2010 Senior External Examination
Assessment report — Chemistry

Statistics

<table>
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<tr>
<th>Year</th>
<th>Number of candidates</th>
<th>Level of achievement</th>
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General comments

Paper One assessed Knowledge and simple application and Scientific processes. Part A consisted of 10 multiple-choice questions and eight short-response questions covering all eight syllabus topics. Part B contained five Scientific processes questions assessed by applying specific criteria to each question. In Part B, candidates were required to respond to any four of the five questions.

Paper Two assessed Complex reasoning processes. Candidates were required to respond to all four questions.

A significant number of candidates showed serious deficiencies in their recall of material from the Knowledge and simple application objective listed in the syllabus. Without this knowledge, candidates struggled to demonstrate their ability to complete Scientific processes or demonstrate Complex reasoning processes.

Paper One

Part A — Knowledge and simple application

Multiple-choice questions

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<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>7</th>
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<td>Correct response</td>
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<td>A</td>
<td>D</td>
<td>B</td>
<td>D</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>C</td>
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Correct responses to Questions 1, 2, 7 and 9 were provided by 26 or more candidates.
Correct responses to Questions 3, 4, 6 and 10 were provided by between 17 and 25 candidates.
Less than half of the candidates responded correctly to Questions 5 and 8.
The topics for these two questions were:

- **Question 5 (balancing chemical equations)**
  Most candidates were unsure about what is conserved during a chemical reaction and what is not always conserved

- **Question 8 (calculating Ksp)**
  Candidates did not seem to take into account that silver chromate dissociates to give two silver ions and one chromate ion.

**Short-response questions**

This part of the examination required candidates to demonstrate their knowledge and understanding of the eight syllabus topics.

**Question 11**

**Question 11a:** Almost all candidates responded well to this question. No particular errors were noted.

**Question 11b:** Responses to Question 11b (i) were generally good. Responses to (ii) were not as good, with a number of candidates giving a response of 21 or 41 rather than 20.

**Question 11c:** The most common error that candidates made was not using the correct prefix of “penta” before the chloride to indicate that there are five chlorine atoms present.

**Question 11d:** A significant number of candidates could not name this ion correctly.

**Question 11e:** Most candidates responded fairly well to this question. The main error was the incorrect naming of the shape with many candidates confusing planar triangular with pyramidal.

**Question 11f:** The most common error was in naming the forces within the molecule rather than those between the molecules.

**Question 11g:** Candidates who responded to this question generally answered it well. Some candidates did not seem to have any idea of how to respond.

**Question 12**

**Question 12a:** Again, the candidates who attempted the question responded fairly well. Some candidates seemed to have little or no understanding of the difference between the two terms.

**Question 12b:** The majority of candidates were able to balance the equation correctly. The main error was the failure to use a multiplication factor so that the coefficients were all whole numbers. A number of candidates left the coefficient for oxygen as a mixed number.

**Question 12c i:** Generally answered fairly well.

**Question 12c ii:** Not handled as well as Question 12c i. The most common mistakes were using the incorrect formula to calculate molarity and not converting volume to litres.

**Question 12d:** The candidates who attempted this question generally responded fairly well, although a significant number of candidates did not attempt a response. The most common mistakes encountered were candidates not recognising the equation as a limiting reagent reaction and not using the correct molar mass for hydrogen.

Regrettably, Question 12d included a typographical error. Markers were aware of the error when scripts were marked and made sure that candidates who responded to the question were not disadvantaged.
Question 13

Question 13a: Candidates responded fairly well to this question.

Question 13b: Candidates responded fairly well to this question.

Question 13c: Only a few candidates provided good responses. Many were not able to write the two half equations for the reaction that may occur. Many seemed unable to use the standard half cell potentials to determine a possible overall cell potential and then decide whether the reaction will occur or not.

Question 13d: Again, only a few candidates provided good responses. The major error made was not recognising that the copper ion is a double positive ion which resulted in calculating the incorrect number of moles of copper obtained.

Question 14

Question 14a i: Most candidates responded correctly.

Question 14a ii: Few candidates responded correctly. A range of incorrect responses was provided.

Question 14b: Most candidates responded to both parts of this question moderately well. The wording used in some responses was difficult to follow. The examples given were generally acceptable.

Question 14c: The major errors in responses to this question were not including the designation for the presence of chlorine and using the incorrect number to indicate the location of the attached groups.

Question 14d: This question was answered moderately well. The major error was writing the structure as a benzene ring rather than as a cyclo-alkane structure.

Question 14e i: Most candidates were able to name at least one method of preparing ethanol and give some description of the process.

Question 14e ii: Most candidates were able to provide at least one use of ethanol. Some were able to give two uses of ethanol although many candidates did not describe why these uses are significant in today’s society.

Question 15

Question 15a: Most candidates performed fairly well in responses to this question.

Question 15b: Many candidates were unable to correctly explain the term valence electrons.

Question 15c: This question was generally answered fairly well.

Question 15d: This question was generally answered poorly.

Question 16

Question 16a: Responses to both parts of this question were generally poor with many candidates not showing an understanding of Ideal gases.

Question 16b: Candidates who gave a definition generally did well. A noticeable number of candidates did not respond to the question.

Question 16c: The major error in responses to this question was that candidates did not convert the temperature to Kelvin.
Question 17

**Question 17a:** Responses to this question, by those who attempted it, were generally poor. No particular error stood out.

**Question 17b:** Candidates who attempted this question generally did well.

**Question 17c:** A reasonable number of candidates attempted this question and generally did quite well.

**Question 17d:** Few candidates seemed to have an understanding of the concept of reaction mechanism. The most common incorrect response to this question made reference to something missing from the equation, such as heat of reaction.

**Question 17(e):** This question was answered correctly by only a small number of candidates. The main errors encountered were using an incorrect equation for the formation of water and not using a multiplication factor of 2 with the equation for the formation of carbon dioxide.

Question 18

**Question 18a:** This was not answered well by most candidates. Few were able to show a clear understanding of a steady state. Some indicated an understanding of dynamic equilibrium.

**Question 18b:** This was also not answered well by most candidates. Very few referred to the amount of dissociation into ions when trying to define the terms. A reasonable number of candidates gave appropriate examples.

**Question 18c:** Candidates who attempted the question responded reasonably well. The most common error was including the concentration of water in the expression.

**Question 18d:** This question was not attempted by many candidates. The most common error was simply stating that the concentrations of the solids are not included rather than explaining why they are not included.

**Question 18e:** This question was attempted by only a small number of candidates. Those who did respond generally demonstrated an understanding of Le Chatelier’s Principle.

**Question 18f:** Very few candidates attempted this question. Of those who did, the most common error was not recognising that two fluoride ions are obtained when the calcium fluoride dissolves and dissociates. Some candidates did not write the Ksp expression correctly.

**Question 18g:** Very few candidates attempted this question. Of those who did, the major error was not writing the $K_a$ expression for the acid correctly.

**Part B — Scientific processes**

**Question 1**

20 candidates attempted all or part of this question. A reasonable number of candidates knew the formula for calculating the quantity of energy used to heat a given amount of water. The major error evident was candidates using the mass of the methanol rather than the mass of water in this calculation. Another error was not correctly calculating the mass of methanol used. Part b of this question was completed reasonably well by candidates even if they could not complete part a successfully. Candidates were generally able to suggest changes that could be made to the equipment. The wording of responses to part b could have been more descriptive.

**Question 2**

22 candidates attempted all or part of this question, with most doing reasonably well. The main error encountered was the selection of cations to precipitate the anions that would precipitate
more than one of the cations at a time. This meant that the cations were not separated one at a time as the question required. Another error was that candidates separated out two of the cations but left the third one in solution, although the question did not require this.

**Question 3**

22 candidates also responded to this question. Most failed to outline in sufficient detail the equipment and procedure needed for the analysis. There was often then a lack of explanation about how this data was to be used to determine the pH of the pool water. Some candidates described the procedure of a titration, and they generally did well.

**Question 4**

28 candidates attempted all or part of this question, with most able to correctly identify the elements at each end of the third row of the Periodic Table. Candidates who made errors seemed to have not used all the information given about each element or were not aware of the changes in properties of elements across the Periodic Table. The major deficiency in most responses was a lack of justification for decisions.

**Question 5**

24 candidates attempted all or part of this question. Generally, candidates were able to complete a graph reasonably well. The main errors were not putting the independent variable on the horizontal axis and not labelling the graph appropriately. In part b of the question, candidates were generally able to determine whether it was a direct or inverse relationship but often omitted to give an explanation. Responses to part c were generally good. For part d, the value for Absolute Zero was often given but some candidates did not indicate how the information given and the graph they had drawn were used to arrive at this value.

**Paper Two — Complex reasoning processes**

**Question 1**

The majority of candidates were able to make some progress in responses to this question and consequently demonstrated some logical reasoning and critical reasoning. A good number of candidates determined the empirical formula, often with a variety of approaches. If candidates were unsuccessful in determining the correct empirical formula, they were able to obtain credit for part b if they applied critical thinking to the information given relating to the empirical formula they had determined.

**Question 2**

Many candidates successfully utilised Faraday’s Law to interpret the given electrolytic data. It was not necessary to perform all four calculations to satisfy the requirements for part b. If candidates understood that for each cell the number of moles of electrons passing through the cell is the same, and then applied that to the most common ion of each element, the moles of metal electrolysed could be determined. The mass of metal plated out can then be related to the molar mass of the metal.

**Question 3**

It was disappointing that the majority of candidates did not approach this question in a logical and systematic manner. Fundamental problem-solving strategies such as drawing a diagram to represent the scenario were often not employed. Many candidates failed to make use of the notes
provided to the question which added necessary information. Another frequent error was the failure of most candidates to recognise that at 25° C, one mole of air would occupy 24.5 L and therefore provided incorrect responses for the mass of air displaced.

**Question 4**

The majority of candidates failed to realise that the addition of soluble salt provided a large quantity of additional common anions to the solution. Most candidates failed to determine the equilibrium concentrations of the relevant species and failed to implement a process where they could consider the initial concentrations, impose change and then determine the new equilibrium concentrations.

**Sample solutions**

The sample solutions on the following pages show possible ways of responding to the questions. They do not provide the only method of approaching a question. Other approaches and problem-solving strategies may be acceptable.
Section 2 — Short response

Section 2 has eight questions. Attempt all questions.

Write your responses in the spaces provided. You must show all working where applicable.

If you need more space for a response, continue on pages 25 and 26 of this book.

Label any continued response with the question number.

Question 11 — Materials: Properties, bonding and structure

a. Describe two differences between mixtures and compounds and give an example of each.

Differences: Mixtures consist of different substances not chemically combined.

Compound consists of elements chemically combined.

Example of a mixture: Saltwater.

Example of a compound: Carbon dioxide $\text{CO}_2$.

(2 marks)

b. A particular isotope of calcium can be represented as $^{41}_{20}\text{Ca}$.

For this isotope, what is the:

i. mass number $41$

ii. number of electrons in a neutral atom $20$

(2 marks)

c. Name the substance that is represented by the formula $\text{PCl}_5$.

$\text{phosphorus penta}

(1 mark)

d. Give the formula for the permanganate ion (including the charge).

$\text{MnO}_4^-$

(1 mark)

e. Draw diagrams for the following molecules and state the shape of each molecule.

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Diagram</th>
<th>Name of shape</th>
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<tbody>
<tr>
<td>$\text{PH}_3$</td>
<td><img src="image1" alt="Diagram" /></td>
<td>pyramidal</td>
</tr>
<tr>
<td>$\text{BCl}_3$</td>
<td><img src="image2" alt="Diagram" /></td>
<td>planar triangular</td>
</tr>
</tbody>
</table>

(2 marks)
f. For each of the substances CH₄, CH₂Cl₂ and H₂O, state what the main intermolecular forces are that hold the molecules together when the pure substance exists as a solid.

i. CH₄ [Van der Waals forces]

ii. CH₂Cl₂ [dipole–dipole forces]

iii. H₂O [Hydrogen bonding] (1.5 marks)

g. Naturally occurring carbon is composed of 98.93%¹²C and 1.07%¹³C. Calculate the atomic mass of carbon to two decimal places. Show your working.

\[
\text{Average Atomic Mass} = \frac{\text{Mass No. of isotopes} \times \% \text{ occurrence} + \text{Mass No. of isotopes} \times \% \text{ occurrence}}{100}
\]

\[
= \frac{12 \times 98.93 + 13 \times 1.07}{100}
\]

\[
= 12.01
\]

(1.5 marks)

Question 12 — Reacting quantities and chemical analysis

a. The term “relative molecular mass” should not be used when referring to the mass of an ionic substance. Explain, using an example, why it is correct to use the term “relative formula mass” for ionic substances.

Ionic substances do not exist as separate molecules but rather as 3D lattices of ions which exist in the same proportion as the formula of that substance. NaCl is the formula of an ionic substance made of Na⁺ and Cl⁻ ions in a 3D lattice in a 1:1 ratio (2 marks)

b. Rewrite the following as a balanced equation.

\[
\text{C}_2\text{H}_4\text{(g)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} + \text{H}_2\text{O(g)}
\]

\[
\text{C}_2\text{H}_4 + 6\text{O}_2 \rightarrow 4\text{CO}_2 + 5\text{H}_2\text{O}
\]

Use only whole numbers. Balanced equation is … [2 marks]
c. Calculate:

i. The number of moles of CO₂ in a 33.0 g sample of CO₂.
\[ \text{Number of moles} = \frac{\text{mass of sample}}{\text{Molar Mass}} \]
\[ = \frac{33}{44} \text{ mole} = 0.75 \text{ mole} \]

(1.5 marks)

ii. The molarity of solution when 0.25 mole of NaCl is dissolved in 750 ml of water.
\[ \text{Concentration} = \frac{\text{Number of moles}}{\text{Volume (litres)}} \]
\[ = \frac{0.25}{0.750} = 0.33 \text{ M} \]

(1.5 marks)

d. The reaction between magnesium and sulfuric acid may be represented by the balanced equation
\[ \text{Mg}(g) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{Mg}^{2+}(aq) + \text{SO}_4^{2-}(aq) + \text{H}_2(g) \]

What is the mass of H₂(g) obtained when 12.13 g of Mg is allowed to react in 500 ml of 0.5 M H₂SO₄ solution?

\[ \text{Moles of Mg} = \frac{12.13}{24.31} \text{ mole} = 0.5 \text{ mole} \]

\[ \text{Moles of H₂SO₄} = 0.5 \times 0.5 \text{ mole} = 0.25 \text{ mole} \]

\[ \text{Ratio in equation} \text{ Mg : H₂SO₄ = 1 : 1} \]

\[ \text{H}_2\text{SO₄} \text{ is the limiting reagent (0.25 mole reacted)} \]

\[ \text{No. of mole H}_2 \text{ formed} = 0.25 \text{ mole} \]

\[ \text{Mass of H}_2 = 0.25 \times 2 = 0.5 \text{g} \]

(4 marks)

Question 13 — Oxidation and reduction

a. Define the following terms:

i. oxidation \[ \text{oxidation is the loss of electrons} \]

ii. reduction \[ \text{reduction is the gaining of electrons} \]

(2 marks)

b. Determine the oxidation number of:

i. Fe in Fe₂O₃ \[ \text{Do your working here: } \text{Fe}_2\text{O}_3 \]

\[ -2 \times 3 = -6 \]

\[ x + 2 + (-6) = 0 \]

\[ x = +3 \]

ii. N in KNO₃

\[ +1 + x + (-2) = 0 \]

\[ x = +5 \]

(2 marks)
c. Use the table of standard reduction potentials to determine whether the following reaction will occur spontaneously when the reactants are put together. Explain your reasoning.

\[2\text{Al(NO}_3\text{)}_3(\text{aq}) + 3\text{Pb}(s) \rightarrow 2\text{Al}(s) + 3\text{Pb(NO}_3\text{)}_2(\text{aq})\]

\[\text{Use } E^0 \text{ values:} \quad \text{Al}^{3+} + 3e^- \rightarrow \text{Al} \quad E^0 = -1.66 \text{V}\]

\[\text{Pb} \rightarrow \text{Pb}^{2+} + 2e^- \quad E^0 = 0.13 \text{V}\]

Overall: \[E^0 = -1.53 \text{V}\]

Overall \(E^0\) is negative; no spontaneous reaction will occur.

(2 marks)

d. A group of students set up the following electrolytic cell in order to obtain pure copper from an impure sample.

![Electrolytic Cell Diagram]

What mass of copper will be formed on the cathode if a 2 ampere current is run through the cell for 12 hours? (1 ampere = 1 coulomb sec\(^{-1}\); 1 mole = 96500 coulombs.)

\[Q = It\]

\[= 2 \times (12 \times 60 \times 60) = 86400 \text{ coulombs}\]

\[\text{Ni}(\text{anode}) = 2 \times \text{Ni}(\text{cathode})\]

\[= 86400 \div 2 = 43200 \text{ mole}\]

\[\text{Mass(cathode)} = \text{M} \times \text{n}\]

\[0.4477 \times 63.5 = 28.42 \text{ g}\]

(2 marks)
Question 14 — Organic chemistry

a. Write the general formula for:
   i. alkynes
      \[ \text{C}_n \text{H}_n \text{H}_2 \text{O} \]
   ii. aldehydes (alkanals)
      \[ \text{C}_n \text{H}_n \text{CHO} \] or \[ \text{C}_n \text{H}_n \text{O} \]

b. Explain the following terms, giving an example of each showing the structural formula.
   i. Saturated hydrocarbon
      A saturated hydrocarbon contains only single carbon to carbon bonds.
      Example: ethane \[ \text{H} - \text{C} - \text{C} - \text{H} \]
   ii. Unsaturated hydrocarbon
      An unsaturated hydrocarbon contains at least one double carbon to carbon bond or one triple carbon to carbon bond.
      Example: ethene \[ \text{H} - \text{C} = \text{C} - \text{H} \]

(2 marks)

c. Name the organic substance with the following structure.

\[ \text{H} \text{Cl} \text{H} \text{H} \text{H} \text{H} \]
\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \]
\[ \text{H} \text{H} \text{Br} \text{O} \text{O} \text{H} \]

3-bromo-1-chloro-2-pentanol
or 3-bromo-1-chloro-pentan-2-ol

(1 mark)

d. Draw the structure of 1, 3, 5-trifluorocyclohexane.

(1 mark)

e. Describe:
   i. one method for the preparation of ethanol
      Fermentation of sucrose: dissolve some sugar in water and add yeast. Allow the mixture to ferment for 5 days or more. Distill the mixture and collect the alcohol that boils off. Repeated distillations will increase the concentration of alcohol.

(1 mark)
ii. two major uses of ethanol and why these are significant in today's society

Possible answers include: 1. Use as an additive in fuels for cars, which is significant as it extend to available supply of petrol from oil. 2. As a constituent of alcoholic drinks, which is significant due to its widespread recreational use and the social consequences such as the road toll.

(2 marks)

Question 15 — Chemical periodicity

a. Identify, on the diagram below, the s, p, d and f block groups of elements.

(b) What are valence electrons?

Valence electrons are those electrons in the outer unfilled energy level of an atom.

(1 mark)

c. Write the electron configuration for:

i. carbon  \[ 1s^2 \ 2s^2 \ 2p^2 \]

ii. calcium  \[ 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \]

(1 mark)
d. Sodium and chlorine are both very reactive but react differently. Explain this difference with reference to the electron configuration, ionisation energy and electronegativity when they react with oxygen.

Na has... lower shell electron and a low ionisation energy and electronegativity (both lower than oxygen) so it will tend to lose an electron to form the Na⁺ ion while the Oxygen forms a negative ion Cl⁻ and O both have high ionisation energy and electronegativity of non-metals so a polar covalent bond results from unequal sharing of the electron pair.

(2 marks)

Question 16 — Gases and the atmosphere

a. Explain:
   i. how real gases differ from ideal gases

      Ideal gases obey the gas laws exactly while real gases do not since their particles do occupy some space and there is some attraction between the particles.

   (1 mark)

   ii. the conditions under which real gases behave most like ideal gases

      a. at high temperature and low pressure real gases behave most like ideal gases

   (1 mark)


   Total pressure is equal to the sum of the partial pressures of all gases present. $P_{total} = P_1 + P_2 + \ldots$ etc.

   (1 mark)

c. Calculate the number of moles of gas needed to fill a balloon to a volume of 8.5 litres at a pressure of 1.25 atmospheres and a temperature of 20°C.

   $P = 1.25 \text{ atm} = 125 \times 10^3 \text{ kPa} = 126.6 \text{ kPa}$
   $T = 20°C = 293K$

   $\frac{PV}{RT} = \frac{126.6 \times 8.5}{9.31 \times 293}$

   $= 0.44 \text{ moles}$

   (3 marks)
Question 17 — Energy and rates of chemical reactions

a. State how the enthalpy of reactants and enthalpy of products relate to the heat of reaction.

\[ \text{Heat of reaction (AH)} = \text{Enthalpy of products} - \text{Enthalpy of reactants} \]

IF \( AH \) is negative reaction is exothermic

IF \( AH \) is positive reaction is endothermic

(1 mark)

b. On the diagram below, indicate how a potential energy-reaction coordinate diagram changes if a catalyst is present in a reaction.

![Diagram of energy reaction coordinate showing a lower activation energy]

(1 mark)

c. Use the collision theory to describe how changes to each of the following affect the rate of a reaction.

i. Concentration of reactants
   As concentration increases so does the frequency of successful collisions allowing reaction rate to increase.

ii. Surface area of reactants
   As surface area increases there are more collisions in a given time, which leads to an increased rate of reaction.

iii. Temperature of the reaction system
   As temperature increases, the average kinetic energy of particles increases, given more successful collisions and an increased rate of reaction.

(3 marks)

d. Explain why the following equation for the burning of methane does not represent the reaction mechanism.

\[ \text{CH}_4(g) + 2\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(g) \]

For this to represent the reaction mechanism, it implies that three particles would have to collide at exactly the same time. The probability of this happening is virtually zero, so there must be intermediate steps in the reaction.

(1 mark)
e. Given the following heats of formation,

\[ \begin{align*}
(1) & \quad C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H^\circ_f = -393.5 \text{ kJ mole}^{-1} \\
(2) & \quad 2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \quad \Delta H^\circ_f = -285.8 \text{ kJ mole}^{-1} \\
(3) & \quad 2H_2(g) + O_2(g) \rightarrow 2H_2O(g) \quad \Delta H^\circ_f = -241.8 \text{ kJ mole}^{-1} \\
(4) & \quad 2C(s) + 2H_2(g) \rightarrow C_2H_4(g) \quad \Delta H^\circ_f = -52.30 \text{ kJ mole}^{-1} \\
\end{align*} \]

determine the $\Delta H$ for the following reaction.

\[ C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l) \]

\[ \text{using (1)} \quad 2C(s) + 2O_2(g) \rightarrow 2CO_2(g) \quad \Delta H^\circ_f = -393.5 \text{ kJ mole}^{-1} \]

\[ \text{using (2)} \quad 2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \quad \Delta H^\circ_f = -285.8 \text{ kJ mole}^{-1} \]

\[ \text{using (4)} \quad 2C(s) + 2H_2(g) \rightarrow C_2H_4(g) \quad \Delta H^\circ_f = -52.30 \text{ kJ mole}^{-1} \]

(5) is not needed

\[ \text{add equations} \]

\[ 2C(s) + 2O_2(g) + 2H_2(g) + O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l) + 2C_2H_4(g) \]

\[ \text{net equation} \quad 4C_2H_4(g) + 6O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l) + 2C_2H_4(g) \]

\[ \Delta H = (523 - 285.8 - 737) \text{ kJ mole}^{-1} \]

\[ = -1020.5 \text{ kJ mole}^{-1} \]

(2 marks)

Question 18 — Chemical equilibrium

a. State the similarities and differences between a steady state reaction and a dynamic equilibrium.

**Similarities:**
- No changes in macroscopic properties
- Concentrations of reactants and products are constant

**Differences:**
- Dynamic equilibrium is a closed system
- While steady state is an open system with constant addition of reactants and removal of products to maintain constant properties

(1.5 marks)
b. Define the terms strong electrolyte, weak electrolyte and non-electrolyte. Give an example of each.

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>strong electrolyte</td>
<td>virtually complete dissociation into ions when dissolved</td>
<td>( \text{NaCl}_\text{(aq)} \rightarrow \text{Na}^{+}(\text{aq}) + \text{Cl}^{-}(\text{aq}) )</td>
</tr>
<tr>
<td>weak electrolyte</td>
<td>partial dissociation when dissolved</td>
<td>( \text{CH}<em>3\text{COOH}</em>\text{(aq)} \rightarrow \text{H}^{+}(\text{aq}) + (\text{CH}_3\text{COO})^{-}(\text{aq}) )</td>
</tr>
<tr>
<td>non-electrolyte</td>
<td>does not dissociate into ions</td>
<td>sucrose ( \text{C}_12\text{H}_22\text{O}_11 )</td>
</tr>
</tbody>
</table>

(3 marks)

c. Write the equilibrium law expression for the following reaction.

\[ \text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^- (\text{aq}) \]

\[ K = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} \]

(1 mark)

d. For the reaction \( 2\text{Ag}^+(\text{aq}) + \text{Pb(s)} \rightleftharpoons 2\text{Ag(s)} + \text{Pb}^{2+}(\text{aq}) \)

the equilibrium law expression is given as

\[ K = \frac{[\text{Pb}^{2+}]}{[\text{Ag}^+]^2} \]

Explain why the concentrations of \( \text{Pb(s)} \) and \( \text{Ag(s)} \) are not included in the expression.

Concentrations of substances which remain constant are omitted from K calculations. Solids have a constant concentration and so are omitted.

(1 mark)

e. Explain what will happen to the concentration of \( \text{H}^+ \) ions if more \( \text{ClO}^- \) ions are added to a reaction vessel containing the following reaction at equilibrium.

\[ \text{ClO}^- (\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{I}^- (\text{aq}) \rightleftharpoons \text{I}_2(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \]

When \([\text{ClO}^-]\) is increased, the system responds by using some of the added \( \text{ClO}^- \) thus using more reactants so \([\text{H}^+]\) will decrease.

(1 mark)
f. Calculate the Ca\(^{2+}\) ion concentration in a saturated solution of CaF\(_2\).

For CaF\(_2\), \(K_{sp} = 3.9 \times 10^{-11}\)

\[
K_{sp} = [Ca^{2+}][F^-]^2
\]

\[
10^{+} [Ca^{2+}] = x \quad \Rightarrow \quad [F^-] = 2x
\]

Thus, \(3.9 \times 10^{-11} = x \cdot (2x)^2\)

\[
\Rightarrow \quad x = \left(\frac{3.9 \times 10^{-11}}{4}\right)^{1/3}
\]

\[
[Ca^{2+}] = 2.4 \times 10^{-4} \text{ mol L}^{-1}
\]

(2 marks)

g. Calculate the H\(^+\) ion concentration, OH\(^-\) ion concentration and pH of a 2 mole L\(^{-1}\) solution of hypochlorous acid (HClO).

For HClO, \(K_a = 3.0 \times 10^{-8}\)

(State any assumptions you make in order to simplify your calculations.)

\(HClO \rightarrow H^+ + ClO^-\)

Initial state: \(\begin{array}{ccc} HClO & H^+ & ClO^- \end{array}\)

Equilibrium state: \(\begin{array}{ccc} 2 & 0 & x \end{array}\)

Since \(K_a\) is small, assume \(2-x = 2\)

\[
K_a = \frac{[H^+][ClO^-]}{[HClO]}
\]

\[
\Rightarrow \quad 3.0 \times 10^{-8} = \frac{x}{2-x}
\]

Hence, \(x = 3.0 \times 10^{-8}\)

\[
[H^+] = 1 \times 10^{-4} \quad \Rightarrow \quad [ClO^-] = 1 \times 10^{-4}
\]

\[
[OH^-] = \frac{4.0 \times 10^{-10}}{2.4 \times 10^{-8}}
\]

\[
[H^+] = 2.45 \times 10^{-4} \text{ mol L}^{-1}
\]

(2.5 marks)
Part B — Scientific processes

Part B assesses scientific processes based on the eight topics in the 1998 senior external syllabus for Chemistry and practical work undertaken during your study of the subject.

Part B has five questions of equal value. Attempt only four questions.

Write your responses in the spaces provided.

Suggested time allocation: 40 minutes.

Question 1

A group of students were set the task of determining experimentally the heat of combustion of methanol. They set up the equipment as shown below:

![Diagram of experiment setup]

They heated the water for 10 minutes and obtained the following data:

<table>
<thead>
<tr>
<th>Volume of water</th>
<th>100 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial temperature</td>
<td>23.5°C</td>
</tr>
<tr>
<td>Final temperature</td>
<td>78.5°C</td>
</tr>
<tr>
<td>Initial mass of glass bulb, methanol and wick</td>
<td>185.2 g</td>
</tr>
<tr>
<td>Final mass of glass bulb, methanol and wick</td>
<td>183.6 g</td>
</tr>
</tbody>
</table>

a. Use this data to determine an experimental value for the molar heat of combustion of methanol.

\[
\Delta t = 78.5°C - 23.5°C = 55°C \quad \text{Mass of methanol}
\]

\[
Q = m \cdot c \cdot \Delta t = 100 \times 4.2 \times 55 \text{ J}
\]

\[
= 23100 \text{ J} \quad \left( \frac{231 \text{ kJ}}{1 \text{ J}} \right)
\]

\[
= 185.2 \text{ g} - 183.6 \text{ g}
\]

\[
\Delta H = \frac{23100 \text{ J}}{185.2 \text{ g} \times \frac{1 \text{ mol}}{32 \text{ g}}}
\]

\[
= 4620 \text{ kJ mole}^{-1}
\]
b. The value for the molar heat of combustion of methanol obtained from scientific literature is 726.5 kJ mole\(^{-1}\).

i. Explain why the experimental value obtained differs from this value.
   
   The experimental value is significantly lower than the literature value, indicating the inefficiency of the experimental design. Heat escapes from the system directly into the atmosphere and some is captured by the glass beaker.

ii. Describe two changes that could be made to the equipment used that would result in the experimental value being closer to the value obtained from scientific literature.
   
   (a) Insulation of the system to trap all the heat would improve the results.
   
   (b) Position the thermometer higher in the liquid and incorporate the capacity to stir the liquid.
Question 2

In a laboratory session for a chemistry class, the teacher gave each group of students a solution containing a number of dissolved ionic substances.

One group was given a solution containing silver nitrate (AgNO₃), lead nitrate (Pb(NO₃)₂) and copper nitrate (Cu(NO₃)₂).

Their task is to separate the Ag⁺ ions, Pb²⁺ ions and Cu²⁺ ions from the solution, one at a time, to form three different salts.

Based on your knowledge of solubility of salts in water, determine how this can be achieved.

Decide which reagents should be used, and in what order, and state which salts are formed.

INITIALLY:

1. Add 100 ml of 1M Na₂SO₄ solution to the mixture, stir well and allow precipitate (PbSO₄) to form.
   - Filter the solution to separate the PbSO₄(s) and wash with distilled water.

2. To the filtrate add 100 ml of 1M NaCl solution, stir well and allow precipitate (AgCl) to form.
   - Filter to separate the AgCl(s) and wash with distilled water.

3. To the remaining filtrate add 100 ml of 1M NaOH solution, stir well and allow precipitate to form.
   - Filter to separate the Cu(OH)₂(s) and wash with distilled water.
Question 3

A student presented his chemistry teacher with a 4-litre bottle of water from his home swimming pool. The student had lost the family’s pool testing equipment. He asked for the teacher’s help to determine the pH so he would know whether chemicals needed to be added to the pool to make it safe for swimming.

The teacher asks her class to describe the procedure they would follow to determine the pH using standard laboratory glassware and solutions of indicators, acids and alkalis.

Outline the equipment and procedure you would use if you were a member of this class.

Note: The teacher specifies that using indicator solutions or indicator paper to find the pH is not appropriate as it does not give an accurate enough pH value for this purpose.

**EQUIPMENT** 10ml pipette, 250 ml conical flask, 50ml burette phenolphthalein solution distilled water dropper standardised solution of NaOH white tile

**PROCEDURE**
- Pipette 10mls of pool water into 250ml conical flask
- Add a few drops of phenolphthalein solution
- Add the NaOH solution to the burette, record the initial volume
- Titrate the pool water against the standardised NaOH solution, swirling the conical flask as you proceed
- Continue until the indicator just changes colour and holds its colour change
- Record the volume of NaOH remaining in the burette
- Calculate the volume of NaOH used.
- Repeat the process at least three times to obtain consistent results.

Perform the appropriate calculations using \( C_{V_i} = C_{V_f} \) to obtain \( [H^+] \) and \( pH = -\log [H^+] \) to obtain the pH.

Diagrams over page
Question 4

The table below gives the properties of the elements in row three of the Periodic Table although they are not given in their correct order across the table.

Based on the properties given, match the elements to those of row three.

Justify your decisions.

<table>
<thead>
<tr>
<th>Property</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting point</td>
<td>−101.5° C</td>
<td>660.3° C</td>
<td>44.2° C or 610° C (allotrope)</td>
<td>650° C</td>
<td>−189° C</td>
<td>1416° C</td>
<td>97.7° C</td>
<td>115.2° C</td>
</tr>
<tr>
<td>Boiling point</td>
<td>−34.04° C</td>
<td>2519° C</td>
<td>280.5° C</td>
<td>1091° C</td>
<td>−185° C</td>
<td>3265° C</td>
<td>883° C</td>
<td>444.6° C</td>
</tr>
<tr>
<td>Electrical conductivity in solid state</td>
<td>poor</td>
<td>very good</td>
<td>poor</td>
<td>very good</td>
<td>poor</td>
<td>poor</td>
<td>very good</td>
<td>poor</td>
</tr>
<tr>
<td>Ductility</td>
<td>not ductile</td>
<td>ductile</td>
<td>not ductile</td>
<td>ductile</td>
<td>not ductile</td>
<td>ductile</td>
<td>not ductile</td>
<td></td>
</tr>
<tr>
<td>Density in solid state (unless otherwise indicated)</td>
<td>3.2 g/L in gaseous state</td>
<td>2.7 g/cm³</td>
<td>1.823 g/cm³ to 2.69 g/cm³</td>
<td>1.736 g/cm³</td>
<td>1.78 g/L in gaseous state</td>
<td>2.32 g/cm³</td>
<td>0.963 g/cm³</td>
<td>2.07 g/cm³</td>
</tr>
<tr>
<td>Nature of oxide</td>
<td>acidic</td>
<td>basic</td>
<td>acidic</td>
<td>basic</td>
<td>non-existent</td>
<td>neutral</td>
<td>basic</td>
<td>acidic</td>
</tr>
</tbody>
</table>

- **Argon** is inert so will not form an oxide. **E** is **Argon**
- **Chlorine** is the only row three element other than **Argon** that is a gas at room temperature. **A** is **Chlorine**
- **Silicon** has the highest melting and boiling points of the elements in row three and is the only one to form a neutral oxide. **F** is **Silicon**
- **B**, **D** and **G** form basic oxide so are metallic which is confirmed by them being ductile. The boiling points of metals increase across the row three.

**Element**

<table>
<thead>
<tr>
<th>B.P.</th>
<th>B</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>889° C</td>
<td><strong>B</strong></td>
<td><strong>G</strong></td>
</tr>
</tbody>
</table>

**B** is **Aluminium**

**G** is **Sodium**

**D** is **Magnesium**
- Phosphorus is an element in row three that forms 2 familiar allotropes of yellow (mp 44°C) and red (mp approx 600°C). No C is phosphorus.
- Sulphur is the only remaining element of row three still to be identified. H is Sulphur.

A - Chlorine
B - Aluminium
C - Phosphorus
D - Magnesium
E - Argon
F - Silicon
G - Sodium
H - Sulphur
Question 5

A scientist performed an experiment measuring the volume of a gas sample at various temperatures. She obtained the following data:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Temperature (°C)</th>
<th>Volume (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>in boiling water</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>in warm water</td>
<td>65</td>
<td>37.32</td>
</tr>
<tr>
<td>in tap water</td>
<td>23</td>
<td>31.73</td>
</tr>
<tr>
<td>in ice water</td>
<td>0</td>
<td>29.26</td>
</tr>
<tr>
<td>in dry ice</td>
<td>-78.5</td>
<td>20.85</td>
</tr>
<tr>
<td>in frozen ethanol</td>
<td>-114.3</td>
<td>17.01</td>
</tr>
</tbody>
</table>

a. Graph these results on the following page.

b. Use these results to determine whether there is a direct relationship or an inverse relationship between the temperature and the volume of a gas. Explain how you arrived at this conclusion.

c. Write a mathematical equation that represents the relationship determined in Question 5b above.

d. Use the information given and the graph you have drawn to estimate the value for Absolute Zero in terms of the Celsius temperature scale.

b... As the temperature increases so does the volume... that is, they are directly proportional as indicated by the straight line graph.

c. since they are directly proportional

\[
\frac{V}{T} = \text{constant}
\]

d. Extrapolate the graph to where it intersects the axis at volume equals zero (V=0)

Extrapolation given: - Absolute Zero = approx -273°C
Paper Two

Question 1

a. A 35.00 g sample of a compound containing carbon, hydrogen and oxygen is burnt in excess oxygen to produce 83.23 g of carbon dioxide (CO₂) and 42.56 g of water (H₂O). Determine an empirical formula for this compound.

b. Given that the molar mass of the compound is 74.0 g mole⁻¹ and that it can be oxidised by potassium dichromate to produce a substance that will react with zinc to produce hydrogen, draw two possible structures for the compound.

\[ \text{No. of mole CO}_2 \text{ formed} = \frac{83.23}{44} \text{ mole} = 1.892 \text{ mole} \]

\[ \text{No. of mole H}_2\text{O formed} = \frac{42.56}{18} \text{ mole} = 2.364 \text{ mole} \]

\[ \text{No. of mole C in sample} = 1.892 \text{ mole} \]

\[ \text{No. of mole H in sample} = 2 \times 2.364 \text{ mole} = 4.728 \text{ mole} \]

\[ \text{Mass of C in sample} = 1.892 \times 12 = 22.704 \text{ g} \]

\[ \text{Mass of H in sample} = 4.728 \times 1 = 4.728 \text{ g} \]

\[ \text{Mass of C} + \text{Mass of H} = 22.704 + 4.728 = 27.432 \text{ g} \]

\[ \text{Mass of O in sample} = 35.00 - 27.432 = 7.568 \text{ g} \]

\[ \text{No. of mole O in sample} = \frac{7.568}{16} \text{ mole} = 0.473 \text{ mole} \]

\[ \text{Ratio C : H : O} = 1.892 : 4.728 : 0.473 \]

\[ \text{Empirical formula} = \text{C}_4\text{H}_{10}\text{O} \]

b. Empirical formula mass = 4(12) + 10(1) + 16

\[ = 74 \]

given Molar mass = 74 g mol⁻¹ \text{ ; Molecular formula} = \text{C}_4\text{H}_{10}\text{O} \]
given it can be oxidised by $K_2Cr_2O_7$ to form a substance that reacted with a metal to liberate hydrogen means that it was oxidised to give an acid. Therefore, it was a primary alcohol.

Two possible structures:

(a) $\text{H} - \text{C} - \text{C} - \text{C} - \text{OH}$

(b) $\text{H} - \text{C} - \text{C} - \text{O} - \text{H}$
Question 2

In an experiment to demonstrate how the relative atomic masses of metals can be determined, a teacher set up a series of electrolytic cells as shown below. A current of 10.0 ampere was applied.

![Diagram of electrolytic cells]

a. For what length of time must the 10.0 ampere current be run through the cells for 19.05 g of Cu to be formed on the cathode of the copper cell?

b. The cells were then dismantled and the mass of metal that had formed on the cathodes in the other four cells was found. The following data table was constructed.

<table>
<thead>
<tr>
<th>Cell</th>
<th>Mass of metal formed on cathode (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag</td>
<td>64.76</td>
</tr>
<tr>
<td>Zn</td>
<td>19.62</td>
</tr>
<tr>
<td>Cu</td>
<td>19.05</td>
</tr>
<tr>
<td>Al</td>
<td>5.40</td>
</tr>
<tr>
<td>Sn</td>
<td>35.61</td>
</tr>
</tbody>
</table>

Explain how the results from this experiment can be used to determine the relative atomic masses of these elements.

\[
\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu} \quad \text{(a)}
\]

\[
\text{No. of mole Cu formed} = \frac{\text{Mass of sample}}{\text{Molar Mass}} = \frac{19.05}{63.5} = 0.3 \text{ mole}
\]

\[
\therefore \text{No. of mole e} \text{ required} = 2 \times 0.3 \text{ mole} = 0.6 \text{ mole}
\]
\[ Q = n \times F \]
\[ = 0.6 \times 96500 \text{ coulombs} \]
\[ = 57900 \text{ coulombs} \]

\[ Q = I \times t \quad I = 10 \text{ amps} \]
\[ = 57900 = 10 \times t \text{ (sec)} \]
\[ \therefore t \text{ (sec)} = \frac{57900}{10} \]
\[ = 5790 \text{ sec} \]
\[ = 1 \text{ hr} \ 36 \text{ mins} \ 30 \text{ sec} \]

b. Knowing \( Q \) and coulombs/faceaday, we can calculate the number of moles of electrons associated with each deposit.

Knowing the charge on the most common ion for each metal, we can calculate the number of moles represented by each of the masses.

Then, by the formula, moles = \( \frac{\text{mass of sample}}{\text{mass of 1 mole}} \)

we can calculate the relative atomic masses.
Question 3

A teenage boy buys some balloons to fill with Helium (He) for a party. To stop them floating away, he decides to tie small metal rings to each balloon.

Use the following information to find the minimum number of metal rings he will need to tie to each balloon to stop it floating away.

- Mass of a balloon: 3.6 g
- Mass of string tied to each balloon: 1.5 g
- Mass of each metal ring: 1.2 g
- Volume of balloon when inflated: 15 L
- Pressure of gas in inflated balloon: 1.2 atm
- Temperature: 25°C

Notes:
1. The balloon will float upwards if the total mass of the balloon, string, metal rings and the helium gas inside the balloon is less than the mass of the air displaced.
2. The density of air is 28.8 g mole⁻¹.

\[
N = \frac{\text{Volume of balloon}}{\text{Molar Volume}} = \frac{15 \text{ L}}{24.5 \text{ L/mole}} = 0.612 \text{ mole}
\]

\[
\text{Mass of air displaced} = N \times \text{density} = 0.612 \times 28.8 \text{ g} = 17.63 \text{ g}
\]

A balloon floats if its total mass < 17.63 g

Use \( PV = nRT \) to calculate

\[
\begin{align*}
N &= \frac{PV}{RT} \\
&= \frac{1.2 \times 15}{0.082 \times 298} \\
&= 1.8 \text{ mole} = 0.74 \text{ mole}
\end{align*}
\]

\[
\text{Mass of He} = 0.74 \times 4 \text{ g} = 2.96 \text{ g}
\]
Total Mass = Mass of He + Mass of balloon + Mass of string
= (2.96 + 3.6 + 1.5) g
= 8.06 g.

Require Mass greater than 17.63 g.

\[
\text{Mass of metal rings required} = (17.63 - 8.06) g = 9.57 g
\]

\[
\text{No. of rings required} = \frac{9.57}{1.2} \text{ rings}
\]

\[
= 7.975 \text{ rings}
\]

\[\Rightarrow 8 \text{ rings are required to stop balloons floating}\]
Question 4

Calculate the pH of a solution made by adding 500 ml of 1.0 mole L\(^{-1}\) acetic acid (CH\(_3\)COOH) with 500 ml of 1.0 mole L\(^{-1}\) sodium acetate (NaCH\(_3\)COO).

State any assumptions you have used to simplify your calculations.

Calculate what the pH will be when 1 L of 1.0 mole L\(^{-1}\) hydrochloric acid is added to the solution.

Notes:
1. For CH\(_3\)COOH, \(K_a = 1.8 \times 10^{-5}\).
2. NaCH\(_3\)COO is highly soluble.

\[
\begin{align*}
\text{CH}_3\text{COOH}_\text{aq} & \rightleftharpoons \text{CH}_3\text{COO}^\text{-}_\text{aq} + \text{H}^+_\text{aq} \quad \text{(weak acid, partial dissociation)} \\
\text{NaCH}_3\text{COO}_\text{aq} & \rightarrow \text{Na}^{+}_\text{aq} + \text{CH}_3\text{COO}^\text{-}_\text{aq} \quad \text{(all dissociates and dissolves)} \\
K_a & = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]} \quad \text{(dissociates)} \\
\text{conc.} & \quad \text{0.5 mole} \quad \text{0.5 mole} \quad \text{0.5 mole} \\
\text{after mixing} & \quad \text{0.5} \times x \quad \text{0.5} + x \quad x \\
\text{Since } K_a \text{ is very small assume} & \\
\text{0} & \quad \text{0.5} - x = 0.5 \\
\text{2} & \quad 0.5 + x = 0.5 \\
\therefore & \quad 1.8 \times 10^{-5} = \frac{0.5 \times x}{0.5} \\
& \quad x = 1.8 \times 10^{-5} \\
\text{pH} & = -\log \text{[H}^+] \\
& = -\log 1.8 \times 10^{-5} \\
& = 4.74
\end{align*}
\]
\[
\begin{align*}
\text{Initial M.} & \quad \text{M.} & \quad \text{M.} & \quad \text{M.} \\
\text{N. of mole} & \quad 0.5 & \quad 0.5 & \quad 1.8 \times 10^{-5} \\
\text{N. of mole added} & \quad 0 & \quad 0 & \quad 1 \\
\text{N. of mole after mixing} & \quad 0.5 & \quad 0.5 & \quad 1.8 \times 10^{-5} \\
\text{but before equil} & \\
\text{Cone after mixing} & \quad 0.25 & \quad 0.25 & \quad \frac{1}{2} \left(1 \times 1.8 \times 10^{-5}\right) \\
\text{but before equil} & \text{established} & \\
\text{Given K_a is very small} \left(1.8 \times 10^{-5}\right) \\
\text{cone at equilibrium} & \quad 0.25 + (0.25 - x) \quad \text{and} \quad \frac{1}{2} (1 \times 1.8 \times 10^{-5}) - (0.25 - x) \\
\end{align*}
\]

Assume \( x \) is so small that \( (0.25 - x) = 0.25 \)

\( 1 + 1.8 \times 10^{-5} = 1 \)

\( 1.8 \times 10^{-5} = 1 \)

\( \therefore [H^+] = \frac{1}{2} \left(1 + 1.8 \times 10^{-5}\right) - (0.25 - x) \) M

\( = \frac{1}{2} \left(0.5 - 0.25\right) \) M

\( = 0.25 \) M

\( \therefore p[H^+] = -\log[0.25] \)

\( = 0.6 \)