Chemistry
Course Code: CHM415115

Part I - Criterion 5

This section was on the whole answered quite well with a large percentage of candidates receiving a better than pass mark, with approximately 60% of students receiving a mark greater than 24 out of 40. As an indication of this section being easier than previous years, 26% of students received a mark of 32 or greater.

Question 1

(a) Many students were able to successfully identify the hydrogen sulfide half equation from the electrochemical series and were able to pick up one mark without too much effort. On the other hand, developing a half equation for the reduction process proved to be more challenging with many students unable to successfully generate the necessary equation. Students would come up with a vast array of possibilities, some which involved sulfur dioxide, but many that did not really address the information in the question. The fact that sulfur was a product of both half equations proved to be a stumbling block for many students. Students were given some credit for valid attempts that involved some reference to sulfur dioxide converting to sulfur in the reduction half equation, but no credit was given if totally unrelated reactants and products were introduced. Similarly, the markers were reluctant to award any “error carried forward” (E.C.F.) marks when an implausible or unrelated equation was generated. In addition, of the students who were able to generate both half equations, too many made errors in combining the two half-equations to produce the overall equation, often despite recognising that the oxidation half-equation required multiplication by a factor of two.

(b) Marks were allocated if the oxidiser was successfully identified from whatever reduction half equation students had generated.

(c)(i) & (ii) Many students were able to reverse the $E^\circ$ value of the hydrogen sulfide oxidation equation from the E.C.S. and give the correct value of -0.14 V. However this proved to be a problem for students when following up on the second part of the question. When using $E^{\text{TOTAL}} = E^\circ_{\text{oxidiser}} - E^\circ_{\text{reducer}}$, students either incorrectly transposed or substituted incorrect values into the equation. Part credit was given for some incorrect answers, but only if full working was shown and it was deemed appropriate to apply ‘error carried forward’. No credit was given for single value answers if they were incorrect.

(d) Many students did not read the question carefully and omitted the reference to sulfur dioxide (or at least the oxidiser they had chosen in part (b)) so they automatically lost credit if that comparison was not made. Students found it difficult to justify why $H_2SO_4$ was the better oxidiser. For full marks, students were expected to explain why a higher oxidation state resulted in a stronger oxidiser.

(e) Many students incorrectly identified that the two substances mentioned were both “reducers” and therefore could not possibly react. This was given part credit for E.C.F. if clear evidence was given, such as the relevant half equation or $E^\circ$ value for the hydrogen peroxide half equation ($E^\circ = 0.68V$) in which it is in fact a reducer. For those students who correctly stated that a redox reaction could occur, giving valid evidence, included some reference to the fact that both a reducer and an oxidiser were present and that $H_2O_2$ was a stronger oxidiser than $S$, hence would react with $H_2S$. Credit was also given for giving an overall equation with a $E^{\text{TOTAL}} = E^\circ_{\text{oxidiser}} - E^\circ_{\text{reducer}}$ calculation showing an $E^\circ$ value of greater than zero. Markers did not accept statements such as “$H_2O_2$ is above $H_2S$ on the E.C.S.” as suitable evidence, nor did they accept graphics or diagrams showing a “Z” pattern or “S” pattern as justification for a reaction.
Question 2

(a) Markers were looking for some mention of two metals being in contact as justification for the establishment of an electrochemical cell causing corrosion of zinc. Students were also required to identify the cathode and anode reactions. Markers accepted verbal explanations or suitable half-equations. The white substance produced also attracted one mark with most students identifying it as either zinc hydroxide or zinc oxide. A number of students incorrectly identified the white substance as copper.

(b) Students were required to give two appropriate processes that could prevent further corrosion of zinc and give an explanation of the chemistry involved. Some suggested highly impractical or inappropriate methods that were not allocated any credit. However some credit was given to any chemistry involved in the method chosen, regardless of its validity. Painting the engine block or fully coating it with other metals were not considered suitable methods in this context. It seemed like students were just prepared to name all possible corrosion prevention methods without actually considering the situation. Markers deducted marks if students chose sodium, potassium, lithium or calcium as sacrificial anodes as part of their corrosion prevention method as this was an example of some of the inappropriate choices that students made. It should also be pointed out that when students mentioned galvanising (i.e. coating with zinc) as a corrosion prevention method, no marks were allocated as this was an inappropriate choice given that it was zinc that was reacting in the alloy. Many students seemed to think that “zinc” is actually spelt “zink”. Maybe communication should also be assessed?

Question 3

(a) Most students had little difficulty in answering this question however for those who made errors in this section, follow on answers in parts (b) and (c) were given credit if the information given was consistent with their incorrect choices.

(b) Students would often mention that the tin electrode would degrade over time due to the oxidation process but were sometimes unsure as to what colour change occurred at the other electrode. Given that reaction with bromine and its consequent discolouration is a noted test for the presence of alkenes/alkynes in the organic chemistry unit, it was surprising that its colour was not known or remembered for this section. It is important that students carefully consider what changes can actually be observed, as changes in the concentration of non-coloured species, such as Sn$^{2+}$ (aq), whilst true, were not accepted, as they are not immediately observable.

(c) Students needed to state the tin electrode was the anode and that oxidation was occurring at this electrode and consequently was the source of electrons. Each of these four points attracted 0.5 marks giving a total of two for the question. E.C.F. was given for valid and consistent chemistry for earlier errors. It was quite possible to get question 3(a) incorrect and still attract full marks for both parts (b) and (c).

(d) Teachers should note that students really struggled with this question.

(e) Students also struggled with this question, especially part (i), launching into all sorts of explanations relating to ethanol’s reactivity with bromine, reactive metals and chlorides, rather than discussing its suitability as an electrolyte. The second part (ii) was answered more successfully, although, it is important that students articulate why the formation of a precipitate causes cell cessation.

Question 4

(a) Students were required to give valid evidence for either a yes or no answer. Markers accepted calculations or assigned oxidation numbers on top of the relevant species in the given equations but were more likely to allocate full marks for students who had written explanations describing whether any substances had undergone oxidation or reduction. Markers however did not accept statements such as C(s) → C^{2+} + 2e^- as justification for the oxidation of carbon to carbon monoxide.
(b) This question was generally well attempted with most students obtaining full marks. Even though the question did not ask for the polarity of the electrodes, students volunteered this information as well. Unfortunately if the polarities were given incorrectly, markers were obliged to deduct half a mark.

(c) This question was answered successfully by a large majority of students although some switched the half equations around giving them as an anode reaction when it should have been a cathode reaction and vice-versa. Unfortunately, if this occurred, no credit was given for this question but students would be given follow on credit in the next part of the question. Markers did also accept the reduction of water half equation at $E^o = -0.83V$ given that it was a relevant equation to be discussed in the next part of the question.

(d) Many students possibly did not quite understand the context of this question. The question required an explanation as to why gas was evolved at the cathode as well as at the anode. Given that the predicted anode and cathode reactions were already given in part (c), a restatement of these two reactions simply attracted 0.5 marks for this question. To gain the remaining 1.5 marks, students needed to identify hydrogen as the gas evolved and to explain how it was possible for it to be evolved at the cathode as well as the reduction of the zinc ions. Some students discussed that after some time the hydrogen ions evolved at the anode could drift across to the cathode and be reduced to hydrogen. Though less plausible, this was also given some credit (1 mark instead of 1.5 marks). *(Note: In Industry a 10% acidified solution of zinc sulfate is used and that is why hydrogen is also produced at the cathode.)*

(e) This question was mostly well attempted although incorrect statements like “Cd and Ni are stronger oxidisers” instead of “Cd^{2+} and Ni^{2+} ions” are stronger oxidisers were penalised. Similarly students who referred to “Cd^{2+} and Ni^{2+} ions” being weaker reducers were also penalised.

Question 5

(a) This question was a standard corrosion question demanding identification of the concept of differential aeration and correct anodic/cathodic sites. It is always easier for students to gain full marks if relevant half equations are given but most students who did not give half equations, were able to give a written description the processes occurring at the two sites.

(b) Most students received some credit for this question as long as they mentioned parts of the accepted answer that the corrosion process resulted in a new substance that had a different bonding structure, a higher molar mass and consequently had expanded, causing the cracking. Degradation of the iron bars and loss of structural integrity was also awarded some credit.

(c) Surprisingly, this question was poorly answered. Many students went off on a tangent discussing such things as chlorine’s ability to be a powerful oxidiser rather than the fact that the presence of chloride ions would assist in the establishment of a more suitable salt bridge with a far more effective transfer of electrical charge between anodic and cathodic sites.

Part 2 - Criterion 6

The overall marks for this criterion were low due to a combination of some basic concepts not being clearly understood. For the vast majority of candidates, question 11 proved to be a particularly difficult question. Many candidates used pencil rather than pen. If they make this decision they should ensure that the pencil is dark enough to be clearly legible. Some candidates had writing that was extremely small and challenging to read. Poor spelling from candidates was noted, but was not penalised.

Question 6

(a) The majority of candidates realised that the reaction was exothermic. Several explanations were accepted:
   - $\Delta H$ negative
• Enthalpy of products less than enthalpy of reactants
• Energy of products less that energy of reactants
• The amount of energy required to break the bonds of the reactants is less than the amount of energy released when new bonds are formed.

(b) In answering this question, a number of candidates merely restated the choices given by Option 1 or Option2.

(c) Most candidates realised that the reverse reaction direction drives the equilibrium process towards maximum entropy and the forward reaction direction towards minimum enthalpy. Direction was a key word in the question. Some responses included north/south, up/down, endo/exo, and downwards/upwards.

Question 7

This question was not particularly well done. The word pure was not noted by many candidates.

(a) The given pH of water at 40°C needed to be used to determine the \([H^+]\), then \(K_w\) calculated from \(K_w = [H^+_{aq}] [OH^-_{aq}]\). Some candidates lost ½ mark by not showing that \(K_w = 2.89 \times 10^{-14} \text{ mol}^2 \text{ L}^{-2}\).

(b) This question was very poorly answered. Candidates did not note the word pure associated with water. As the water was pure, it was neutral, thus \([H^+_{aq}] = [OH^-_{aq}]\).

(c) This was again poorly answered. The dissociation of water was endothermic. There were a number of possible answers for this:
(i) As temperature decreased, the pH increased, therefore, \([H^+_{aq}]\) decreased, as equilibrium moved to the left which must be the exothermic direction to raise the temperature again.
(ii) Bond breaking is endothermic. Bonds in H-O-H broken.
(iii) \(K_w\) increases with increased temperature, so \([H^+_{aq}]\) and \([OH^-_{aq}]\) must have increased. Forward direction must be endothermic thus lowering the temperature.
(iv) Forward direction has maximum entropy, so reverse must have minimum enthalpy (be exothermic). The forward direction, dissociation of water must by endothermic.

Question 8

(a) A half mark was awarded for recognising that reactions don’t stop when equilibrium is reached, and a half mark for the explanation. This question was generally satisfactorily answered.

(b) Was poorly answered. A number of candidates partially answered the question. They may have identified that water was acting as a solvent, or that its concentration was effectively constant, but didn’t provide the complete answer.

(c)(i) This question was generally quite well answered. For full marks the role of the catalyst needed to be linked to how it increased the rate of reaction i.e. allowed for more collisions and subsequently more effective collisions.

(ii) Generally well answered.

Question 9

(a)(i) The sketch graph was generally poorly done by the candidates. A Boltzmann Distribution curve was required with \(E_a\) shown on the far right of the curve. Many candidates drew a curve showing a large number of particles beyond the \(E_a\) which was incorrect. A significant number of candidates provided an energy ~ course of reaction diagram as on page 3 of the booklet which was also incorrect. It was not necessary to draw a different
curve for when the candle was used, the question merely asked for a sketch graph at room temperature. No marks were elicited by the 2nd curve.

(ii) A number of candidates incorrectly viewed the heat of the candle as being a catalyst. Collision theory was not necessarily applied to the E<sub>k</sub> of molecules both before and after the use of the candle.

(b) Satisfactory.

(c) Collision theory was not always well used in providing an explanation of why using pure oxygen was better. It was not always recognised that pure oxygen would have an approximately five times higher concentration of oxygen than air.

(d) Was poorly done. A number of candidates have difficulty with the mathematics involved; e.g. finding half of 496. The majority of candidates who decided to double the coefficients in the equation failed to also double the value of ΔH. Finding the bond energy, of a bond given ΔH, was a challenge for a significant number.

**Question 10**

(a) Finding K<sub>c</sub> was generally well done. As units were not included for K<sub>c</sub> in the question, marks were not lost for not including it in the answer. As the reaction vessel was 1 L concentrations did not involve calculations, although some students showed that they knew that values were mol L<sup>-1</sup> in the equilibrium expression. (Criterion 8 was using concentration and K<sub>c</sub>.) Some students forgot that that K<sub>c</sub> was calculated from concentration of products / reactants.

(b) Candidates needed to assume that the system was still at 25°C. Candidates were expected to show that the system had not reached equilibrium, by calculating the equilibrium quotient, Q, for the reaction, and showing that Q > K<sub>c</sub>. Some very creative responses were provided.

(c) The graph was either very well done or poorly done. Things that were looked for included: (i) Number of moles of B<sub>2</sub>(g) decreased from 1.2 to 0.6 moles

(ii) Correct ratios: Number of moles of A<sub>2</sub> increases by x, moles of B<sub>2</sub> increase by 2x, and moles of AB<sub>2</sub> decrease by 2x.

(iii) Correct shape of curves

(iv) New equilibrium established at 15 minutes, and graph lines now horizontal.

(d) Majority of candidates understood the effect of decreasing the volumes of the equilibrium mixture, but a significant number of candidates did not realise that adding helium to the mixture causes no change to the position of equilibrium.

**Question 11**

This question was generally very poorly done. Some students omitted totally or only partially answered this question.

(a) The effect of having excess OH<sup>-</sup> on the position of equilibrium was not identified by many of the candidates.

(b) The strength of hypochlorous acid was answered correctly by very few candidates. The relationship between a low Ka value and the strength of an acid was not identified by the majority of candidates.

(c) Only a small minority of candidates related the equation provided this question with the earlier equation for the equilibrium. The effect of pH on the body and bacteria featured highly in answers, but was only given ½ mark.

(d) The two equilibria were not understood by the candidates. Only a handful of students provided appropriate answers.
Part 3 - Criterion 7

Question 12

Most students attempted this question with confidence and on the whole it was quite well done. Empirical formula was often confused with molecular formula and the number of hydrogen atoms on the aromatic ring was often thought to be six rather than four. A few candidates gave the positioning of the chloro groups as -2,3-.

This was not accepted.

Although redundant in the systematic name, the examiners accepted a -2- in propanone.

Question 13

(a)(i) Oxidation of the ethanol was identified as the cause of the ethanoic acid contaminant and students who identified oxygen gas from the atmosphere and water as the oxidant were rewarded. To gain full marks, an equation or half equation was expected.

A surprising number of candidates suggested that permanganate or dichromate ions from the atmosphere were the oxidant. Similarly, some said the oxidant was associated with an incorrectly washed out reagent bottle.

(ii) Most students identified at least one expected change in the I.R. absorption spectrum caused by the ethanoic acid contamination. Surprisingly, many omitted the most substantial expected change caused by the C=O absorption at around 1700 cm⁻¹ and concentrated on the less clear changes expected for the O-H absorption. Some candidates clearly identified absorption variations but failed to assign them to either O-H or C=O and thus lost marks.

(b) This question was well done by most. To gain full marks students needed to clearly distinguish between intermolecular and intramolecular bonding. Acronyms such as I.M.F. (intermolecular forces) should be defined before using it in this section. A diagram showing the H-bonding process (δ⁺….δ⁻) assisted explanations greatly.

(c) Apart from a chemical equation for the reaction between sodium and ethanol, the examiners were expecting a description of what happened and this included such things as the sodium dissolving, a flammable gas being evolved and an exothermic process occurring.

It was apparent that some students had not performed this reaction as it was often described as being 'explosive' or 'violent'.

The naming of the sodium ethoxide product resulted in a great number of unacceptable answers with sodium ethanoate and sodium alkoxide being common.

Question 14

(a) Pleasingly, the ester hydrolysis reaction was well recognised and most students gained full marks for this part.

(b) Compound B’s acidity implied by the pH of 5 indicated that B was a carboxylic acid. Despite the carboxylic acid’s molar mass of 46 g mol⁻¹ being clearly shown in the mass spectrum data, propanoic acid (M = 74 g mol⁻¹) was a very common choice rather than the correct answer of methanoic acid.

(c) In essence, the identity of C follows from the residue left from ester C minus acid B, namely an alcohol with three carbons. With C giving two oxidation products it was clear that C was the primary alcohol propan-1-ol. Propanol was not sufficient.

Those identifying B as propanoic acid and thus saying C must be methanol were given full marks for part (c) despite it being incorrect. The "error carried forward" (ECF) process meant that students were not penalised twice for the first error.
(d) Students who gave a structural formula and name consistent with their answers to parts (b) and (c) gained full marks.

**Question 15**

This 8 mark question was very poorly done with many students scoring only one or two marks and a number not attempting any parts at all.

(a)(i) There were two potential answers to part (i) but dehydration to give a C=C was essential so that addition polymerisation could occur. Sulfuric acid was an appropriate dehydrating agent for the purpose.

(ii) Candidates struggled to correctly represent the polymer’s repeat units with very few scoring the one mark allocated. The reaction could be directly related to a simple unsaturated monomer such as propene but most did not see it this way.

(b) This was an utter mystery to most. A ‘head to tail’ condensation polymerisation process to form a polyester was expected but only a very limited number achieved this goal.

(c) Answers to this question were often startling even though it was just a straight forward ‘acid/carbonate’ reaction. Clear distinction needs to be made between the acid proton of the COOH functional group and the hydrogen in the OH alcohol functional group.

The product was sodium 3-hydroxypropanoate and the expected observations included the Na₂CO₃ dissolving, a gas (CO₂) given off, pH rising, heat released, …

Some students had reactions involving sodium metal rather than sodium carbonate. This gained no marks. An alarming feature of many answers was the covalent bonding of sodium to carbon sometimes even with double bonds!

**Question 16**

(a) This question was well done by the majority of candidates. The only error was to not specify that the electron was being removed from an electrically neutral atom. Just saying ‘the energy needed to remove an electron’ was not adequate.

(b)(i) & (ii) Also well done by the majority of students with 5000 – 8000 kJ mol⁻¹ considered an acceptable range. For magnesium, E₃ involves the removal of a 2p electron from a significantly lower energy orbital requiring much more energy than the removal of the 3s electrons for E₁ and E₂.

(c)(i) Well done by most candidates but some used very strange symbolic notations such as 1p, s3, p2 and 6s⁶. To give the ground state electronic configuration for neon as Ne = (Ne) was not acceptable although it occurred quite frequently.

(ii) This was very troublesome question for many. Li⁺ was identified by a reasonable number of candidates as the answer but the supporting arguments were often very obscure. The use of electronegativity to explain the answer usually resulted in minimal marks. It was apparent that the distinction between Li atoms and Li⁺ ions was unclear.

**Question 17**

(a) Responses to this question were quite variable. A disappointing number of students focussed on the noble gas nature of helium being the cause of ideal behaviour rather than considering interatomic attractions. Many answers completely neglected to comment on the reasons for ammonia deviating from ideality.
(b) Quite well done. Most assumed that the ammonia gas was escaping from \( \text{NH}_3(aq) \) and discussed \( E_x \) of particles entering the gas phase. However the transference of \( \text{NH}_3(g) \) through the laboratory atmosphere was not well explained apart from many saying “gases expand to fill their container i.e. the room”.

(c) A question like this would have been best answered by initially stating “oxidisers are electron acceptors” and following on from there.

Many answers were partly correct with passing reference to important factors such as electronegativity, electron shell shielding, reduction potential, … There was evidence of confusion between the concepts of oxidation as a chemical process and oxidisers as chemical species.

Students should avoid anthropomorphic statements such as “chlorine atoms want, like, need, are hungry for,… electrons”.

(d) Most found this a nice easy question 2 mark question to finish criterion 7. Discussing the differences in nuclear charge without considering the significance of them being isoelectronic meant that many scored only part marks.

**Part 4 - Criterion 8**

**Question 18**

This question was generally answered well. Half a mark was deducted for not giving the answer corrected to 3 significant figures. A surprising number of students did not address significant figures at all. The 1:2 mole ratio was often omitted from the calculation.

**Question 19**

This question was best attempted according to the ‘empirical formula’ solving method but all logical methods were accepted. Typically, this question scored either the full 3 marks or a zero. In general, this question was not done well although students who used a clear setting out seemed to have more success in solving this correctly.

**Question 20**

(a) Generally done well. Common errors included not converting temperature to kelvin or converting to kelvin by subtracting 273 instead of adding, or using the new temperature as \((160 + 22)\)°C instead of 160°C. \( T_1 \) and \( T_2 \) were sometimes inverted during formula manipulation.

(b) 140 cm\(^3\) confused many students, forgetting that 140 cm\(^3\) = 140 mL = 0.140 L.
Many forgot to convert 140 mL to 0.140 L.

**Question 21**

This question was not done well. Almost all students recognized that (OH\(^-\)) was in excess but could not follow that up with Kw or pOH to calculate pH.

**Question 22**

(a) Well done.
(b) Very few got this correct. A large number of students took 0.17 mol of CO to be the moles of methanol present at equilibrium rather than number of moles of carbon monoxide at equilibrium. Also, students used the mole values rather than the concentration values to calculate K_c. Also, few realised that decrease in moles of H_2 would be double that of CO. Use of the ICE diagram facilitated logical setting out. Errors in units did not receive a deduction.

**Question 23**

Generally done well. Reaction 2 was superfluous which was a source of grief for some. The expected answer was \( \Delta H = +97 \) kJ. In cases of \( \Delta H \) answers, students are advised to write + 97 instead of just 97.

**Question 24**

(a) This question was done well.

(b) This question was deemed very difficult, though there was no problem in understanding the meaning of ‘yield’. This was an exercise in maths rather than chemistry, but students tried mole calculations and got into a mess. Many left this question. A small number solved it correctly. All calculations that attempted to use density, mass and percentage, based on logical reasoning, were assigned part marks.

**Question 25**

(a) Generally done well.

(b) The majority of students found it difficult and did not know where to start. Some credit was given for recognizing that \( M = m/n \). Rearrangement of the formula \( n = m/M \) was also a problem for several. Students should have used their calculated concentration value rather than the 0.09 approximation.

**Question 26**

(a) This question was not done to completion by the vast majority of students even though the calibration factor was correctly calculated by most.

However, then a significant number of students inap propriately used \( E = mc\Delta T \) with the values \( c = 4.18 \) and mass (of sulfur) = 1.00 g.

The expected approach was to say: \( E = (C_f \times 4.45) \) J for the combustion of 1.00 g of sulfur. Subsequently, very few went on and calculated the heat released per mole of sulfur; i.e. \( \Delta H = - (C_f \times 4.45)/(1.00/32.1) \) J mol\(^{-1}\) for the reaction.

or \( \Delta H = -296 \) kJ mol\(^{-1}\)

(b) No marks were deducted for incorrect or omitted states. Half a mark was deducted for not realising that \( \Delta H \) was negative (exothermic reaction since temperature was raised in the calorimeter).
**CHEMISTRY CHM415115**

**TASC EXAMINATIONS**

**NOVEMBER 2015**

**ANSWER SUMMARY**

**CRITERION 5:**

1. (a) $2\text{H}_2\text{S}_2\text{O}_7^{2-} + 2\text{H}_2\text{O} \rightarrow 2\text{SO}_4^{2-} + 4\text{H}_2\text{O}^{+} + 4\text{e}^- \quad E^\circ = -0.14\text{V}$

2. (a) The $\text{Zn}_{(s)}$ is oxidised in the presence of $\text{Cu}/\text{H}_2\text{O}$ forming a white product of $\text{Zn(OH)}_2$ (and possibly $\text{ZnO}$) $\text{Cu} + (\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+} + 2\text{e}^-) \times 2$

3. (b) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the electrode where reduction occurs.

4. (c) The negative terminal of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

5. (d) Short-hand:

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6. (c) 

   - The anode of the $\text{H}_2\text{O}_2$ is oxidised in the presence of $\text{Cu}/\text{H}_2\text{O}$ forming a white product of $\text{Zn(OH)}_2$ (and possibly $\text{ZnO}$) $\text{Cu} + (\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+} + 2\text{e}^-) \times 2$

   - The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the electrode where reduction occurs.

   - Short-hand:

     | Short-hand | Oxidation | Reduction |
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     | $\text{Bi}^{3+}$ | $\text{Bi}^{3+}$ | $\text{Bi}^{3+}$ |

7. (b) The anode of the $\text{H}_2\text{O}_2$ is oxidised in the presence of $\text{Cu}/\text{H}_2\text{O}$ forming a white product of $\text{Zn(OH)}_2$ (and possibly $\text{ZnO}$) $\text{Cu} + (\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+} + 2\text{e}^-) \times 2$

8. (c) The negative terminal of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

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10. (e) Yes - a spontaneous redox reaction will occur (at standard state).

11. (a) $\text{H}_2\text{SO}_4^{2-} + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{O}_2$ (1)

12. (b) The $\text{Sn}_{(s)}$ anode would decrease in mass and in the cathode cell, the brown colour, due to $\text{Bi}^{3+}$ would progressively become paler ($\text{Bi}^{3+}$ colourless).

13. (c) The negative terminal of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

14. (d) Short-hand:

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15. (e) The anode of the $\text{H}_2\text{O}_2$ is oxidised in the presence of $\text{Cu}/\text{H}_2\text{O}$ forming a white product of $\text{Zn(OH)}_2$ (and possibly $\text{ZnO}$) $\text{Cu} + (\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+} + 2\text{e}^-) \times 2$

16. (f) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

17. (g) The negative terminal of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

18. (h) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

19. (i) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

20. (j) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

21. (k) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

22. (l) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

23. (m) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

24. (n) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

25. (o) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

26. (p) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

27. (q) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

28. (r) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

29. (s) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

30. (t) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

31. (u) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

32. (v) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

33. (w) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

34. (x) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

35. (y) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.

36. (z) The oxidation number of an electrochemical cell is the electrode where oxidation occurs, and the positive terminal is the electrode where reduction occurs.
CRITERION 5 (continued)
Q5. (cont.)

take up more space than the original iron from which they were formed; swelling occurs and the concrete cracks!

(c) As corrosion is an electrochemical process it requires a cell between anode and cathode sites. The more ions present; the greater the movement of charge; faster corrosion.

extra Cl\textsuperscript{-} \textsubscript{(aq)} compounds in concrete accelerates the rusting.

CRITERION 6:
Q6. (a) exothermic because the enthalpy of the products (AB\textsubscript{2}) is less than the enthalpy of the reactants A\textsubscript{2} + B\textsubscript{2}.

(b) Option 2: The energy required to break the chemical bonds in A\textsubscript{2} and B\textsubscript{2} is comparatively small but when the new (strong) bonds form in AB\textsubscript{2}, a greater amount of energy is released.

- total bond energy of the reactants is less than the total bond energy of the prod.

(c) (i) max. entropy; reverse process
(ii) min. enthalpy: forward

Q8. (a) No! When equilibrium is reached, the forward and reverse reactions continue to occur, but at a rate that is now occurring at the same rate.

(b) As water is the solvent for this aqueous process the [H\textsubscript{2}O\textsubscript{(aq)}] is about 55 mol L\textsuperscript{-1} and does not change measurably. [H\textsubscript{2}O\textsubscript{(aq)}] is constant. [H\textsubscript{2}O\textsubscript{(aq)}] is not included in K\textsubscript{a}.

Q9. (a) Boltzmann Distribution Law

Q9. (b) (i) At 25\degree C the E\textsubscript{k} of the H\textsubscript{2} + O\textsubscript{2} molecules was lower and thus none of the collisions had E\textsubscript{k} energy exceeding the threshold E\textsubscript{a}.

- no effective collisions at 35\degree C.

- no explosion at 25\degree C.

- the candle flame (at say 35\degree C) heats some of the H\textsubscript{2} + O\textsubscript{2} to 25\degree C or more than E\textsubscript{k} > E\textsubscript{a}.

- they react and the reaction being exothermic (ΔH = -242 kJ) releases energy. E\textsubscript{k} of all molecules rise to a rapid (explosion) occurs due to all collisions now becoming effective.

Q10. (a) At equilibrium [AB\textsubscript{2}] = \frac{0.80}{2} \cdot 0.50 \text{ mol L\textsuperscript{-1}}

- [A\textsubscript{2}] = \frac{2.0}{2} \text{ mol L\textsuperscript{-1}}

- Thus K\textsubscript{c} = \frac{[AB\textsubscript{2}]^{2}}{[A\textsubscript{2}][B\textsubscript{2}]^{2}} = \frac{(0.80)^{2}}{(0.50)^{2}} = 0.25

Q11. (a) Alkaline solution - [OH\textsuperscript{-}] is quite high; LCP we see that the position of equilibrium shifts so as to decrease [OH\textsuperscript{-}] is essential to shift to left... mostly stable ClO\textsubscript{3} and minimal unstable HClO\textsubscript{4} results.

New bonds formed
\begin{align*}
2\text{(O-H)} & \rightleftharpoons 2\times 468 = 936 \text{ kJ} \text{ RELEASED} \\
\text{But } \Delta H & = -242 \text{ kJ} \\
\text{Thus } & = (x+248) - 936 \\
2e & = -242-248+936 = +456 \\
\end{align*}

- H-H bond energy is 436 kJ mol\textsuperscript{-1}

Q10. (b) (i) no effect on position of equilibrium
(ii) forward reaction is favoured.
Criterion 6 (continued)
Q11. (b) Hypochlorous acid is extremely weak as shown by the value of $K_a = 3 \times 10^{-8}$; a very small % dissociation occurs. (c) The pool water has to be kept alkaline ($pH > 7$) as explained in part (a) but if it's too alkaline it would be dangerous, affecting the skin, eyes, etc. Thus HClO$_4$ is added to maintain the pH at an acceptable (safe) level at pH = 7.4. If too much HClO$_4$ is added there will be a release of Cl$_2$ and [HClO$_4$]$^-$ will be too low to provide ClO$_2$ for disinfecting!
(d) A source of CaO or Na$_2$SO$_4$ would shift the equilibrium back to CaSO$_4$ thus minimising the dissolving of the growth. eg add Ca(NO$_3$)$_2$ or Na$_2$SO$_4$.

Criterion 7
Q12. (i) propanone: $\text{CH}_3\text{C}=\text{O}$
(ii) 3-amine functional group
(iii) 1,2-dichloro benzene: $\text{C}_6\text{H}_4\text{Cl}_2$

Q13. (a) The ethanol had been in contact with the atmosphere and undergone oxidation to some extent.
(b) $\text{CaH}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_4\text{O}_2 + \text{H}^+ + \text{OH}^-$ (ethanol)

(ii) The impure ethanol's I.R. spectrum would show a peak at around 1700 cm$^{-1}$ due to the C=O present in the ethanoic acid impurity.
(iii) The O-H peak for ethanol at around 3400 cm$^{-1}$ may show a secondary (adjacent) peak at around 3100 cm$^{-1}$ due to the O-H of the carboxylic acid.
(iv) The O-H groups in ethanol result in strong intermolecular hydrogen bonding between ethanol molecules: a higher temperature is needed to separate CH$_3$CH$_2$OH into a gas. Ethanol molecules are non-polar: only weak van der Waals' dispersion forces between molecules: low B.P.
(c) The sodium metal dissolves slowly and a gas is released. The gas gives a positive 'pop-test' and is hydrogen.

Q14. (a) A : ester $\text{CH}_3\text{C}=\text{O} - \text{C}^\ominus$
B : carboxylic acid $\text{C}_2\text{O}_4^\ominus$
C : alcohol $\text{C}^\ominus - \text{O}^- - \text{H}^+$

(iii) B = carboxylic acid and the mass spectrum data indicate a molar mass of 46 g mol$^{-1}$
(iv) $\text{C}_2\text{H}_4\text{O}_2^\ominus$ methanoic acid

(b) This has to be a 3 carbon alcohol i.e. propan-1-ol or propan-2-ol. But because C gives 2 oxidation products, C must be a primary alcohol i.e. propan-1-ol (oxidises to give propionaldehyde).

(c) A : $\text{CH}_3\text{C}=\text{O} - \text{C}^\ominus$

Organic product is sodium ethoxide.

Q15. (a) (i) $\text{CH}_3\text{C}=\text{C}=\text{C}=\text{O}$ $\text{OH}$

* additional chemical needed is $\text{H}_2\text{SO}_4$

(ii) $\text{C}^\ominus$ $\text{O}^\ominus$ $\text{OH}$

(iii) $\text{C}^\ominus$ $\text{O}^\ominus$ $\text{OH}$

O: sodium ethoxide

Q16. (a) The energy required to remove the first electron from a neutral gaseous atom is $X_{(i)\rightarrow X^+ + e^-}$

(b) (i) $E_1 = 7500$ kJ mol$^{-1}$ (approx)
(ii) Mg = (Ne) 36$^+$ After the removal of the two 2s electrons the third e must be removed from a 3p sub-shell which will require a much greater energy input. As the difference between $E_2$ and $E_3$ is $\approx 3000$ kJ we can estimate that $E_3 = 7800$ kJ less than $E_2$.

(c) $\text{Li}^+ - \frac{16}{14} = \text{(He)}$

$\text{Na}^+ = \text{(Ne)} 2s^1$

$\text{Ne}^- = \text{(He)}^2 2p^6$

(i) Li$^+$ would have the highest (next) ionisation energy due to having the smallest radius and the least amount of screening...greatest attraction of e$^-$. (c) $\text{He}^+$ atoms have negligible van der Waals' dispersion force and thus behave most "ideally". Gases like NH$_3$ have intermolecular attractive force (van der Waals' polar) : do not behave as ideal "perfect" gases.

(b) A gas such as ammonia has molecules with high translational Ex : high average molecular speed. This means gas molecules move quickly from point A to point B.; the rapid movement (diffusion through the air) means NH$_3$ is soon detected across the other side of the room.
**CRITERION 7 (contd)**

Q17. (c) Oxidisers are electron acceptors and the smaller Cl radius means a stronger attractive force is exerted on an incoming e\textsuperscript{-}. A smaller radius means Cl atoms have less shielding than Br atoms, so a stronger attractive force is exerted on e\textsuperscript{-} : stronger oxidiser.

(d) Li\textsuperscript{+} (He), but Li\textsuperscript{+} has 3 protons per nucleus whereas He has only 2. The 3\textsuperscript{rd} nucleus in Li\textsuperscript{+} exerts a stronger attraction on the 2\textsuperscript{nd} than occurs with the 2 protons change in a helium atom:

Li\textsuperscript{+} \[\begin{array}{ccccccc}
\text{Li} & \text{He}
\end{array}\]

**CRITERION 8**

Q18. \( n(\text{KI}) = c \times V = 0.120 \times 0.0200 = 0.00240 \text{ mol} \)

\( n(\text{PbI}_2) \) formed = \( 0.00240 \times 0.5 = 0.00120 \text{ mol} \)

\( n(\text{PbI}_2) = n(\text{PbI}_2) \text{ formed} = 0.00120 \times 4 = 0.00480 \text{ mol} \)

\( \text{mass } \text{PbI}_2 = (n \times M) g = (0.00480 \times 282.004) g = 0.330 g \)

\( \text{mass } \text{PbI}_2 = (n \times M) g = (0.00120 \times 282.004) g = 0.330 g \)

\( n(\text{PbI}_2) = 461.0 g \text{ mol}^{-1} \)

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**Q19. Consider 100 g of Na\textsubscript{2}SO\textsubscript{4} \( \times \) H\textsubscript{2}O. It contains 44.1 g of Na\textsubscript{2}SO\textsubscript{4} and 55.9 g of H\textsubscript{2}O.

\( n(\text{Na}_2\text{SO}_4) : n(\text{H}_2\text{O}) = \frac{44.1}{142} : \frac{55.9}{18.02} = 0.310 : 3.10 \)

\( \Rightarrow x = 10 \quad 4 \quad 4 \quad 4 \)

\( \ell \text{ formula is } \text{Na}_2\text{SO}_4 \times 10\text{H}_2\text{O} \)

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**Q20.**

(a) \( P = 80.00 \text{ kPa} \)

\( T_1 = 295 K \quad \rightarrow \quad T_2 = 428 K \)

\( \text{Using } PV = nRT, \text{ as } V_1 = V_2 \)

\( \frac{80.00 \times 295}{295} = \frac{P_2 \times 428}{428} \)

\( \Rightarrow \text{ new pressure is } 117 \text{ kPa} \) (greater than original kPa)

(b) \( P = 80.00 \text{ kPa} \)

\( V = 0.140 \text{ L} \)

\( n = ? \text{ mol} \)

\( R \) = \( 0.082 \text{ kJ mol}^{-1} \text{ K}^{-1} \)

\( T = 295 \text{ K} \)

\( n(A) = 0.00457 \text{ mol} \)

\( \text{no. of Atoms} = 0.00457 	imes 6.02 \times 10^{23} = 275.1 \times 10^{23} \text{ atoms} \)

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**Q21.**

\( n(\text{KOH}) = (0.150 \times 0.0400) \text{ mol} = 0.00600 \text{ mol} \)

\( \Rightarrow n(\text{OH}^-) = 0.00600 \text{ mol} \)

Also, \( n(\text{HCl}) = 0.00200 \text{ mol} \)

\( \Rightarrow n(\text{H}^+) = 0.00200 \text{ mol} \)

\( \text{Now } \text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O} \)

\( \Rightarrow \text{excess } (0.00600 - 0.00200) \text{ mol} \)

\( \Rightarrow \text{of } \text{OH}^- \text{ is } n(\text{OH}^-) = 0.00400 \text{ mol} \)

\( \Rightarrow \text{final } [\text{OH}^-] = \frac{n}{V} = \frac{0.00400}{0.0600} \)

\( \text{(Note: } V = 60.0 \text{ mL} : 0.0600) \)

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**Q22.**

(a) \( K_c = \frac{[\text{CH}_3\text{OH}(aq)]^2}{[\text{CO}_2] [\text{H}_2\text{O}]^2} \)

\( \text{mol} \)

\( \begin{array}{|c|c|c|c|c|}
\hline
\text{mol} & \text{mol} & \\
\hline
\text{CO}_2 & \text{H}_2\text{O} & \text{CH}_3\text{OH} & \text{K}_c \\
\hline
0.240 & 0.380 & - & - \\
0.090 & 0.140 & +0.070 & \\
0.170 & 0.240 & 0.070 & 0.090 \\
\hline
\end{array} \)

\( \Rightarrow \text{Thus } \text{and } 1.1 \text{ mol L}^{-1} \)

\( \text{CH}_3\text{OH} = 0.0170 = 0.0467 \text{ mol L}^{-1} \)

\( \Rightarrow \text{Thus } K_c = (0.0467)^2 (0.0170) (0.160) = 1.1 \times 10^{-2} \text{ mol}^2 \text{L}^{-2} \)

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**Q23.**

\( \text{C}_F = \frac{V \times n_\text{rev}}{(50 \times 6.42 \times 10^2) J} \)

\( \text{C}_F = 2074.4 \text{ J}^{-1} \)

\( \text{E released} = (C_F \times 4.45) \text{ J} \)

\( \text{Thus } \Delta H = -\frac{(2074.4 \times 4.45)}{25} \text{ mol} \)

\( \Delta H = -296.2 \text{ KJ} \)

\( \text{is } \text{S}_8 + 3\text{O}_2 \rightarrow 2\text{SO}_3 \text{ AH} = 296.2 \text{ KJ} \)

**JAK. DENNY, NOV. 2015**