_3^- is the conjugate base as it is formed by the donation of the proton. However in step 2 HCO_3^- is a BL base as it donates a proton.	1 (identify) 1 1	BL acid/base chemical equations not required

<table>
<tr><th>Question</th><th>Sample answer</th><th>Marks</th><th>Comments / considerations for 2023 exam</th></tr>
<tr><td>10 a)</td><td>Equilibrium reactions are formed when the two driving forces of minimum enthalpy and maximum entropy are in opposition.

In this reaction the forward reaction favours minimum enthalpy as it is exothermic.

The backwards reaction favours maximum entropy as there are greater moles of gas on the left.

Therefore an equilibrium is formed.</td><td>1

1

1</td><td></td></tr>
<tr><td>10 b)</td><td>$$K_c = \frac{[NO_2]^2}{[NO]^2\,[O_2]}$$</td><td>1</td><td></td></tr>
<tr><td>10 c)</td><td><table>
<tr><th>Change</th><th>Effect on the initial reaction quotient (Q)</th><th>Effect on equilibrium constant (K_c)</th><th>Effect on amount of NO</th></tr>
<tr><td>Increase in temperature</td><td>None</td><td>Decrease</td><td>Increase</td></tr>
<tr><td>Removal of NO_2</td><td>Decrease</td><td>None</td><td>Decrease</td></tr>
</table></td><td>1 per box</td><td></td></tr>
<tr><td>10 d</td><td>Ideal conditions are high pressure and moderate temperature.

A high pressure will cause the reaction to shift right to increase the pressure in accordance with LCP, and also increase collisions and increase the rate of reaction, increasing yield.

Low temperature will cause the equilbrium to shift to the right increasing the yield of NO_2,
(However decreaed temperature will also reduce the number of collisions with E_k>E_a, reducing the rate of reaction and decreasing yield. Therefore a balance is required between these factors)</td><td>2

1

1</td><td>E.C.F. from 10 a) if required

(This last statement was not required for full marks; however, is important.)</td></tr>
</table>

Section C

Criterion 7

Question 11 feedback

a. A notable number of students placed the Cl on the 4th carbon.
b. The greyed-out boxes did not need to be filled in. Attempts at doing so were ignored.

Question 12 feedback

a.

i) Nil.

ii) Many students misattributed the large jump as the difference between the 3p and the 3s subshells.

Numerous students received 2 marks for correctly deducing 5 valence electrons and the corresponding large jump, but incorrectly identified the element as sulfur.

Occasionally, the graph was misinterpreted. The points directly above the numbers on the x-axis are the ionisation energies, not the lines connecting those points.

b. Generally well answered.

Some students answered this question with reference to the elements O and Mg, rather than their ionic forms.

Question 13 feedback

a. Since temperature is constant, the E_k of the CO_2 gas particles is, on average, the same as the E_k of the liquid.

Some students incorrectly referred to "effective" or "successful" collisions when answering this question.

b.

i) Many students incorrectly labelled this as "addition".

ii) Nil.

Question 14 feedback

a. Nil.

b. Many students did not link the predicted values with the assumption of ideal gas behaviour, which made it difficult for them to answer the question in full.

Question 15 feedback

Nil.

Question 16 feedback

a. Nil.

b.

i) Nil.

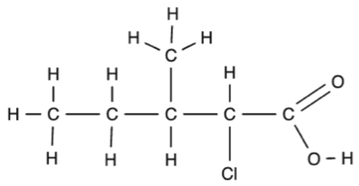
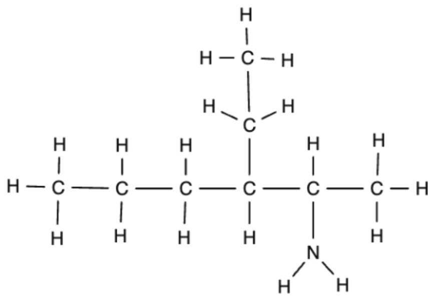
ii) Many students referred to "ease of access" of the –OH group as a factor in solubility. Marks were not awarded for this explanation unless accompanied by a reference to chain length.

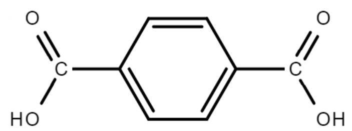
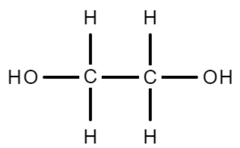
c.

i) Well answered.

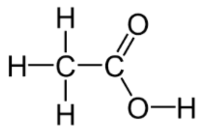
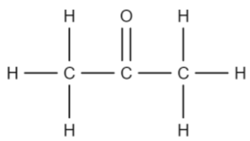
ii) Nil.

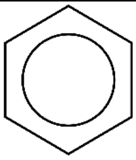
d. A notable number of students incorrectly stated that the delocalised electrons were in the centre/middle of the benzene ring.

Question	Sample answer	Marks	Comments / considerations for 2023 exam
11 a)	A:  B:  C: butyl propanoate	1 1 1	-0.5 for each error in sketching the molecules -0.5 if H atoms were not included in sketch Exact name of ester was needed for the full mark
11 b)	A: S (sulfur) B: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^2$ C: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8$	1 1 1	No penalty if noble gas shorthand was used **or** if subshells were listed in filling order: …$3p^6\ 4s^2\ 3d^7$ 0 marks awarded if ground state of Ni was given
12 a) i.	$X_{(g)} \rightarrow X^+_{(g)} + e^-$	1	0 marks awarded if states were not included Answers were accepted if ionization energy was included on reactant side of equation
12 a) ii.	Phosphorus. There's a large jump in ionisation energy between the 5th and 6th electrons.	1 1	

	The large jump suggests that element X has 5 valence electrons.	1	
12 b)	Ion with larger radii: O^{2-} O^{2-} and Mg^{2+} are isoelectronic O^{2-} has fewer protons than Mg^{2+} O^{2-} has a weaker electrostatic force on the outer electrons, drawing them in towards the nucleus less than Mg^{2+}	1 1 1 1	"Oxygen" and "O" also accepted -0.5 if no. of protons were not quantified ("4 more" or "Mg has 12, O has 8) No penalty if explanation centres around Mg^{2+}
13 a)	As the no. of CO_2 gas particles increases, the pressure in the bottle increases. As there are more gas particles, the number and frequency of collisions made between the particles and the walls/lid of the container increases.	1 1	
13 b) i.	Condensation.	1	
13 b) ii.	 	1 1	-0.5 for each instance where OH was drawn as if the C was bonded to the H rather than the O. -0.5 if H atoms were not included in sketch.
14 a)	Ideal gases are assumed to have: • negligible particle volume • no intermolecular forces • move in random straight line motion • experience perfectly elastic collisions.	1 each for any two correct	0 marks for "no mass" If more than two characteristics were listed, only the first two were marked. 0 marks for "negligible volume".

			Students needed to clarify that the *particles* have negligible volume
14 b)	Prediction is based on ideal gas laws and carbon dioxide is not an ideal gas. At lower temperatures there is less movement due to decreased E_k therefore increased intermolecular forces. Actual pressure will be lower than the prediction due to intermolecular forces which pull particles away from the walls of the container. The actual volume of the gas will be relatively unchanged as it occupies the volume of the container.	1 1 0.5 0.5	No penalty if students assumed the "vessel" was not rigid and did not maintain its shape
15 a)	Butanoic acid: Hydrogen gas and sodium butanoate. Butan-1-ol: Hydrogen gas and sodium butoxide.	1 1	0.5 marks awarded for each correctly identified product Names and structures accepted

15 b)	The statement is incorrect for multiple reasons. Firstly, butan-1-ol has a molecular formula of $C_4H_{10}O$ and thus has 10 hydrogens, whilst butanonoic acid has a molecular formula of $C_4H_8O_2$ and thus has 8 hydrogens. It is the hydroxyl (-OH) group of both compounds that is reacting with the sodium, and each compound has one hydroxyl gorup per molecule. The total number of hydrogen atoms per molecule is irrelevant. Both reactions produce ½ mole of hydrogen for every mole of sodium reacted so they would produce equal amounts of hydrogen gas, which would take up the same amount of space. Additionally, given that the same mass of sodium is reacted with excess of each reactant, the sodium is the limiting reagent, equally inflating the balloons.	1 1 1 1	1 for "incorrect" if supported by subsequent information Marks were awarded if students demonstrated their understanding by including the chemical or structural equations for both reactions as part of their reasoning
16 a)	Ethanol: Primary Propan-2-ol: Secondary	1 each	
16 b) i.	Ethanol will be more soluble in water.	1	
16 b) ii.	Both ethanol and propan-2-ol are soluble in water due to the hydorgen bonding between the hydroxyl group and the water molecule. Ethanol is more soluble because is has a smaller chain length than propan-2-ol, meaning H-bonding has a greater influence on the overall solubility as there is only a small non-polar chain.	1 1	
16 c) i.	 ethanoic acid  propanone	1 1 1 1	-0.5 for missing H atom Error carried forward applied for correctly naming incorrectly identified organic products

16 c) ii.	The spectrum is from ethanoic acid. There is a strong, narrow peak around 1700 cm^{-1} indicating a C=O bond. There is also s a strong, very broad peak in the 3300 – 2500 cm^{-1} range indicating a carboxylic acid OH group.	1 1 1	Students needed to refer to the specific wavelength range of the peaks on the IR spectrum for full marks Students could be awarded marks for highlighting the relevant peaks on the IR spectrum providing they were accompanied by an explanation
16 d)	 Benzene has a ring of six carbons connected by a ring of delocalised electrons. This results in an equivalent of 1.5 bonds in strength and bond length and is very stable.	1 for correct diagram 1 1	Marks were not awarded for reference to alternating C=C and C-C bonds

Section D

Criterion 8

General feedback

Good attempts at all questions by the majority of students.

Throughout this section, students were penalised -0.5 marks for lack of units in their final answer.

Minor deviations in significant figure use were not penalised in this section.

Significant misuse of significant figures were penalised -0.5 marks.

Taking time to understand the context of the question will aid students in identifying unrealistic answers.

Students should not skip recording steps in their calculations as these can be vital to gain full marks according to the set mark scheme for the exam. Combining multiple calculation steps can save time and will gain full marks; however, many errors were seen in doing so.

Although communication was generally clear and logical. In questions involving multiple species, it is recommended that students clearly show the species for which they are doing a calculation in their communication i.e. $n(H^+)$ not just n.

Question 17 feedback

Well answered.

Question 18 feedback

a. A number of students converted P unnecessarily.

b. Majority of students answered this question using PV = nRT.

   A number of errors were made converting T and P using both methods.

Question 19 feedback

Well answered.

Question 20 feedback

a. Students need to include some form of calculations to show that N_2 is limiting.

b. Well answered.

c. Students used original values of reactants not the values at equilibrium.

   Some students did not convert their mole value calculations to concentrations before calculating Kc.

Question 21 feedback

a. Well answered.

b.

i) A number of students missed energy absorbed by the water calculation and substituted ΔH for E in E=mcΔT.

It is recommended that students read question carefully so as to recognise that a drop in temperature of the water would be an unrealistic solution for combustion reaction and that the final temperature was required not just the ΔT.

ii) Students missed multiplying n(CO_2) by 3 and incorrect choice of R was a common error. Temp at SLC was incorrectly substituted.

Question 22 feedback

a. Students did not recognise that a reaction was occurring and that the reactant in excess was required to calculate the pH.

Students incorrectly used the n(H+) to calculate pH.

b. A number of students failed to mention relevant assumption.

Question 23 feedback

Well done, but students were looking for a dilution and added unnecessary steps to their final concentration calculation.

Question	Sample answer	Marks	Comments / considerations for 2023 exam
17	$Cr^{3+}_{(aq)} + 3e^{-} \rightarrow Cr_{(s)}$ $n(e^{-}) = It / F = (10)(12.0 \times 60 \times 60) / 96500 = 4.47$ moles $n(Cr) = 1/3\ n(e^{-}) = 1.49$ moles $m = nM = (1.49)(52) = 77.6$ g	1 1	
18 a)	$PV = nRT$ $n = PV / RT = (740)(2.50)/ ((62.4)(303))$ $n = 0.098$ mole	1 1	
18 b)	$P_1V_1/ T_1 = P_2V_2 / T_2$ $V_2 = P_1V_1T_2/ (T_1P_2) = (740x2.50x(12+273))/(303x1.2x760)$ $V_2 = 1.91$ L	1 1 1	
19	$2XOH_{(aq)} + Zn(NO_3)_{2\ (aq)} \rightarrow Zn(OH)_{2\ (s)} + 2XNO_{3\ (aq)}$ $m(Zn(OH)_2) = 5.31$ g $n\ (Zn(OH)_2) = 5.31 / 99.369 = 0.0534$ mol $n\ (XOH) = 2\ n\ (Zn(OH)_2) = 2\ (0.0534) = 0.107$ mol $M\ (XOH) = n/m = 6.00 / 0.107 = nM = 56.1$ g $M(X) = 56.1 – (1.008 +16) = 39.1$ g mol^{-1} ∴ the element X is potassium	1 1 1 1 1	

<table>
<tr><th>Question</th><th>Sample answer</th><th>Marks</th><th>Comments / considerations for 2023 exam</th></tr>
<tr><td>20 a)</td><td>$n(N_2) = 63.0 \times 10^3/28.02 = 2.24 \times 10^3$ mol
$n(H_2) = 15.0 \times 10^3/2.016 = 7.44 \times 10^3$mol
2.24×10^3 mol N_2 needs 6.74×10^3 mol H_2 which is available – N_2 is limiting
7.44×10^3 mol H_2 needs 2.45×10^3 mol N_2 which is not available – H_2 is in excess
$n(NH_3) = 2 \times n(N_2) = 4.48 \times 10^3$ mol
$m(NH_3) = 4.48 \times 10^3 * 17.034 = 76.6$ kg</td><td>0.5
0.5
1

1
1</td><td></td></tr>
<tr><td>20 b)</td><td>Percentage yield = actual / theoretical
= 58.0/76.6
= 75.7%</td><td>1</td><td></td></tr>
<tr><td>20 c)</td><td>$n(N_2) = 63.0/28.02 = 2.24$ mol
$n(H_2) = 15.0/2.016 = 7.44$ mol
$n(NH_3) = 58/17.034 = 3.40$ mol
<table>
<tr><td>Moles</td><td>N_2</td><td>$3H_2$</td><td>$2NH_3$</td></tr>
<tr><td>Initial moles</td><td>2.24</td><td>7.44</td><td>0</td></tr>
<tr><td>Change in moles (1)</td><td>-1.13</td><td>-2.27</td><td>+3.40</td></tr>
<tr><td>Equil moles (1)</td><td>1.11</td><td>5.17</td><td>3.40</td></tr>
<tr><td>Equil conc (1)</td><td>1.11×10^{-3}</td><td>5.17×10^{-3}</td><td>3.40×10^{-3}</td></tr>
</table>
$K_c = [NH_3]^2 / ([N_2][H_2]^3) = 16245$</td><td>1
1
1
1
1</td><td>An ICE diagram was not required for full marks but its use aids calculation of concentrations at equilibrium</td></tr>
<tr><td>21 a)</td><td>A $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -393.5$ kJ mol^{-1}
B $3C_{(s)} + 4H_{2(g)} + ½ O_{2(g)} \rightarrow C_3H_8O_{(l)}$ $\Delta H = -303.0$ kJ mol^{-1}
C $H_{2(g)} + ½ O_{2(g)} \rightarrow H_2O_{(g)}$ $\Delta H = -241.8$ kJ mol^{-1}
ΔH = -B + 3A +4C
= -(-303.0)+3(-393.5)+4(-241.8)
= -1845 kJ mol^{-1}</td><td>2
1</td><td></td></tr>
<tr><td>21 b) i.</td><td>n = 1.41 / 60.09 = 0.023 mol</td><td>1</td><td></td></tr>
</table>

<table>
<tr><th>Question</th><th>Sample answer</th><th>Marks</th><th>Comments / considerations for 2023 exam</th></tr>
<tr><td></td><td>$E = n * \Delta H = 0.023 * 1845 = 43.3$ kJ $= 43.3 \times 10^3$ J

$E = mc\Delta T$

$\Delta T = E / mc = 43.3 \times 10^3 / (250 \times 4.184) = 41.4$°C

Final temp = 41.4 + 20.0 = 61.4 °C</td><td>1

1

1</td><td></td></tr>
<tr><td>21 b) ii.</td><td>$n(CO_2) = 3*n(C_3H_8O) = 3* 0.023 = 0.0704$ mol

v = n * molar volume at SLC = 0.0704 * 24.5 = 1.72 L</td><td>1

1</td><td></td></tr>
<tr><td>22 a)</td><td>$H^+ + OH^-$ à H_2O

$n(H^+) = cV = (0.20)(20/1000) = 0.004$ mol Limiting

$n(OH^-) = cV = (0.50)(10/1000) = 0.005$ mol Excess

Excess $n(OH^-) = 0.005 – 0.004 = 0.0010$ mol

$[OH^-] = n/V = 0.0010 / 0.03 = 0.033$ mol L^{-1}

$K_w = [H^+] [OH^-]$

$[H^+] = K_w / [OH^-] = 1 \times 10^{-14} / 0.033 = 3 \times 10^{-13}$ mol L^{-1}

$pH = -\log[H^+] = -\log (3 \times 10^{-13}) = 12.5$</td><td>

1

0.5

0.5

1

1</td><td></td></tr>
<tr><td>22 b)</td><td>$C_6H_5COOH \rightleftharpoons C_6H_5COO^- + H^+$
<table><tr><th></th><th>C_6H_5COOH</th><th>$C_6H_5COO^-$</th><th>H^+</th></tr><tr><td>Initial conc</td><td>1.40</td><td>0</td><td>0</td></tr><tr><td>Change in conc</td><td>-x</td><td>+x</td><td>+x</td></tr><tr><td>Equil conc</td><td>1.40 - x</td><td>x</td><td>x</td></tr></table>$K_a = [C_6H_5COO^-][H^+] / [C_6H_5COOH]$

$= x^2 / (1.40 – x) = 6.46 \times 10^{-5}$

As this is a very weak acid, x can be assumed to be very small and therefore $1.40 – x \approx 1.40$

Therefore: $x^2 / (1.40) = 6.46 \times 10^{-5}$

$x = \sqrt{(6.46 \times 10^{-5} * 1.4)} = 0.00951$ mol L^{-1}

$[H^+] = x = 0.00951$ mol L^{-1}

$pH = -\log[H^+] = 2.02$</td><td>1

1

1

1

1</td><td>An ICE diagram was not required for full marks

A number of students failed to mention relevant assumption</td></tr>
</table>

Question	Sample answer	Marks	Comments / considerations for 2023 exam
23	$n(S_2O_3^{2-}) = cV = (0.0500)(40/1000) = 0.00200$ mol $n(I_2) = 2*n(S_2O_3^{2-}) = 0.00100$ mol $n(Cu^{2+}) = 2*n(I_2) = 0.00200$ mol $c = n / V = 0.00200 / (25/1000) = 0.0800$ mol	1 1 1 1	