ASSESSMENT REPORT 2021

CHM415115 - Chemistry

Part 1

Criterion 5

General Comments

Students found the Criterion 5 section of the exam challenging, possibly due to wording in the stimulus, as their answers were often far removed from the intent of the questions. A common problem throughout this entire section was, as in previous years, failure to recognise that metal ions are generally oxidisers and that metals are reducers. Metals are not oxidisers. Also, students often neglected to use chemical equations to support their answers.

Question 1

Many students were able to engage with this question.

A. A number of students calculated the oxidation number of VO2+ as +3. Many students did not state the connection between highest oxidation number and the ability to oxidise. Students also interchanged the term charge for oxidation number.

B. i. Many students did not refer to actual electron structure. Several thought Al lost only p1 electron to become Al+, isoelectronic to Ne. Some did not connect the term reducer to the species losing electrons.

ii. Most students multiplied each equation correctly BUT many students did not reverse equation 2 and combined two reduction half equations.

Question	Answer	Marks	Comments / considerations for 2021 exam
1a i	$Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2e^-$ $VO^+_{2(aq)} + 4H^+_{(aq)} + 3e^- \longrightarrow V^{2+}_{(aq)} + 2H_2O_{(l)}$ Oxidiser: $VO^+_{2(aq)}$	0.5 2 0.5	–1.0 mark for each error If the oxidation and reduction half-equations were swapped, then max 1 mark.
1a ii	ON ($VO^+_{2(aq)}$) = +5 ON($VOCl_2$) = +4 ON($V^{2+}_{(aq)}$) = +2 Highest oxidation state corresponds to the strongest oxidiser, so $VO^+_{2(aq)}$ is best oxidiser.	1 1	–0.5 marks for each incorrect oxidation state, to a min of 0 marks out of 1. -0.5 marks if not referred to either oxidation state or ability to attract electrons

Question	Answer	Marks	Comments / considerations for 2021 exam
1b i	Al 2,8,3) loses 3 valence electrons to obtain stable electron configuration. Reducers lose electrons	1 1	either (2.8.3) or $1s^2 2s^2 2p^6 3s^2 3p^1$
1b ii	$3O_{2(g)} + 6H_2O_{(l)} + 4Al_{(s)} + 4OH^-_{(aq)} \longrightarrow 4Al(OH)^-_{4(aq)}$ Correctly present ox and red half equations: Multiply & add correctly: 1 Cancel down OH^-: 0.5	0.5 1 0.5	E^0 values were not required for the net cell equation. 0.5 marks given if no equation was provided, BUT the correct E^0 value was calculated.

Question 2

Students displayed many misconceptions in this question.

A. This was well answered.

B. Many students calculated the E^o_{oxid} but then did not state the E^o_{red}

C. Some students did not identify the non-standard conditions in the labelled diagram.

D. Many students thought electrode P would completely oxidise before Cu^{2+} ions are reduced in cell Q.

E. Generally answered well. Some students stated that ethanol produces hydroxide ions in solution which precipitate out with copper ions.

F. This was not answered well. Most students did not refer to their standard reduction potentials and identify that copper ions are not strong enough oxidants to cause silver anode to be oxidised i.e., cell will not operate. A common error was the failure to recognise that metal ions are generally oxidisers and that metals are reducers. Metals are not oxidisers.

Question	Answer	Marks	Comments / considerations for 2021 exam
2a	$Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$ Polarity of electrode: negative	1 1	Accept (-) sign for negative
2b	Set up reduction potential calculation Eg $E^0_{cell\ potential} = E^0_{ox'n\ pot} + E^0_{red'n\ pot}$ $0.16 = E^0_{ox'n\ potential} + 0.34$ $-0.18 = E^0_{ox'n}$ $\therefore E^0_{red'n\ potential} = 0.18$ V Answer with correct units and sign	1 1	Other techniques eg 0.16 = 0.34 – x, where x is reduction potential of half-cell P. –0.5 mark for each error (if answer oxidation potential -1 mark)

Question	Answer	Marks	Comments / considerations for 2021 exam
2c	Not at standard condition of 1 mol L^{-1}	1	
2d	Will have reached equilibrium or $[Cu^{2+}]$ decrease/increase reaching equilibrium.	1	No marks for Cu(s) /electrode depleted
2e	Solution 1: Barium chloride Reason: Electrical neutrality is maintained through movement of ions through the salt bridge connecting the half-cells. Precipitate of $BaSO_4$ will prevent this movement. Solution 2: Ethanol Reason: Does not contain ions so there is no movement of ions through salt bridge.	1 1	No mark allocated if reason not given or incorrect reason given (even if species was identified) Absence of ions/charge needed must be mentioned.
2f	Cell can't function Explanation E°<0, not spontaneous, or Copper ions not strong enough oxidant to cause silver to be oxidised	1 1	

Question 3

This question was generally not answered well.

Students who were skilled at the use of the reduction potential table to calculate reaction Eo values should have scored well on this question. Unfortunately, this was rarely the case.

A. This was not answered well. Many students interpreted "can exist together" as meaning can react together.

B. i. This was generally well answered. Some students did not balance the equation.

ii. This was generally well answered. The order of the species within each cell was well structured. Spectator ions are NOT included. Symbols of states should be included.

iii. Many students received full marks. Some did not include the hydrogen reference half-cell. Students are encouraged to provide some indication about whether the half-equations written are in order of increasing or decreasing oxidising strength.

Question	Answer	Marks	Comments / considerations for 2021 exam
3a	Identify $Sn^{2+}_{(aq)}$ and $Br^{-}_{(aq)}$ Explain Since $Br^{-}_{(aq)}$ is not a strong enough reducer to reduce $Sn^{2+}_{(aq)}$ to Sn. E° = - 1.23V $Sn^{2+}_{(aq)}$ and $Fe^{3+}_{(aq)}$ cannot exist together since $Sn^{2+}_{(aq)}$ would be oxidised to $Sn^{4+}_{(aq)}$ by $Fe^{3+}_{(aq)}$, a strong enough oxidiser: $Sn^{2+}_{(aq)} + 2Fe^{3+}_{(aq)} \longrightarrow Sn^{4+}_{(aq)} + 2Fe^{2+}_{(aq)}$ E° = +0.62V	1 2	Students scored higher marks by including equations and E^0 values showing spontaneous or non-spontaneous reactions.
3bi	$C_{(s)} + 2B^{+}_{(aq)} \longrightarrow C^{2+}_{(aq)} + 2B_{(s)}$	1	–0.5 each error (eg, missing the 2 prefix). No deduction for missing states.
3bii	$A_{(s)}\|A^{2+}_{(aq)} \parallel C^{2+}_{(aq)}\|C_{(s)}$	1	–0.5 each error, states expected
3biii	Reduction potential table $B^{+}_{(aq)} + e^{-} \rightleftharpoons B_{(s)}$ $2H^{+}_{(aq)} + 2e^{-} \rightleftharpoons H_{2(g)}$ $C^{2+}_{(aq)} + 2e^{-} \rightleftharpoons C_{(s)}$ $A^{2+}_{(aq)} + 2e^{-} \rightleftharpoons A_{(s)}$ Correctly written as reduction potentials: Correct order, including placement with respect to hydrogen half equation:	1 2	No penalty if not using equilibrium arrows If hydrogen not second or not included -1 mark. (if correct equation but written in complete reverse order -1)

Question 4

The situation described was that of two metals in contact in a damp environment with oxygen present which students should recognise as accelerated corrosion to the most reactive (or strongest reducer) metal.

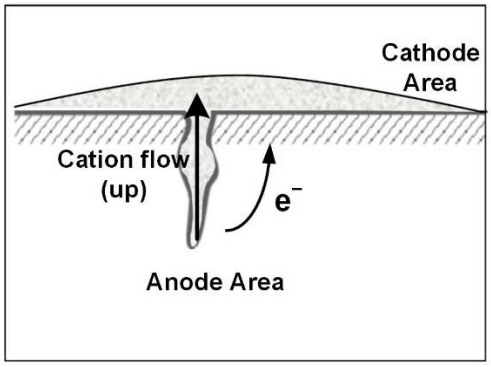
A. i. (A number of students used the term 'differential aeration'. Many did not recognise the conditions for an electrochemical cell or the fact that copper metal becomes an efficient conducting cathodic site which accelerated the corrosion of the iron nails.

ii. Very few students recognised that paper, hair, wool are non-conductors of electricity and thought that they prevented iron from coming into contact with water, oxygen and salt.

B. i. The protective zinc layer confused many students. Common errors included electrons travelling through water AND ions travelling through metal.

ii. Very few students recognised this as a differential aeration scenario. Answers often did not use any terms connected to REDOX. Many students received full marks. Some did not include the hydrogen reference half-cell. Students are encouraged to provide some

indication about whether the half-equations written are in order of increasing or decreasing oxidising strength.

Question	Answer	Marks	Comments / considerations for 2021 exam
4a i	An electrochemical cell is made with the two metals in contact in seawater (the electrolyte). Fe nails form the anodes, and is oxidised The Cu plate (cathodes) becomes the site of reduction of oxygen: $Fe_{(s)} \longrightarrow Fe^{2+}_{(aq)} + e^-$ $O_{2(g)} + 2H_2O_{(l)} + 4e^- \longrightarrow 4OH^-_{(aq)}$ The Cu plates become detached because the Fe nails holding them in place corrode more quickly than they would if they were not attached to the Cu.	1 Equat'n = 1 1	Dissimilar metals in contact required Fe corrodes in preference to copper. Link to question in some form required
4a ii	There is no electrical contact between metals because the wool/paper/hair mixture does not allow for the flow of electrons from Fe to Cu	1	Need to consider e^- flow or electrical contact or no marks allocated.
4b i		2 (0.5 each label)	Any reasonable presentation (marks were deduced for ions flow through metal, electrons flow through water, anode and cathode not spaced apart)
4b ii	Oxidation occurs at the edges of the hole, since there is less O_2 present, turning metal into metal ions. Mass of iron metal decreases, hence hole gets deeper	1 1	Oxygen concentration gradient or differential aeration (1 mark) and loss of Fe mass required (1 mark)

Question 5

Students who were skilled at the use of the reduction potential table to identify oxidant strengths should have scored well on this question.

A. This was generally well answered. However, weaker responses were common because students failed to clearly identify that metal ions are generally oxidisers and that metals are reducers. Metals are not oxidisers. A common error noted was 'zinc is a stronger oxidant than water' rather than zinc ions are stronger oxidants than water.'

B. This was not answered well. Few students identified that Al had to be the cathode. Even fewer recognised the contaminant problem if Al was set as the anode.

Question	Answer	Marks	Comments / considerations for 2021 exam
5a	$Zn^{2+}_{(aq)} + 2e^- \longrightarrow Zn_{(s)}$ E^0 = -0.76 V $H_2O_{(l)} + 2e^- \longrightarrow 2OH^-_{(aq)} + H_{2(g)}$ E^0= -0.83 V $Al^{3+}_{(aq)} + 3e^- \longrightarrow Al_{(s)}$ E^0 = -1.71 V Zn^{2+} is a stronger oxidiser than water so is preferentially reduced to Zn metal. Al^{3+} is a weaker oxidiser than water, so water is reduced, and Al metal is not produced.	1 1 1	Water and only one metal ion reduction equation required. (-0.5 for each error)
5b	Cathode If it was the anode Al would get preferentially oxidised because it is a stronger reducer	1 1	

Part 2
Criterion 6

General Comments

Students are advised to stop using abbreviations and confusing arrows in 'Explaining' type questions. LCP for Le Chatelier's Principle is acceptable but other abbreviations should be avoided.

Question 6

This was generally answered well by most students. Question 6a requires explanation and some students lacked detailed working and did not gain full marks. Interestingly in question 6b, many students did not realise that the pH of water is 7 at 25 °C. Some students believe that the concentration of water needs to be included when quoting its pH.

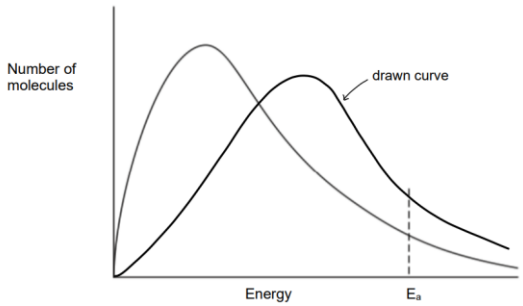
In part (c) some students wrote that a catalyst provides a surface for a reaction. This only applies to heterogenous catalysts and is not a general definition.

Question	Answer	Marks	Comments / considerations for 2021 exam
6a	Calculation steps: $c(HCl) = \frac{320}{36.46} = 8.78 \text{ mol L}^{-1}$ $\therefore$ $c(H^+) = 8.78$ mol L^{-1} pH $= -\log[H^+] = -\log 8.78 = -0.94$ This shows that pH is not in the 0 to 14 range.	1 0.5 1 0.5	0.5 marks for relating [HCl] with $[H^+]$ Answer must include comment for full marks
6b	Temperature **or** Must be at 25°C **or** Standard laboratory conditions	1	No marks for *Standard temperature and pressure* (STP) *Pressure* was ignored
6c	A catalyst: - increases the rate of a chemical reaction without being consumed - provides alternate pathway/reaction mechanism - lowers the activation energy barrier Explanation linked to UV light not being a substance **or** UV light would provide sufficient energy to break up bonds	1 1	2 out of 4 things required for the mark No mark awarded for *UV light is not regenerated*
6		6	

Question 7

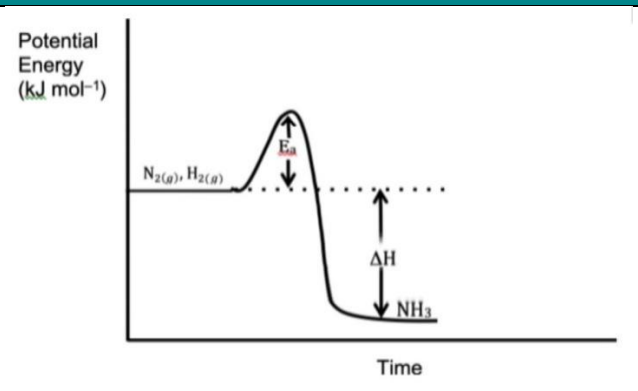
It was pleasing to see that many students have a good grasp of how pressure and temperature effect the equilibrium position and how a compromise between reaction rate and equilibrium can occur.

The drawing of the higher temperature curve proved challenging for some. Students are reminded that the curve is not a semicircle and that the area beneath the curves should be approximately the same.

Question	Answer	Marks	Comments / considerations for 2021 exam
7a	Minimum enthalpy: forward Maximum entropy: back	1	No part marks awarded
7b	LCP states that an equilibrium will adjust to counteract a change placed on the system Equilibrium favours the forward (right) reaction Methanol yield will increase	1 0.5 0.5	
7c i		1	0.5 mark for areas under curves being approximately equal 0.5 mark if graph is skewed right
7c ii	An increase in temperature increases kinetic energy of particles (on average) Increases number of collisions Increases energy of collisions (on average), with more particles able to overcome the activation energy Hence there will be more effective collisions, so reaction rate increases.	0.5 0.5 1 1	**OR** refer to the area under the graph above E_a. Marks also awarded for explaining the increase in Ek as an exothermic reaction proceeds.
7d	High temperatures favour the endothermic reaction (equilibrium shifts towards the reactants) High temperatures increase overall reaction rate Hence a balance must be reached to maximise yield of methanol without compromising reaction rate.	1 1 1	

Question 8

This question was generally well answered by most students. Some students struggled with part (b) and gave a range of numeric values rather than considering the bond forming or breaking concept. The more challenging part (e) was well answered with the most common error relating to students not reading the question and missing information relating to the dynamic equilibrium reactions when the lid is on the bottle.

Question	Answer	Marks	Comments / considerations for 2021 exam
8a		2	0.5 if correct shape (exothermic) 0.5 if appropriate scale **OR** numbers included 0.5 Include Ea and ΔH **OR** numbers in correct places 0.5 Include product (NH_3)
8b	The amount of energy required to break (or energy released to form) the N≡N bond in gaseous nitrogen	1	No penalty for mixing up "required" or "released"
8c	Energy required to break reactant bonds = 941 + 3 x 436 = 2249 kJ (endo) Energy given out when N–H bonds form = 6 x 391 = 2346 kJ (exo) $\Delta H = E_{bonds\ broken} - E_{bonds\ formed}$ = 2249 – 2346 = –97 kJ	1 1 1	Or ΔH = –48.5 kJ mol^{-1} 0.5 marks for –97 0.5 marks for kJ units
8d	$H_2O_{(l)}$ Bronsted-Lowry acids donate protons	1 1	
8e	Lid on: Rate of forward reaction = rate of back reaction Lid off: open system, gaseous ammonia escapes According to LCP equilibrium shifts left **or** $Q>K_c$ **or** Rate of forwards reaction would decrease Producing more ammonia	1 0.5 1 0.5	
8		11	

Question 9

An interesting and quite challenging question relating to an autocatalytic redox reaction.

Many students failed to gain marks on the easier parts of this question. In part (a), many did not see the word 'properties' and wrote general ideas such as concentration, moles, MnO_4^- or even CO_2 without stating its property. In (b) many students incorrectly measured the slope of the line as 0.006/50 = 1.2×10^{-4} by using the coordinates of the curve at the 50 second mark, rather than determining the rate of change. The challenging part (d) required an explanation of the initial slow reaction rate, the rapid rate in the middle and the slow reaction rate at the end. Many students either described the shape of the curve (gaining no marks) or explained only one section of the curve.

Question	Answer	Marks	Comments / considerations for 2021 exam
9a	Mass of flask **or** Gas produced – volume or mass of $CO_{2\,(g)}$ produced **or** Colour change: purple to pink **or** pH will increase as $[H^+]$ decreases	1	Any two, 0.5 each
9b	Rate $= \frac{0.01-0.006}{50} = 8 \times 10^{-5}$ mol L^{-1} s^{-1}	1	No penalty for no units Sign of final answer ignored
9c	Catalyst	1	
9d	Rate is slow at first, when the concentration of the catalyst (Mn^{2+}) is low As catalyst concentration increases (as it is a product of the reaction), reaction rate increases As the concentration of reactants decreases, so does rate of reaction	1 1 1	No marks awarded for explanations based about temperature
9		6	

Question 10

Most students found this question quite challenging.

In part (a) many neglected to include the equilibrium equation and part (b) most students don't understand that HCl is a strong acid and fully dissociates making Ka irrelevant. Perhaps some students were discussing HClO and many students wrote 'it is a weak acid'.

Part (c) was easier, although many students incorrectly think that Cl_2 and $2Cl^-$ are the same. Interestingly, the strongest answer has the HCl dissociated into H+ and Cl- as this allows an easy discussion point for part (d).

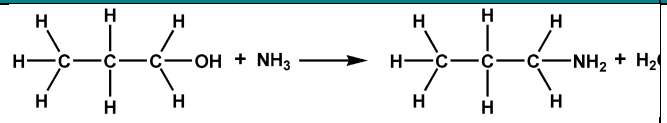
Part (d) was answered well by only a few students. This is a straightforward acid equilibrium equation, so that a decrease in pH means high $[H^+]$ which shift the equilibrium to the left forming more Cl_2. Some students understood that the low pH means high $[H^+]$, but either forgot about LCP, or forgot about the equation in part (c), or some assumed the H^+ was from the weak acid HClO.

Question	Answer	Marks	Comments / considerations for 2021 exam
10a	$K_a = \frac{[H^+_{(aq)}][ClO^-_{(aq)}]}{[HClO_{(aq)}]}$ $HClO_{(aq)}$ **or** Reactants	1 1	No penalty for missing states –1 mark for no square brackets Accept "H^+ *and* ClO^-" if K_a expression was written upside-down
10b	HCl fully dissociates in water	1	0.5 marks for "HCl is a strong acid"
10c	$Cl_{2(aq)} + H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + Cl^-_{(aq)} + HClO_{(aq)}$ **or** $Cl_{2(aq)} + H_2O_{(l)} \rightleftharpoons HCl_{(aq)} + HClO_{(aq)}$	1 1 for states	–0.5 marks if no equilibrium arrows included –0.5 mark if $2Cl^-_{(aq)}$ is written instead of $Cl_{2\,(aq)}$ 0.5 marks for including states for nearly all species
10d	Cl_2 At low pH, $[H^+_{(aq)}]$ is high therefore, equilibrium is positioned to the left	0.5 0.5 1	Full marks if explanation includes relationship between pH and $[H^+]$ **and** direction of equilibrium shift
10		7	

Part 3
Criterion 7

- Students are reminded to use their reading time effectively before commencing their exam as it was clear in this section that a significant number of students completely missed question 17 which came after a "BLANK PAGE. Exam Continues over the page" instruction. Whilst it can be argued that the formatting of the booklet misled some students, the instructions were very clear and should not have been missed.
- Students should also refrain from using acronyms to answer questions. In many instances' students were using very unusual and unfamiliar acronyms and expecting markers to understand what they were meant to represent.
- Students are reminded to always draw hydrogens to complete structural formula. C- is not the same as C-H.
- Students should take care with their handwriting when naming and drawing organic compounds to avoid confusion and unintentional errors.

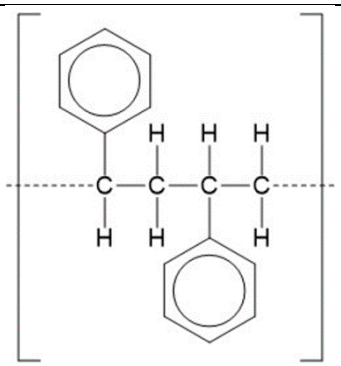
Question 11

Question	Answer	Marks	Comments / considerations for 2021 exam
11a i		1	- 0.5 if H_2O missing - 0.5 if semi-structural (in CH_2) No points molecular formula
11a ii	The –OH group and –NH_2 in the organic molecules are both polar due to uneven sharing of electrons in the covalent bond between the functional group and the carbon chain. Polar molecules interact with polar water molecules, forming H-bonds, hence the molecules dissolve readily.	1 1	1 for clarity around polarity; expecting mention of H-bonding 1 for bonding in water being the same as bonding in alcohol/amine Drawings to illustrate interactions were helpful and gained marks
11b	Further oxidation is possible with excess acidified dichromate solution, forming ethanoic acid. Ethanal is the final product in Cu catalyst reaction; no further oxidation occurs.	1 1	Discussion of purity is good, but not required; max 1 mark. Full marks must include Cu not oxidising to carboxylic acid.
11c	Condensation polymer (accept polyester) **Esterification** reaction between the –**OH** and –**COOH** functional groups in neighbouring molecules.	1 1	0.5 for identifying that this is not an addition polymerisation but failing to identify esterification and functional groups.
11		7	

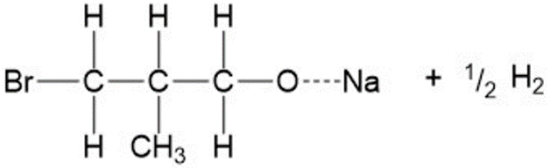
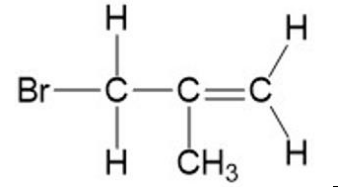
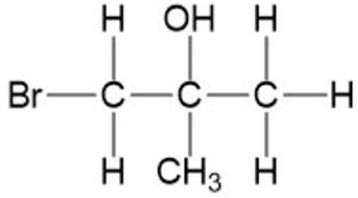
Question 12

Question	Answer	Marks	Comments / considerations for 2021 exam
12	X = 1-iodopropane Y = propan-1-ol Z = propanoic acid	1 1 1	If formulae only: – 1 mark -0.5 overall if incorrect dashes between number and letter -0.5 per location number absent
12		3	

Question 13

Question	Answer	Marks	Comments / considerations for 2021 exam
13a	Structure I shows the 3 different types of bonds (single, double and 6 equal bonds in benzene ring). The circle represents delocalised electrons above and below the benzene ring; there are no double bonds present in ring.	1 1	1 Accept arguments for substitution reactions instead of addition reactions **or** Bond lengths are equal 1 Electrons are delocalised
13b		1	-0.5 if no indication of continuing polymer chain
13		3	

Question 14

Question	Answer	Marks	Comments / considerations for 2021 exam
14a	3-bromomethylpropan-1-ol	1	Ignore inclusion of 2 in methyl? Ignore missing hyphens – assessed elsewhere -0.5 if missing one number (either 3 or 1)
14b	(Product side of equation) 	1	Ignore states due to 1 mark Ignore ionic interaction notation -0.5 for excluding hydrogen -0.5 for not balancing
14c	Carbonyl/aldehyde	1	No points for drawing a functional group.
14d i		1	
14d ii		1	
14		5	

Question 15

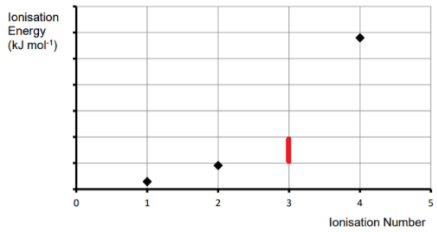
Question	Answer	Marks	Comments / considerations for 2021 exam
15a i	The gas particles **collide with the tyre wall** as they move randomly.	1	
15a ii	When temperature increases, the molecules are **moving more quickly**. With increased speed, they **hit the walls more often and with more force**, hence the pressure increases.	1 1	1 mark for molecules moving faster 0.5 marks hitting the walls more often 0.5 marks hitting the wall with more energy
15b	Yes Treating both as ideal gases, PV = nRT. Same volume so same no of molecules/moles; same temperature increase, so pressure increase is the same.	0.5 0.5 1	
15c	From combined gas equation, since T constant: $nP_tV_t = P_cV_c$, where n is no of tyres filled. n x 8.5 x 220 = 18000 x 50 ∴ n = 481 tyres	1: 1	Students not required to consider residual pressure in cylinder but are required to consider full tyres; answer must be 481 or fewer tyres, with a justification. – 0.5 if they have 481.3 tyres
15d	In the respective molecules, the oxygen atoms have a higher electronegativity due to a higher nuclear charge **(+8) than nitrogen (+7)** Oxygen and nitrogen have **similar shielding or valence electrons** in second shell. Hence oxygen's electrons are **held closer**/attracted to the nucleus, and so oxygen molecules are smaller.	1 1 1	
15		10	

Question 16

Question	Answer	Marks	Comments / considerations for 2021 exam
16a	$1s^2 2s^2 2p^6$	1	
16b	Mg_3N_2	1	
16c	When electrons return to lower energy states	0.5	

	they emit photons of a specific wavelength which correspond to the difference in energy between energy levels.	1 0.5	
16		4	

Question 17

Question	Answer	Marks	Comments / considerations for 2021 exam
17a	$Al_{(g)} \rightarrow Al^{+}_{(g)} + e^{-}$	1	-0.5 if not gas state (symbols required) Ignore energy and must include electron
17b		1	X is higher in energy than 2nd ionisation X is significantly lower than ionisation 4. Accept range marked on graph
17c	Electron configurations of Al is $[Ne)3s^2 3p^1$. The unstable Al^+ ion is formed when the $3p^1$ electron is lost – not at stable electron configuration, but the full $3s^2$ gives limited stability. Then losing one 3s electron gives no such stability, so the Al^{2+} ion is not observed. The stable Al^{3+} ion is formed when the 3rd electron (shell) is lost; this ion has a noble gas electron configuration.	1 1 1	Reasonable justification for Al^+ forming Reasonable justification for Al^{2+} not forming The stable Al^{3+} ion is formed when the 3rd electron (shell) is lost; this ion has a noble gas electron configuration. *note: reasonable justification must identify the subshell from which each e^- is removed and/ or what remains
17d	Al loses 3 electrons to react compared to Na (1) and Mg (2) Al has the highest nuclear charge of the metals in period 3 Electrons are harder to remove so Al is less reactive Chlorine has the highest nuclear charge. Hence it has the highest affinity for electrons, so is the most electronegative	0.5 1 0.5	0.5 Al loses 3 e^- to achieve noble gas configuration 1 Removing an electron from a positive species requires more energy than removing electrons from neutral species. 0.5 The valence electrons for Period 3 elements are in the same shell

		1	0.5 Chlorine has the greatest nuclear charge 0.5 Therefore it has the strongest attraction to additional electrons
17		8	

Part 4
Criterion 8

General comments:

- Overall students did very well on this section of the paper.
- However, many calculation errors were made such as dividing instead of multiplying, calculator errors, transcribing numbers from calculators or the question incorrectly which all led to loss of part marks.

Question 18

A. This question was answered well.

B. Students are reminded to read the question carefully as many tried to use values from part (a) that were not relevant. A number of students ignored the water of hydration.

Question	Answer	Marks	Comments / considerations for 2021 exam
18a	$n(Na_2CO_3) = 0.02335 \times 0.0729$ $= 1.702 \times 10^{-3}$ mol $\therefore n(HCl) = 2 \times n(Na_2CO_3)$ $= 2 \times 1.702 \times 10^{-3}$ $= 3.40 \times 10^{-3}$ mol $\therefore c(HCl) = \frac{3.40 \times 10^{-3}}{0.025}$ $= 0.136$ mol L^{-1}	1 1 1	
18b	$M(Na_2CO_3.10H_2O) = 286.14$ g mol $^{-1}$ $n(Na_2CO_3.10H_2O) = cV$ $= 0.0729 \times 0.25$ $= 1.823 \times 10^{-2}$ mol $m(Na_2CO_3.10H_2O) = mM$ $= 1.823 \times 10^{-2} \times 286.14$ $= 5.21$ g	1 0.5 0.5	Ignored H_2O maximum 1 mark
18		5	

Question 19

A. Common errors were misreading the units of density that were in g/mL and trying to find ΔH instead of the E released.

B. Only having the specific heat capacity for water is an indication that students can only use the mass of water for this E=mcΔT calculation. Many students found the energy released and did not go on to calculate the no. of moles or ΔH. Students need to be mindful that exothermic reactions releasing heat should have a negative ΔH with units in kJ/mol. Temperature change does not need to be converted into Kelvin.

C. This question was generally well answered.

Question	Answer	Marks	Comments / considerations for 2021 exam
19a	p = m/V ∴ m(C_2H_5OH) = 0.789 x 20 = 15.78 g ∴ n(C_2H_5OH) = $\frac{15.78}{46.07}$ = 0.343 mol ∴ Heat released = 0.343 x 1367 = 468 kJ	1 1 1	-0.5 for 0.020 rather than 20 (g/mL not g/L) -1 used ΔH =E/n but then found ΔH instead of E. -0.5 for kJ/mol
19b	E(H_2O) = mc Δ T = 200 x 4.184 x 53.3 = 44.6 kJ n(C_2H_5OH) = $\frac{1.75}{46.07}$ = 0.0380 mol ∴ ΔH = $\frac{44.6}{0.0380}$ = -1174 kJ mol^{-1}	1 1 1	-0.5 for converting to Kelvin -0.5 for using the mass of Ethanol instead of water -0.5 for incorrect conversion of 1 mL= 1 g of H_2O -0.5 for kJ not kJ/mol -0.5 for not including –'ve
19c	Equation 1: (given equation reversed and multiplied by 2) $2CO_{2\,(g)} \longrightarrow 2CO_{(g)} + O_{2\,(g)}$ ΔH_1 = +566 kJ Equation 2: $C_2H_5OH_{(l)} + 3O_{2\,(g)} \longrightarrow 2CO_{2\,(g)} + 3H_2O_{(l)}$ ΔH_2 = –1367 kJ Hence, Δ H for incomplete combustion: $C_2H_5OH_{(l)} + 2O_{2\,(g)} \longrightarrow 2CO_{(g)} + 3H_2O_{(l)}$ Δ H = Δ H_1 + Δ H_2 = (+566) + (–1367) = – 801 kJ	1 1	0.5 for each step For common incorrect answers some working must be shown for part mark. Variation to method accepted. -0.5 for incorrect sign in this calculation
19		8	

Question 20

Generally, this question was answered well. Most students lost half a mark for incorrect significant figures in part (b). Two significant figures were expected as that is the smallest number of significant figures for the values used to calculate the answer.

Question	Answer	Marks	Comments / considerations for 2021 exam
20a	$n(MnO_4^-) = cV$ $= 0.020 \times 1.00 \times 10^{-3}$ $= 2.0 \times 10^{-5}$ mol from equation $n(H_2O_2) = \frac{5}{2} \times n(MnO_4^-)$ $= \frac{5}{2} \times 2.0 \times 10^{-5}$ $= 5.0 \times 10^{-5}$ $\therefore m(H_2O_2) = 5.0 \times 10^{-5} \times 34.016$ $= 1.70 \times 10^{-3}$ g $= 1.7$ mg	0.5 1 0.5	
20b	$n(MnO_4^-) = 0.02 \times .00534 = 1.068 \times 10^{-4}$ mol $n(H_2O_2) = \frac{5}{2} \times n(MnO_4^-) = 2.67 \times 10^{-4}$ mol $m(H_2O_2) = 2.67 \times 10^{-4} \times 34.016 = 0.00908$ g % by mass = $\frac{0.00908}{0.334} \times 100$ $= 2.72\%$ To correct no. of significant figures = 2.7%	1 1 1	Alternative Method from part (a) 1.00 mL MnO_4^- ≡ 1.7 mg H_2O_2 ∴ 5.34 mL MnO_4^- ≡ 1.70×5.34 mg H_2O_2 $= 9.078$ mg H_2O_2 % by mass = $\frac{9.078}{334} \times 100 =$ 2.7% -0.5 for incorrect sig fig (2 s.f. required)
20		5	

Question 21

A. Students who recognised that they needed to find the hydroxide concentration and use Kw or pOH to find the pH answered this question well. Some students did not use coefficients to correctly identify n(OH−)=n(NaOH)=n(Na). Many students incorrectly tried to use the concentration of water or hydrogen to find the concentration of H+ ions for the pH calculation. Students should note that if it is not an equilibrium reaction the use of ICE tables is not appropriate for calculating moles.

B. i. This question was generally well answered. Marks were lost for unclear communication. It is recommended that students clearly state which quantities are available and which are required to show which substance is in excess. Use of the abbreviation XS was misleading.

ii. Many students did not use the n(Mg) that reacted to calculate the n(Mg2+). Instead, they used total n(Mg) or calculated the n(Mg) remaining.

Question	Answer	Marks	Comments / considerations for 2021 exam
21a	From equation $n(OH^-) = n(Na) = 1.08 \times 10^{-2}$ mol $c = \frac{n}{V} = \frac{1.08 \times 10^{-2}}{0.5} = 2.16 \times 10^{-2}$ mol L^{-1} Since $[OH^-][H^+] = 1 \times 10^{-14}$ $[H^+] = \frac{1 \times 10^{-14}}{2.16 \times 10^{-2}} = 4.63 \times 10^{-13}$ mol L^{-1} $pH = -\log[H^+] = -\log 4.63 \times 10^{-13} = 12.3$	1 1 1	-0.5 for using V= 500 Alternative method pOH = $-\log[OH^-]$ $= -\log 2.16 \times 10^{-2}$ = 1.67 pH =14 – pOH = 14 – 1.67 = 12.3 If pH calculation used incorrect $[H^+]$, then error carried forward if workings shown for $[H^+]$. However, -0.5 for an unrealistic answer of a low pH for a hydroxide solution
21b i	$n(Mg) = \frac{0635}{24.31} = 0.0261$ mol $n(H^+) = 0.0500 \times 0.98 = 0.049$ mol If all the H^+ reacts, n(Mg) required = 0.49/2 = 0.0245 mol This is available, so Mg is in excess by 1.6×10^{-3} mol	1 1 1	Value of excess not required in the answer provided Mg is identified in excess by a correct comparison of how much reactant is present vs how much reactant is required. -0.5 for correct calculations but small error in communication
21b ii	$n(Mg^{2+}) = 0.0245$mol Conc $(Mg^{2+}) = \frac{0.0245}{0.0500} = 0.490$ mol L^{-1}	1 1	If any calculation involves $[H^+]$, max 1 mark
21		8	

Question 22

A. Generally, well answered but a clear statement that Q does not equal Ka was required.

B. i. This was well answered.

ii. This was also well answered. However, some students used moles instead of concentration for the Kc calculation and some did not use the coefficients in the Kc expression.

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th><th>Comments / considerations for 2021 exam</th></tr>
<tr><td>22a</td><td>$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} = 1.76 \times 10^{-5}$
$Q = \frac{1.2 \times 10^{-3} \times 8.3 \times 10^{-6}}{1.5 \times 10^{-3}} = 6.64 \times 10^{-6}$
Since $Q \neq K_a$ the system is not at equilibrium</td><td>1
1</td><td>–0.5 Not using Q</td></tr>
<tr><td>22b i</td><td><table><tr><td></td><td>E</td><td>F</td><td>G</td></tr><tr><td>I</td><td>2.0 mol</td><td>1.0 mol</td><td>0</td></tr><tr><td>C</td><td>– 0.4 mol</td><td>– 0.8 mol</td><td>+0.8 mol</td></tr><tr><td>E</td><td>1.6 mol</td><td>0.2 mol</td><td>0.8 mol</td></tr></table>n(E) = 1.6 mol; n(F) = 0.2 mol</td><td>1
1</td><td>1 mark for E or F correct.
1 mark for correct numbers in C but incorrect final moles
1 mark for incorrect numbers in C but correct moles for what they did use.</td></tr>
<tr><td>22b ii</td><td>[E] = $\frac{2.5}{1.5}$ = 1.67 mol L^{-1} [F] = $\frac{1.2}{1.5}$ = 0.80 mol L^{-1}
[G] = $\frac{0.85}{1.5}$ = 0.567 mol L^{-1}
Kc = $\frac{[G]^2}{[E][F]^2}$
= $\frac{[0.567]^2}{[1.67][0.8]^2}$ = 0.300 (mol L^{-1})$^{-1}$</td><td>1
1
1</td><td>-1 for no calculations
-1 for Kc expression error
States not required because expression not explicitly asked for in question.</td></tr>
<tr><td>22</td><td></td><td>7</td><td></td></tr>
</table>

Question 23

A. Generally, well answered but a common error was using the moles of oxygen instead of calculating the moles of KClO3 for the mass calculation

B. Students who attempted this question were successful. There were many methods of approaching this question such as comparing coulombs, n(O2), n(e-) and V(O2). For full marks, a statement was required regarding the accuracy of the claim.

Question	Answer	Marks	Comments / considerations for 2021 exam
23a	PV = nRT $n(O_2) = \frac{98.2 \times 0.0502}{8.31 \times 293} = 2.025 \times 10^{-3}$ mol $\therefore n(KClO_3) = 2.025 \times 10^{-3} \times \frac{2}{3} = 1.35 \times 10^{-3}$ mol $\therefore m(KClO_3) = 1.35 \times 10^{-3} \times 122.5$ $= 0.165$ g	1 1 1	
23b	1 amp hour = 3600 C $\therefore\ n(e^-) = \frac{q}{F} = \frac{3600}{96500} = 0.0373$ mol $\therefore n(O_2) = \frac{1}{4} \times n(e^-)$ (from half equation) $= \frac{1}{4} \times 0.0373$ $= 9.33 \times 10^{-3}$ mol At SLC 1 mol of O_2 occupies 24.5 L $\therefore 9.33 \times 10^{-3}$ mol occupies $9.33 \times 10^{-3} \times 24.5$ $= 0.228$ L $\therefore V(air) = 0.228 \times \frac{100}{21} = 1.09$ L = 1 L Statement: Claim is correct to 1 sig fig, since data of 1 L is to 1 sig fig, or claim ~ 9% wrong	1 1 1 1	Various methods possible, which will elicit different responses for accuracy of claim. The initial assumption of 1 L air requiring 1 Ahr not quite accurate. Eg V (air) = 1 L ⇒ $V(O_2) = 0.21$ L ⇒$n(O_2) = 8.57 \times 10^{-3}$ ⇒$n(e^-) = .0343$ mol ⇒ q = 3309 C = ~0.9 Ahr NB which ever method is used the error is ~ 9% error. -1 if no statement of error or explanation of results mentioned
23		7	