2024 ASSESSMENT REPORT

CHM415115 CHEMISTRY

Criterion 5

General Feedback

Students largely did well in this section of the exam, with a majority of students achieving 70% (31.5 out of 45) or higher. A range of answers were accepted based on the wording of the exam questions. See the feedback below on each specific question for areas of improvement.

Question 1 feedback

a) Generally well answered.

Some students incorrectly wrote the “+” sign after the oxidation number (e.g. Ox(Mn) = 7+ when it should be +7).

In part i), others forgot to consider that there were two MnO_3 anions present, leading to Ox(Mn) = +10.

b) Generally well answered.

A few students incorrectly stated that the species with the highest charge would be the strongest reducer (oxidation state ≠ charge).

Some students stated that MnO_4^- was the strongest oxidiser “because it has an oxidation state of +7”. This was not enough for the 0.5 marks as it is merely stating what the oxidation state is and does not give a reason as to why it’s the strongest oxidiser.

Question 2 feedback

a) Generally well answered.

When multiplying half equations for part b), students should avoid directly writing on/over their answer to part a). It makes it difficult for markers to interpret what they have answered for part a).

b) A common error was misunderstanding the meaning of a “net ionic equation”. This is the same as a full redox equation. Removing non-ionic species from the equation or breaking species up into individual ions is incorrect.

c) Poorly answered.

There was a lack of accuracy and specificity when discussing particular chemical species. Use “chloride ions” or “$Cl^-(aq)$” rather than “chlorine”. “Chlorine” is too general of a name.

There was also confusion and a lack of accuracy around the use of the terms “oxidiser” and “reducer”, as well as “strong” and “weak”.

Question 3 feedback

a) Nil.

b)

   i) From reading the question, a notable number of students misinterpreted that the cell must be operating as an electrolytic cell.

   Some mentioned that there must be a porous barrier. Such a barrier is not present in this cell and is not needed for the cell to function.

   ii) Nil.

c) It is recommended that students use all the space they can to draw their cell. Some were drawn very small and were difficult to read/interpret.

Species that are not present in the cell (e.g. Pb^{2+}, O^{2-}) were included in the diagram. Further practice was needed to identify which species would be present based on the information given in the question.

Question 4 feedback

a) The symbol for a DC power source was often poorly drawn, drawn in the wrong orientation, or missing entirely.

b)

   i) A significant number of students wrote $Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^-$ as the oxidation half equation, despite the fact that the cathode was made of aluminium metal.

   Recall that oxidation occurs at the anode and reduction occurs at the cathode (An OIL RIG Cat).

   Some students wrote half equations whose reactants involved species that weren't present in the cell (e.g. $Al^{3+}_{(aq)}$, $Zn_{(s)}$). Practice is needed in identifying the chemical species present and determining which ones are the strongest reducer at the anode and the strongest oxidiser at the cathode.

   ii) Most students forgot to mention, or didn't recognise, that the voltage calculated was the minimum needed for the reaction to occur.

c) Same feedback as mentioned above for 4 b) i).

d) Nil.

e) Same feedback as mentioned above for 4 b) i).

Also, students should be aware that this electrolytic cell involves a molten salt. There are no ions dissolved in water, so the states of the ions should be (l), not (aq).

f) Some students mentioned that Fe^{2+} would be reduced. Note that the question asks for **initial** products. Fe^{2+} won't be reduced initially as it will take some time for its concentration to increase enough and for it to migrate over to the cathode.

Question 5 feedback

a) A few students stated or implied that $H_2O_{(l)}$ is the oxidiser. $O_{2\,(g)}$ is the oxidiser that is itself reduced, in the presence of $H_2O_{(l)}$.

b) Nil.

c) Some students mentioned galvanisation as their alternative. This is fine; however note that galvanisation is a specific type of sacrificial coating, when the coating is $Zn_{(s)}$. If the sacrificial coating is made with another stronger reducer like $Mg_{(s)}$ or $Al_{(s)}$, it's not called galvanisation.

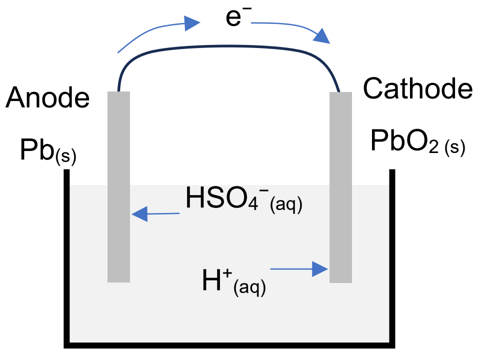
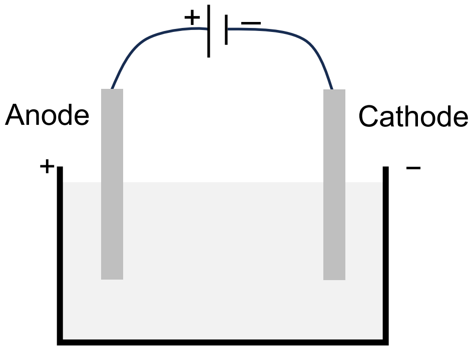
d) Nil.

e)

- i) Nil.
- ii) There were a notable number of students that correctly identified the magnesium rod as a sacrificial anode in part i), but then interpreted part ii) as two separated metals, as if the magnesium rod and the steel unit were not electrically connected and therefore giving two sets of half equations (oxidation and reduction on the magnesium, and oxidation and reduction on the steel). Note that if the magnesium rod is a sacrificial anode, then the magnesium must be preferentially oxidised, meaning the metal that is being protected is the site of reduction.

Question	Sample answer	Marks	Comments / considerations for 2024 exam
1 a)	i. MnO_4^- Ox(Mn) = +7 ii. $Ba(MnO_3)_2$ Ox(Mn) = +5 iii. MnO_2 Ox(Mn) = +4	1 1 1	−0.5 overall if no plus sign is given.
1 b)	MnO_4^- would be the strongest oxidiser. It has the highest oxidation state. Mn behaves as if it was missing 7 electrons so has the strongest attraction for additional electrons.	1 0.5 0.5 (explanation, e.g. "greatest capacity to be reduced")	Nil.
2 a)	$MnO_{2(s)} + 2H_2O_{(l)} \rightarrow MnO_4{}^-{}_{(aq)} + 4H^+{}_{(aq)} + 3e^-$.	2	−0.5 overall for incorrect/missing states. −0.5 each error.

2 b)	3 × red: $3IO_{4\,(aq)}^{-}, + 6H^{+}_{(aq)} + 6e^{-} \rightarrow 3IO_{3\,(aq)}^{-} + 3H_2O_{(l)}$. 2 × ox: $2MnO_{2(s)} + 4H_2O_{(l)} \rightarrow 2MnO_{4\,(aq)}^{-} + 8H^{+}_{(aq)} + 6e^{-}$ $3IO_{4\,(aq)}^{-} + 2MnO_{2(s)} + H_2O_{(l)} \rightarrow 3IO_{3\,(aq)}^{-} + 2MnO_{4\,(aq)}^{-} + 2H^{+}_{(aq)}$	1 (correct multiplication of each half equation) 2	Writing out the half equations after the multiplication step was not needed for full marks. −0.5 overall for incorrect/missing states. −0.5 each error. −1 if answer is correct but equation is further adjusted to be "more ionic". E.C.F. from 2 a) when appropriate.
2 c)	The chloride ions in the hydrochloric acid could be preferentially oxidised into toxic chlorine gas. Because $IO_{4\,(aq)}^{-}$ is a strong enough oxidiser to oxidise chloride ions.	1 (stating that Cl^{-} acts as a reducer) 1 (relevant explanation)	0.5 if stated "Cl^{-} reacts". No marks if stated "HCl reacts".
3 a)	The salt bridge allows the cell to maintain electroneutrality. It completes the circuit. And allows the transfer of charge through the movement of ions.	1 1 1 (explanation)	
3 b) i)	The electrolyte is the same for both electrodes Allowing charge to be carried between them.	1 1 (justification, e.g. "ions flow in solution")	Can't just repeat the "electrodes are immersed in sulfuric acid solution" from the question stem. 0 for porous barrier.
3 b) ii)	2.25 V −1.69 V = 0.56 V ∴ E^0 for reduction half equation = −0.56 V	1	−0.5 if no units (volts) Accept both + / − (question doesn't explicitly ask for oxidation or reduction E^0).

3 c) i)		1	−0.5 if composition of electrodes not included. −0.5 if incorrect electrode polarity included.
3 c) ii)		1 (identifying anions and cations) 1 (direction of anion and cation movement) 1 (direction of electron movement)	−0.5 overall for errors in diagram that are inaccurate or functionally impossible. Marks deducted if species that are not present in solution were included. E.C.F. if they misidentified cell as being electrolytic in 3 b) i) or 3 c) i) or having a porous barrier in 3 b) i).
4 a)		1 (polarity) 1 (anode and cathode)	Needs power source in diagram for full marks, with polarities shown on power supply terminals OR power source symbol in correct orientation.
4 b) i)	Cathode: $Zn^{2+}{}_{(aq)} + 2e^- \rightarrow Zn_{(s)}$ Anode: $2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+{}_{(aq)} + 4e^-$	1 1	E.C.F. from diagram (complicated marking).
4 b) ii)	$E^0_{cell} = -1.23 + -0.76 = -1.99$ V	1 (calculation)	−0.5 if only one sign is reversed in the calculation step.
	Voltage required ≥ 1.99 V	1 (noting that the calculated voltage is the minimum required)	

4 c)	Cathode: $2H_2O_{(l)} + 2e^- \rightarrow 2OH^-_{(aq)} + H_{2(g)}$ Anode: $2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$	1 1	E.C.F. if the strongest oxidiser/reducer misidentified earlier is still the strongest in this scenario.
4 e)	Cathode: $Mg^{2+}_{(l)} + 2e^- \rightarrow Mg_{(l)}$ Anode: $2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$	1 1	−0.5 for incorrect/no states.
4 f)	Mg metal is still being produced at the cathode ($Mg^{2+}_{(l)} + 2e^- \rightarrow Mg_{(l)}$) Fe metal is preferentially produced at the anode instead of Cl_2 gas Because Fe^{2+} is a stronger reducer than Cl^-) $Fe_{(s)} \rightarrow Fe^{2+}_{(l)} + 2e^-$	0.5 0.5 0.5 0.5 (half equation)	No marks awarded for Fe^{2+} being reduced E.C.F. from 4 e).
5 a)	• The presence of oxygen and water • A difference in the concentration of oxygen • Different metals in contact • The presence of dissolved salts • Stress or fatigue on metal • Increase in temperature	1 each (max. of 2)	0.5 if factors are simply identified.
5 b)	Painting the metal surface creates a physical barrier that excludes water and oxygen from contacting the metal.	1 1 (explaining reactants blocked: O_2 and H_2O)	Answers explaining the use of paints containing stronger reducers that preferentially oxidise were also accepted.
5 c)	• Sacrificial Anode • Applied EMF • Noble Coating • Sacrificial coating	1 each (max. of 2)	“Creating an alloy” is not a practical alternative.

5 d)	Two different metals in contact with an electrolyte make an electrochemical cell. The more reactive metal becomes the anode and corrodes.	1 1 (identifying formation of an anode at strongest reducer)	First mark was awarded to either “formation of electrochemical cell” OR “increase in corrosion rate”.
5 e) i)	It acts as a sacrificial anode.	1	“Prevents corrosion” also accepted.
5 e ii)	$Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2e^-$ $O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$	1 1	Deductions made if more than two half equations were given. Reduction of H_2O without O_2 also accepted.

Criterion 6

General Feedback

This section was well answered by the majority of students. Most students attempted nearly every question.

Question 6 feedback

Many students were able to access this question.

Surprisingly, several students answered part a) incorrectly yet were able to answer part b).

The unfamiliar nature of a biochemistry diagram resulted in students attempting to explain in terms of intermolecular forces (e.g. Hydrogen bonding, dispersion forces) rather than intramolecular forces.

Question 7 feedback

Many students answered this question well.

a) The most common error was forgetting the two C-C bonds. Also, several listed/drew the molecules instead of listing which bonds were broken or formed.

b) Nil.

c) This question was answered well, but a few students recognised that the activation energy is required to break bonds.

d) Mostly answered well. Errors arose from not determining the correct bonds in part a) and then carrying this error forward.

Question 8 feedback

a) Few students explained the significance of the gradient (i.e., it measures the rate of reaction). Part b) and c)

b) Many students incorrectly used the concentration of HCl to attempt to find moles of CO_2 formed. Part b)

   ii) Many students did not recognise the need to draw and use a tangent to support their calculation for the rate of reaction. Additionally, many students were unable to convert volume of gas into moles or unable to convert cm^3 into L (then moles).

c) As in part b), many students were unable to convert volume of gas into moles or unable to convert cm^3 into L (then moles).

   ii) many students only explained why their graph was steeper or plateaued earlier but not both.

d) There were many good responses explaining changes in temperature or surface area. Those that suggested a catalyst often stated that it provides an alternate pathway without referring to how effective collisions are increased. Changes to concentration were not accepted as this was the stem of the question.

Question 9 feedback

Most students were able to engage with this question.

a) Despite the forward arrow indicated, a number of students attempted to explain the reaction as an equilibrium reaction, overcomplicating their response by addressing the major driving force in each direction.

b) Some students listed specific conditions (e.g. SLC, STP) despite the question not listing the conditions at which the ΔH was measured.

Question 10 feedback

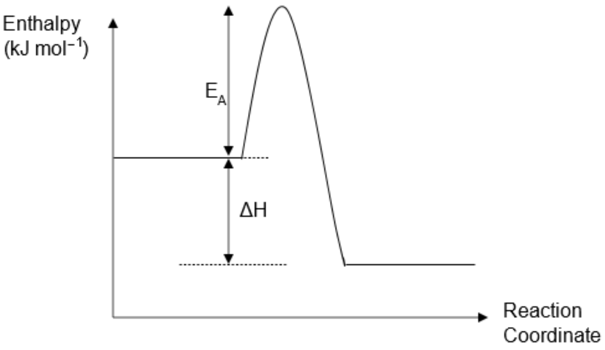
A large number of students were unfamiliar with heterogenous equilibria and, as a result, were unable to explain equilibrium changes appropriately – specifically b) ii) and iv).

Some students were unfamiliar with $\Delta H > 0$ inferring an endothermic reaction.

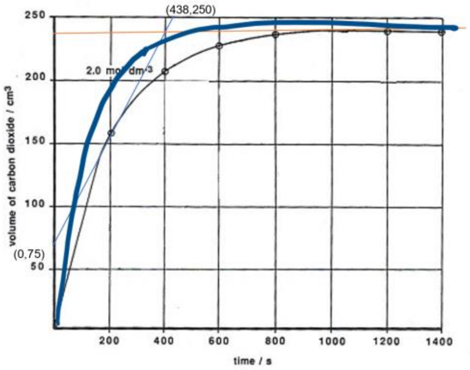
Some students restated the imposed change to the equilibrium rather than the response to the change.

b)

   iii) Many students did not recognise that a catalyst increases the rate of both forward and reverse reactions and made no mention of the position of equilibrium.

Question	Sample answer	Marks	Comments / considerations for 2024 exam
6 a)	This statement is not true as breaking bonds absorbs energy. This reaction is exothermic as forming new bonds releases **more energy** than energy to break bonds.	1 1	Good answers stated that more energy was released when bond formed than required to break bonds, hence exothermic. 0.5 awarded if the student only said false or the statement was not correct.
6 b)	The bonds in ATP and H_2O are weaker than the bonds in ADP and PO_4^{3-} as there was a net release of energy (or the reaction was exothermic).	1 1	
7 a)	The bonds broken are 2 C-C single bonds, 8 C-H single bonds and 5 O=O. The bonds formed are 8 O-H single bonds and 6 C=O double bonds.	1 1	The number of each bond type was not required for full marks, but mistakes were penalised.
7 b)		2	Needed to have the correct shape (1 mark). E_A and ΔH 0.5 mark each.
7 c)	The shape is that of an exothermic reaction, where the reactants have higher enthalpy than the products.	1	Marks were deducted for not referring to the

	Energy is required (activation energy) to break bonds initiating the reaction.	1	shape of the graph as part of their answer.
7 d)	Bonds broken Energy absorbed 2 C-C 696 kJ 8 C-H 3304 kJ 5 O=O 2490 kJ Sum: 6490 kJ Bonds made Energy released 8 H-O 3712 kJ 6 C=O 4818 kJ Sum: 8530 kJ $\Delta H = 6490 - 8530 = -2040\ kJ$	1 1 1	Needed to have each total correct to receive full marks. The answer needed to have a negative sign and units for full mark. Many students forgot the C-C bond, or had 3 C-C bonds, or mistakenly chose incorrect bond types from the table above (e.g. C-O).
7 e)	The difference in the equations is the calculated equation considered gaseous water (or steam) and the literature uses liquid water. More energy is released when steam condenses to liquid water. This is why the calculated value is less (smaller or less negative) than the value given by the literature.	1 1	Awarded 1 mark if students mentioned another relevant reason, such as the bond energies in the table were averages.
8 a)	The gradient of the graph is the rate of change of volume which is proportional to the reaction rate. The gradient starts off very steep due to the high number of **collisions** between reactant particles. The reason the rate slows and plateaus is that as the reactants are used up there are fewer collisions between reactant particles, with calcium carbonate being the limiting reagent being used up.	1 1 1	Students were required to explain the rate in terms of the number of collisions to gain full marks.
8 b) i)	Average rate = $\frac{0.16\ \text{L}}{24.0\ \text{L mol}^{-1} \times 200\ s}$ = 3.3×10^{-5} mol s^{-1}	2	Marks were deducted for not converting cm^3 to L and then volume to moles using the molar volume.

8 b) ii)	Instantaneous rate using tangent = $\frac{0.175\ \mathrm{L}}{24.0\ \mathrm{L\ mol^{-1}} \times 438\ s}$ $= 1.66 \times 10^{-5}$ mol s^{-1}	2	Students were awarded some marks for an appropriate tangent and gradient.
8 b) iii)	Instantaneous rate = 0 mol s^{-1}	1	Most students assumed reaction has ceased.
8 c) i)		1	Steeper gradient and earlier plateau required. 0.5 mark deducted if plateaued at different volume.
8 c) ii)	The graph was initially steeper as there were more collisions between hydrogen ions and the calcium carbonate. The graph plateaued earlier as the calcium carbonate was used up more quickly.	1 1	
8 d)	A number of appropriate alternatives including: e.g. Instead of a lump of calcium carbonate, powdered calcium carbonate could be used. The larger surface area results in more collisions which make the reaction much faster. e.g. The temperature of the reaction could be increased. More particles would have the activation energy needed for particles to react successfully. The number of particles with sufficient energy increases exponentially with temperature.	2	0.5 marks for the appropriate method. 1.5 marks for an appropriate explanation that had to include discussion on the effect on the number of successful collisions.
9 a) i)	Maximise randomness (entropy/disorder).	1	
9 a) ii)	Minimise enthalpy.	1	
9 b) i)	Either/or increase in temperature or decrease in pressure.	1	

9 b) ii.	Either/or decrease in temperature or increase in pressure.	1	0.5 marks deducted for non-committal terms e.g. moderate.
10 a)	$K_c = [CO_{2(g)}]$	1	Most students answered correctly. A common mistake was including the solids.
10 b) i)	**Effect:** Equilibrium shifts to the right (products). **Explanation:** According to Le Chatelier's Principle more $CaCO_{3(s)}$ would form to counteract the addition of $CO_{2(g)}$. Or Increasing $pCO_{2(g)}$ would increase the reverse reaction rate without affecting the forwards rate. As $CO_{2(g)}$ is used up, the reverse rate would decrease till equilibrium returns.	0.5 1.5	Marks were deducted for not clearly stating the effect.
10 b) ii)	**Effect:** No effect on the equilibrium position. **Explanation:** Solids are not part of the K_c expression, thus adding $CaCO_{3(s)}$ would not affect the position of the equilibrium.	1 1	
10 b) iii)	**Effect:** No effect on the position of equilibrium. **Explanation:** A catalyst will increase the rates of both the forward and reverse reactions equally, thus there would be no effect on the position of the equilibrium. The equilibrium would be reached faster (or more quickly) but the position would not change.	0.5 1.5	0.5 marks deducted if no statement of change to the position of equilibrium. 0.5 mark deducted for not identifying that the rate of both forward and reverse reaction increases.
10 b) iv)	**Effect:** No effect on the position of equilibrium. **Explanation:** Adding an inert gas does not change the partial pressure of $CO_{2(g)}$. The rates of the forward and reverse reactions are not affected.	0.5 1.5	Not answered by many correctly. Most assumed that the addition of an inert gas would cause the equilibrium to shift towards the left.

10 b) v)	**Effect:** This would shift the equilibrium to the right (products). **Explanation:** Forward reaction is endothermic. To oppose the increase in temperature the reaction that absorbs energy is favoured, hence the forward (endothermic) reaction is favoured.	0.5 1.5	

Criterion 7

General Feedback

This section was well answered by the majority of candidates, with 40% of all students achieving a score of greater than 34/45 (75%).

There was an error in Q13b which did not negatively affect students responses significantly. However, responses which were deemed relevant based on the erroneous question were generally marked as correct.

Question 11 feedback

Students are encouraged to spend more time revising the kinetic theory of gases as many candidates did not link their graphical analysis of the relationship between pressure and temperature to this theory.

Question 12 feedback

Students were well prepared to name and draw these simple organic structures with most candidates achieving 5 or 6 marks on this question.

Question 13 feedback

This question had an error in which propane was written as propene. The relevant section of the question was therefore removed and consideration was given in other parts of the question for relevant working following through from the error.

Question 14 feedback

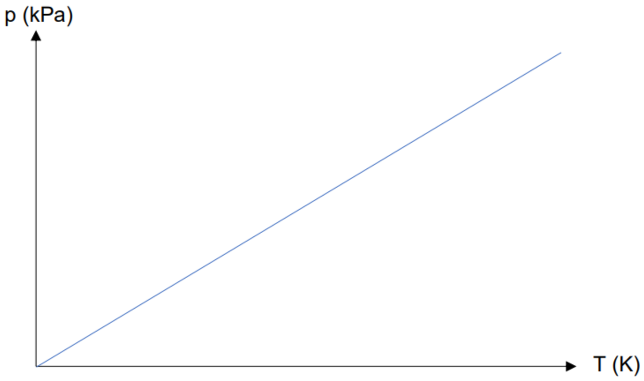
Most candidates were able to analyse the IR spectrum quite well; however, the use of empirical formula in the question challenged many.

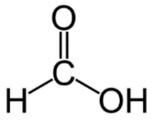
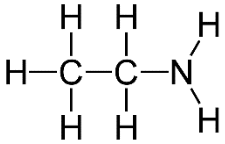
Question 15 feedback

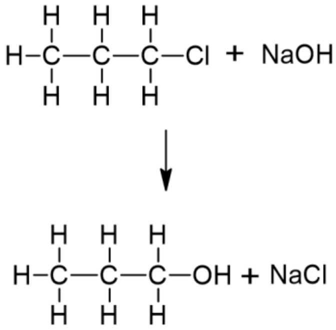
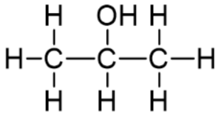
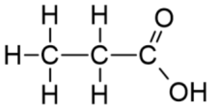
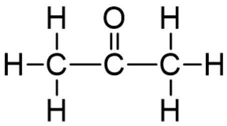
This question proved to be much harder than other questions in this section, with students not showing a good understanding of successive ionisation energies or emission/absorption spectra.

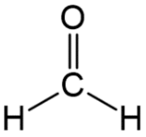
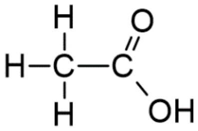
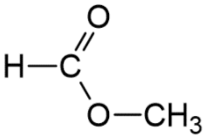
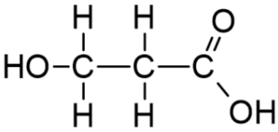
Question 16 feedback

This routine question was well handled by most students.

Question	Sample Answer	Marks	Comments/ considerations for 2024 exam
11 a)	Intermolecular forces between particles are negligible. Ideal gas have no **particle** volume. Ideal gas particles undergo elastic collisions.	1 mark each for two correct responses	Candidates also need to be specific when referring to the properties of ideal gases to emphasise that the molecules/particles of the gas have no volume as many erroneously referred to the particles having no mass.
11 b)		2	No coordinates were required to be plotted.
11 c)	As temperature increases the average kinetic energy of the gas particles increases. As $E_k = \frac{1}{2}mv^2$ this increases the average velocity of the particles. Therefore, the particles collide with the wall of the container more frequently and with greater momentum. Therefore, more force is exerted on the walls and hence pressure increases.	1 1 1 1	Partial credit was given to students who either used the combined gas equation or the ideal gas equation to justify the linear nature of the graph given in part b). Students are reminded that increasing kinetic energy of the gas increases the average velocity of the gas particles not vice versa.

12	Methanoic acid  Propanal / aldehyde Ethanamine 	2 2 2	A few students identified the aldehyde as a ketone and named as such or used propan-1-al rather than propanal.
13 a)	Halogens (e.g. chlorine) are highly electronegative and hence forms polar covalent bonds with carbon. As dipole-dipole forces are stronger than dispersion forces they require more energy to break and hence alkyl halides have higher boiling points. The polar nature of alkyl halides allows for the formation of intermolecular dipole-dipole forces (as well as dispersion forces). Alkanes are non-polar and hence only have intermolecular dispersion forces. As dipole-dipole forces are stronger than dispersion forces they require more energy to break and hence alkyl halides have higher boiling points.	1 1 1 1	This question was allocated 4 marks rather than the initial 2 marks.
13 b) i)	$C_3H_{6\,(g)} + Cl_{2\,(g)} \rightarrow C_3H_6Cl_{2\,(l)}$	0	This question was **not marked** as part ii) and further parts of the question needed two isomers which are not formed from addition of Cl_2 to propene.
13 b) ii)	1-chloropropane 2-chloropropane	1 1	Many students omitted the numbering of 1-chloropropane instead opting to name it chloropropane.

13 c) i)		1	Many students did not include the sodium chloride as a second product.
13 c) ii)		1	Many students provided a full reaction equation unnecessarily, as such they are reminded to read the question carefully.
13 c) iii)	Propan-1-ol Propan-2-ol	1 1	Again, many students incorrectly omitted the numbering of propan-1-ol instead opting to name it propanol.
13 d) i)	Propanoic acid  Propanone 	1 1	Propan-2-one was accepted The most common error in this question was to have a hydrogen atom continue to bond to the carbonyl carbon in propanone.
13 e)	Propanoic acid contains a carboxyl (carbonyl and hydroxyl) group. This functional group can form intermolecular hydrogen bonds with neighbouring molecules which are stronger than the dipole-dipole intermolecular bonds formed between propanone molecules. Therefore, propanoic acid will require more energy to break its intermolecular bonds and have a higher B.P. OR	1 1	Many students discussed the chemical reactivity differences between the molecules rather than physical properties.

	Propanoic acid contains a carboxyl (carbonyl and hydroxyl) group. This functional group can form intermolecular hydrogen bonds with water molecules which means it is highly soluble in aqueous solution. Propanone molecules cannot hydrogen bond to water and hence are less soluble.		
14 a)	    and many other structures.	1 1	1 mark for each correct structure. A disturbingly large number of students drew 2 different structures of methanal in different orientations naming the second structure methanone. Commonly the students regarded the empirical formula as CH_2O as having a ratio of C_nH_{2n} and a single O. This led to many ketones or aldehydes such as Butanone or Propanone. Less than half identified ethanoic acid as a possible answer.
14 b)	The IR spectrum shows evidence of a carbonyl group through the strong absorption band at 1700 cm^{-1} and the presence of the hydroxyl group of a carboxylic acid through the strong, broad absorption between 3200 – 2900 cm^{-1}. Therefore, the structure is likely a carboxylic acid which indicates ethanoic acid based on the empirical formula.	1 1 2	Many students disregarded the hydroxyl absorption band based on their isomers drawn above. Students are also advised to be specific regarding the wavenumbers of the absorption bands of hydroxyl groups as compounds with an alcohol and carboxylic acid functional group match the empirical formula but not the IR spectrum.

15 a)	The successive ionisation energies of an atom increase with each ionisation until there is a significant increase in the ionisation energy which corresponds with ionising electrons from a lower primary energy level (lower electron shell). This is because electrons in a lower shell orbit closer to the nucleus and experience less shielding and hence feel a stronger electrostatic force of attraction from the nucleus dramatically increasing the ionisation energy.	1 1	This was poorly answered by the cohort. Most students failed to mention that large jumps in I.E. provide evidence for electron shells as this corresponds to decreased shielding and electrons being closer to the nucleus. Many candidates also confused successive ionisation energies of an element with the trends in ionisation energy across a period or down a group.
15 b)	When an atom is excited (through heating or electrical excitation), electrons are promoted to higher energy subshells. An electron will then transition into the vacant subshell the electron was excited from and in the process release energy in the form a photon (light). The energy difference between the subshells when the electron returns to ground state is proportional to the colour / frequency / wavelength of the light and hence an emission spectrum is formed showing colours proportional to the energy differences in the atoms electron energy levels.	1 1	This was equally poorly answered. Many students understood the concept of photons causing the promotion of an electron to an excited state or the relaxation of an excited state, releasing a photon.. Many failed to link the different colours or wavelengths absorbed or emitted as evidence for different energy levels or shells in a single element. Rather students often stated that one energy level was seen per element.
16 a)	$1s^2 2s^2 2p^6 3s^2 3p^6$	1	The most common error in this question was to give the electron

			configuration of the phosphorous atom.
16 b)	Sc^{3+}, Ca^{2+}, K^{+}, Cl^{-}, S^{2-}, P^{3-} All these ions are isoelectronic / have the same number of electrons / same electron configuration. As their nuclear charge increases there is a larger electrostatic force of attraction from the nucleus to the electrons. This acts to pull the electrons in closer to the nucleus shrinking the radius.	1 1 1	The most common error in this question was confusion in the ordering of ion size (largest to smallest) or students ordering the radius of the atoms instead of ions.
16 c)	Sc^{3+}. All these ions are isoelectronic / have the same number of electrons / same electron configuration. As their nuclear charge increases there is a larger electrostatic force of attraction from the nucleus to the electrons. This increased force from the nucleus increases the energy required to remove an electron. Hence, scandium 3+ will have the highest ionisation energy.	1 1	This was answered well. Commonly students identified Sc as having the greatest number of protons / nuclear charge, but then many failed to link the number of protons to having the greatest electrostatic force and hence the highest ionisation energy.

Criterion 8

General Feedback

This section was well answered by the majority of students with approximately one third of students achieving scores of 36 and above out of a possible 45 marks, despite the error in Question 23 c).

Some students appeared to run out of time in this section.

Students are attempting a greater number of questions rather than leaving blank spaces. This gives the potential to gain part marks.

Students are encouraged to use scientific notation in this section rather than normal notation (on their calculator and written responses). This would avoid transcription errors when recording leading or trailing zeros and save time.

Students must show logical working alongside their answers to gain full marks. Each new step in a calculation must be written separately, not flowing on (e.g. in a multi-step calculation such as n(HCl)= cV = 2.00 x 0.100 = 0.200 mol /2 = 0.100. This is chemically incorrect).

Student need to consistently specify what they are calculating in their answers (e.g. n(NaOH) = …) rather than recording the numbers alone.

Units should be used throughout calculations, not just the final answer. This assists in showing logical working and potentially awarding part marks for incomplete or incorrect calculations.

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 was penalised –0.5 marks. Question 18 and 22 a) are an exception.

Question 17 feedback

Well answered.

Question 18 feedback

Well answered.

2 is the appropriate number of significant figures.

Converting units from µg to g was often ignored or incorrect.

Units should be in $molL^{-1}$ (mol/L) rather than M in this course.

Question 19 feedback

To gain full marks, the limiting reagent must be identified, and supporting calculation/reasoning must be supplied.

The question was misread regularly, giving answers for mass or concentration rather than volume.

Question 20 feedback

a)

i) Well answered

Use of the combination equation of $m=\frac{MIt}{z96500}$ shows little understanding of the chemistry involved. Full marks were not awarded unless the equation is derived or additional information is given, such as how z was determined.

Unit conversion from hours to seconds was a common error.

ii) The majority of students did not account for the vapour pressure of water in this question.

Mole ratio was required to determined the moles of oxygen gas and could not be assumed as 1:1 to $n(e^-)$ or n(Cr).

The Combined Gas Equation was commonly used in this question but is incorrect.

b)

i) Well answered.

ii) A wide range of relevant reasons were deemed correct. Non-specific answers such as "human error" were not awarded marks.

Question 21 feedback

a) Well attempted.

Students need to show chemistry reasoning alongside their calculations. An algebraic approach is fine; however, being too brief will not gain full marks. A brief algebraic approach does not allow for awarding part-marks if a mistake is made.

b) When given the instruction "use your answer in item a)" you must use your answer from a), not the "assume the value…" given. This additional value is for students who were unable to answer a).

The mass of ethanol was given in the stimulus for the question at the top of the page. Students must remember this applies to all parts of the question, not just a).

In this calculation, the answer is already in kJ. Students regularly used J as the unit and incorrectly converted to kJ.

Question 22 feedback

a) Many students lost marks for not giving the equilibrium expression to begin with.

A range of assumptions were given; however, the most important assumption in this calculation is the approximation of (0.100-x) ≈ 0.100 for the equilibrium value for [OCl^-]. This avoids the need to solve the quadratic equation.

b) Well answered.

c) Students needed to apply their equilibrium (L.C.P) understanding to successfully answer this question.

The question asks specifically about the percentage of dissociation, not the value of K_a.

A mathematical approach with supporting reasoning was acceptable but was rarely correct.

Question 23 feedback

Students found this question difficult to work through as it required problem-solving and/or unit analysis to work with the percentage by mass value and the density value correctly.

a) There are multiple approaches to this question. All legitimate approaches were considered.

Logical setting out and units throughout the calculation allowed for part marks to be assigned using 'error carried forward'.

Both the pOH and K_w approaches were accepted for full marks.

b) The word "amount" was problematic for many students - "amount" is referring to moles, not mass or volume.

c) This question contained an error. No markers' comment.

d) Well answered by students who used their value from 23c) or the "show that" value given.

e) There are multiple approaches to this question. All legitimate approaches were considered. Logical setting out and units throughout the calculation allowed for part marks to be assigned.

Question	Sample Answer	Marks	Comments/ considerations for 2024 exam
17	Assume 100 g of the compound is present. $n(C)=\frac{39.98\text{ g}}{12.01\text{ g mol}^{-1}}$ $=3.33\text{ mol}$ $n(H)=\frac{6.71\text{ g}}{1.008\text{ g mol}^{-1}}$ $= 6.66\text{ mol}$ $n(O)=\frac{53.29\text{ g}}{16.00\text{ g mol}^{-1}}$ $=3.33\text{ mol}$ Ratio n(C) : n(H) : n(O) 3.33 : 6.66 : 3.33 Smallest whole number ratio 1 : 2 : 1 ∴ empirical formula is CH_2O	1 1 1	Same information presented in tabulated format (columns) was most common and accepted.
18	nC27H44O= 25×10-6 g384.648 g mol- 1 $n(C_{27}H_{44}O)=\frac{25\times10^{-6}\text{ g}}{384.648\text{ g mol}^{-1}}$ $=6.5\times10^{-8}\text{ mol}$ $[C_{27}H_{44}O]=\frac{6.51\times10^{-8}\text{ mol}}{0.499\text{ L}}$ $=1.3\times10^{-7}\text{ mol L}^{-1}$	1 1 1 (2 s.f)	
19	$n(CaCO_3)=\frac{20.0\text{ g}}{100.09\text{ g mol}^{-1}}$ $=0.200\text{ mol}$ $n(HCl)=2.00\text{ mol L}^{-1}\times0.100\text{ L}$ $=0.200\text{ mol}$ $n(HCl)_{needed}=n(CaCO_3)\times{}^{2}/_{1}$ $=0.200\text{ mol}\times2$ $=0.400\text{ mol}$ As $n(HCl)_{given}$ is < $n(HCl)_{needed}$, HCl is the limiting reagent.	1 1 1	The limiting reagent was determined and communicated in a range of ways and accepted.

	$n(CO_2)=n(HCl)\times {}^{1}/_{2}$ $= 0.200\ mol \times {}^{1}/_{2}$ $= 0.100\ mol$ $V(CO_2)=n(CO_2)\times 24.5\ L\ mol^{-1}$ $=0.100\ mol\times 24.5\ L\ mol^{-1}$ $=2.45\ L$	1	PV=nRT could be used here instead.
20 a) i)	$n(e^-) = \frac{It}{96500}$ $= \frac{1.00\ A \times (1\ h \times 60\ min \times 60\ sec)}{96500\ C\ mol^{-1}}$ $= 3.73 \times 10^{-2}\ mol$ $n(Cr) = \frac{n(e^-)}{3}$ $= \frac{3.73 \times 10^{-2}\ mol}{3}$ $=1.24\times 10^{-2}\ mol$ $n(Cr)=1.24\times 10^{-2}\ mol\times 52.00\ g\ mol^{-1}$ $=0.647\ g$	1 1 1	Could be completed in 2 steps. q=It then n(e-)=q/F
20 a) ii)	$n(e^-)=3.73\times 10^{-2}\ mol$ $n(O_2)=\frac{3.73\times 10^{-2}\ mol}{4}$ $=9.33\times 10^{-3}\ mol$ $p(O_2)=P_{total}-p(H_2O)$ $=101.33\ kPa-2.33\ kPa$ $=99.0\ kPa$ $V=\frac{nRT}{P}$ $=\frac{9.33\times 10^{-3}\ mol\times 8.31\times 293\ K}{99.0\ kPa}$ $=0.299\ L$	1 1 1 1	$n(O_2) = n(Cr) \times {}^{3}/_{4} = 1.24 \times 10^{-2} mol \times {}^{3}/_{4} = 9.33 \times 10^{-2}\ mol$ Could be used here instead.
20 b) i)	$\% \text{ Efficiency}=\frac{0.640\ g}{0.647\ g}\times 100$ $= 99.0\%$	1	
20 b)ii	A single reason required like: - Internal resistance in the system leading to heat loss from the system. - Chromium solid did not adhere to the cathode fully and deposited in the beaker.	1	A range of valid reasons (causing mass decrease) were accepted here.

<table>
<tr><td></td><td>Hydrogen gas was produced at the cathode from nitric acid presence.</td><td></td><td></td></tr>
<tr><td>21 a)</td><td>$C_2H_5OH_{(l)} \rightarrow 2C_{(s)} + 3H_{2(g)} + \frac{1}{2}O_{(g)}$ $\Delta H = +275\ kJ$
$2C_{(s)} + 2O_{2(g)} \rightarrow 2CO_{2(g)}$ $\Delta H = (2 \times -394)$
$= -788\ kJ$
$3H_{2(g)} + 1\frac{1}{2}O_{2(g)} \rightarrow 3H_2O_{(l)}$ $\Delta H = (3 \times -286)$
$= -858\ kJ$
$3H_2O_{(l)} \rightarrow 3H_2O_{(g)}$ $\Delta H = (3 \times +41)$
$= +123 kJ$
$C_2H_5OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)} \Delta H = -1248\ kJ$</td><td>3
1</td><td>Other methods and logical setting out were accepted.</td></tr>
<tr><td>21 b)</td><td>1.00 L methylated spirits = 789 g ethanol
$M(C_2H_5OH) = 46.07\ g\ mol^{-1}$
$n(C_2H_5OH) = \frac{789\ g}{46.068\ g\ mol^{-1}}$
$= 17.13\ mol$
$E = \Delta H \times n$
$= 1248\ kJ\ mol^{-1} \times 17.13\ mol$
$= 2.14 \times 10^4\ kJ$
$= 21.4\ MJ$</td><td>1
1
1</td><td>Full marks were given if 1200 kJ mol⁻¹ was used in this calculation if a) was unsuccessful.</td></tr>
<tr><td>22 a)</td><td><table>
<tr><td></td><td>HOCl ⇋</td><td>H^+</td><td>+ OCl^-</td></tr>
<tr><td>I</td><td>0.100</td><td>0</td><td>0</td></tr>
<tr><td>C</td><td>- x</td><td>+ x</td><td>+ x</td></tr>
<tr><td>E</td><td>(0.100- x)</td><td>x</td><td>x</td></tr>
</table>
$$K_a = \frac{[H^+_{(aq)}][OCl^-_{(aq)}]}{[HOCl_{(aq)}]} = \frac{x \times x}{(0.100 - x)}$$
As x<<0.100 due to HOCl as a weak acid (very low K_a), assume $(0.100 - x) \approx 0.100$</td><td>1
1</td><td>I.C.E. diagram not required
This can be expressed in various ways.</td></tr>
</table>

	$K_a=\frac{x^2}{0.100}$ $3.5\times10^{-8}=\frac{x^2}{0.100}$ $x^2=3.5\times10^{-9}$ $x=5.92\times10^{-5}mol\ L^{-1}$ $=[H^+]$ $pH=-log[H^+]$ $=-log(5.92\times10^{-5})$ $=4.23$	1 1	Must be 2 decimal places.
22 b)	$\%\ dissociation=\frac{5.92\times10^{-5}}{0.100}\times100$ $=0.059\ \%$	1	
22 c)	% dissociation would increase with further dilution. The concentration of all species would decrease when diluted. The equilibrium system will favour the forward reaction to partially increase the overall concentration of species according to L.C.P. (1:2 ratio of reactants to products)	1 1	
23 a)	Assume 1.00 L of disinfectant $\rho = 1.080\ g\ mL^{-1} = 1080\ g\ L^{-1}$ $m(NaOH)=1\ L\times1080\ g\ L^{-1}\times\frac{3}{100}$ $=32.4\ g$ $n(NaOH)=\frac{32.4\ g}{39.998\ g\ mol^{-1}}$ $=0.810\ mol$ $[NaOH]=\frac{0.810\ mol}{1.00\ L}$ $=0.810\ mol\ L^{-1}=[OH^-]$ $K_w=[H^+][OH^-]$ $1\times10^{-14}=[H^+]\times0.810\ mol\ L^{-1}$ $[H^+]=\frac{1\times10^{-14}}{0.810\ mol\ L^{-1}}$ $=1.23\times10^{-14}mol\ L^{-1}$ $pH=-log(1.23\times10^{-14}mol\ L^{-1})$ $=13.9$	1 1 1 1	Multiple approaches were possible for this question. All logical and chemically correct approaches were awarded marks. pOH was regularly used here instead of K_w approach. Full marks were awarded.

23 b)	$n(S_2O_3^{2-}) = 0.05000\ mol\ L^{-1} \times 38.48 \times 10^{-3}\ L$ $= 1.924 \times 10^{-3}\ mol$ $n(I_2) = n(S_2O_3^{2-}) \times {}^1/_2$ $= 1.924 \times 10^{-3}\ mol \times {}^1/_2$ $= 9.620 \times 10^{-4}\ mol$	1 1	
23 c)	$n(I_2)_{total} = n(I_2)_{total} \times \frac{1000}{25}$ $= 9.620 \times 10^{-4}\ mol \times \frac{1000}{25}$ $= 3.848 \times 10^{-2}\ mol$	1	***Error in question on exam paper. "Show that" value incorrect. Correct value shown here.
23 d)	$n(OCl^-)=n(I_2)$ $= 3.848 \times 10^{-2}\ mol$ $m(NaOCl) = 3.848 \times 10^{-2}\ mol \times 74.44\ g\ mol^{-1}$ $= 2.864\ g$	1 1	Full marks given if "show that" value used correctly.
23 e)	$m(disinfectant) = V \times \rho$ $= 50.00\ mL \times 1.080\ g\ mL^{-1}$ $= 54.00\ g$ $\%\ NaOCl\ in\ disinfectant = \frac{2.864\ g}{54.00\ g} \times 100$ $= 5.304\%$	1 1 1 (communication)	Multiple approaches were possible for this question. All logical and chemically correct approaches were awarded marks.