Student Name: _____

2023 **HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION**

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations

Total marks: 100

Section I – 20 marks (pages 3 – 11)

- Attempt Questions 1 – 20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 13 – 30)

- Attempt Questions 21 – 36
- Allow about 2 hours and 25 minutes for this section.

Section I
20 marks

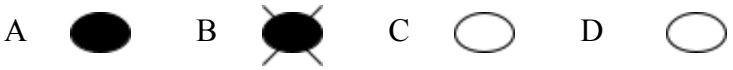
Attempt Questions 1-20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet (yellow colour).

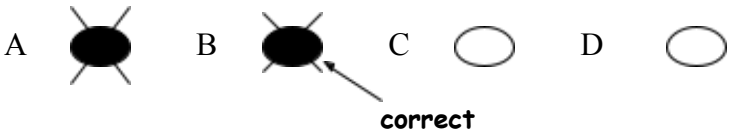
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.



If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



Section I

20 marks
Attempt Questions 1 – 20.
Allow about 35 minutes for this section.

Use the multiple-choice answer sheet for Questions 1–20.

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1. What are two components required to prepare a buffer solution?

(A) A weak acid and a weak base.

(B) A weak acid and its conjugate base.

(C) A strong acid and a strong base.

(D) A strong base and its conjugate acid.

2. Which of the following will change the value of the equilibrium constant (K_{eq}) for a gaseous reaction?

(A) Addition of heat.

(B) Addition of a catalyst.

(C) Addition of a reactant.

(D) Addition of an inert gas at constant volume.

3. Which one of the following species could be analysed using AAS?

(A) Sr^{2+}

(B) S^{2-}

(C) SO_2

(D) SO_4^{2-}

4. The forward reaction in the equilibrium shown below is endothermic.

OCl^- *(aq)* + H_2O *(l)* ⇌ HOCl *(aq)* + OH^- *(aq)*

Which change increases the concentration of hypochlorous acid (HOCl)?

(A) Adding water.

(B) Adding sodium hypochlorite, NaOCl *(aq)*.

(C) Increasing the pH.

(D) Lowering the temperature.

5. A saturated solution of $BaSO_4$ is maintained at a constant temperature. Solid soluble Na_2SO_4 is added to this solution. What happens to the Ba^{2+} and SO_4^{2-} ion concentrations in the resultant solution compared to the initial solution?

(A) Ba^{2+} concentration increases and SO_4^{2-} concentration remains the same.

(B) Ba^{2+} concentration increases and SO_4^{2-} concentration increases.

(C) Ba^{2+} concentration decreases and SO_4^{2-} concentration increases.

(D) Ba^{2+} concentration decreases and SO_4^{2-} concentration remains the same.

6. At a certain temperature, the K_{eq} for the following reaction is 37.5.

$$2O_3(g) \rightleftharpoons 3O_2(g)$$

0.3 mol of O_3 and 1.5 mol of O_2 were introduced to a 4L reaction vessel.

Which row of the table correctly identifies the direction of the equilibrium shift and the reason for the shift?

	Direction favoured	**Reason**
(A)	Left	$Q < K_{eq}$
(B)	Left	$Q > K_{eq}$
(C)	Right	$Q < K_{eq}$
(D)	Right	$Q > K_{eq}$

7. In 1884, Svante Arrhenius proposed a definition for acids. His definition was soon accepted as superior to that put forward by earlier chemists. Why was Arrhenius's definition seen as a major breakthrough?

(A) It explained why some acids do not contain oxygen.

(B) It could be used to explain why some acids are strong and others are weak.

(C) It showed the relationship between pH and the concentration of H^+ ions.

(D) It showed how the solvent can affect the strength of an acid.

8. How many isomers can exist for $C_3H_6F_2$?

(A) 2

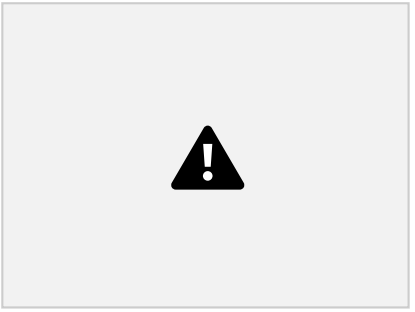
(B) 3

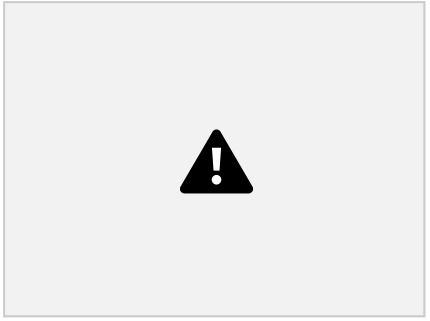
(C) 4

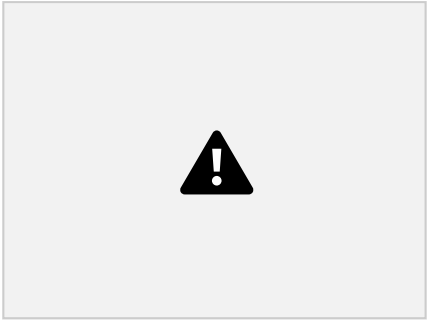
(D) 5

9. Which of the following conductivity curves correctly depicts the titration of nitric acid against potassium hydroxide?

(A) 

(B) 

(C) 

(D) 

10. A solution containing an unknown metal cation is mixed with a concentrated solution of hydrochloric acid. A flame test was performed on the mixture and a brick red flame was observed.

Which of the following is the most appropriate conclusion from this test?

(A) The unknown cation is barium.

(B) The unknown cation is calcium.

(C) The unknown cation is magnesium.

(D) The unknown cation is copper.

11. Which option represents K_{eq} for the reaction below?

$$2SO_3\,(g) \leftrightharpoons 2SO_2\,(g) + O_2\,(g)$$

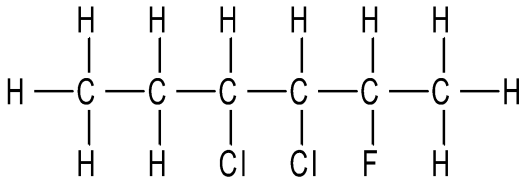
(A) $2[SO_2]\,[O_2] \,/\, 2\,[SO_3]$

(B) $[SO_2]^2\,[O_2] \,/\, [SO_3]^2$

(C) $[SO_3]^2 / \,[SO_2]^2\,[O_2]$

(D) $2[SO_3] / 2\,[SO_2]\,[O_2]$

12. What is the IUPAC name of the following compound?



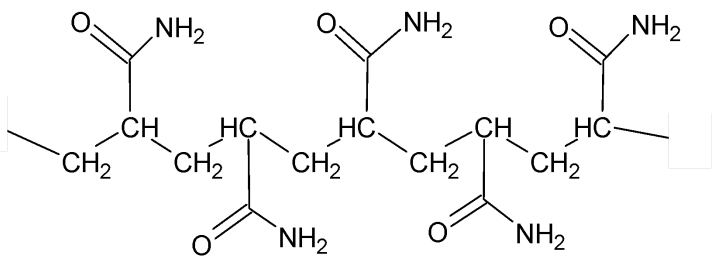
(A) 5-fluoro-3,4-dichlorohexane.

(B) 2-fluoro-3,4-dichlorohexane.

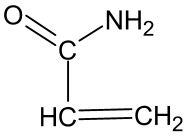
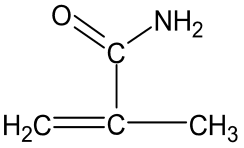
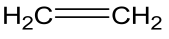
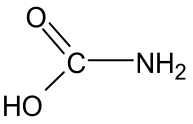
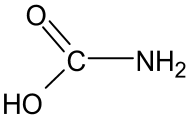
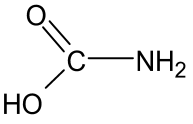
(C) 3,4-dichloro-5-fluorohexane.

(D) 3,4-dichloro-2-fluorohexane.

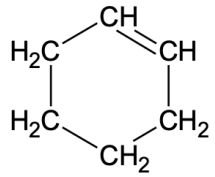
13. The diagram below shows a polymer.

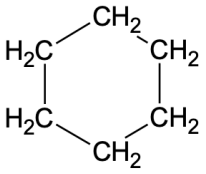


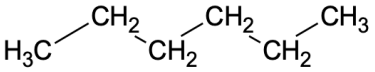
Identify the type of polymerisation reaction used to produce it and the monomer or monomer units used to make it.

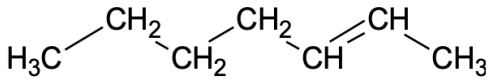
	Type of Polymerisation	Monomer 1	Monomer 2
(A)	Addition		
(B)	Addition		
(C)	Condensation		
(D)	Condensation		

14. Consider the following carbon compounds, which are all clear, colourless liquids.

(i) 

(ii) 

(iii) 

(iv) 

Which of these compounds would decolourise Br_2 *(aq)* under ordinary laboratory light?

(A) i and ii.

(B) ii and iii.

(C) i and iv.

(D) ii and iv.

15. What is the pH of a 0.010 $mol.L^{-1}$ solution of a weak monoprotic acid that is 4.0% ionised?

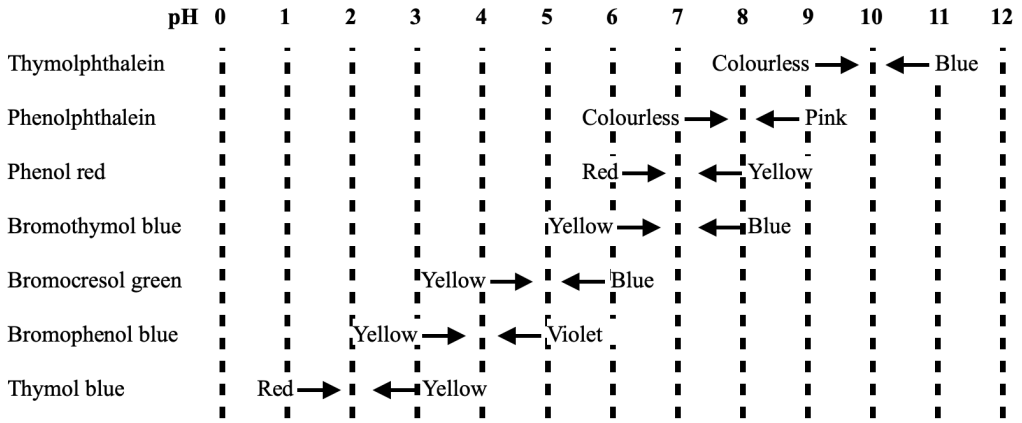
(A) 2.40

(B) 2.80

(C) 3.40

(D) 7.00

16. The chart below shows the colours of some indicators over a range of pH values.



For a solution of pH 4.5, which set of indicators could be used to give the most accurate determination of pH?

(A) Bromocresol green, phenol red and phenolphthalein.

(B) Thymol blue, bromophenol blue and phenolphthalein.

(C) Thymol blue, bromothymol blue and thymolphthalein.

(D) Thymol blue, bromophenol blue and bromocrescol green.

17. A food critic noticed their specialty chicken dish was extremely bland and requested that analysis be carried out to measure the sodium chloride concentration. This was achieved by dissolving the food sample in water and the chloride ion being precipitated by adding an excess of silver nitrate solution. The precipitate was washed and dried.

If the mass of the food sample was 10.0 g and the final precipitate had a mass of 0.188 g, what is the percentage of sodium chloride in the food?

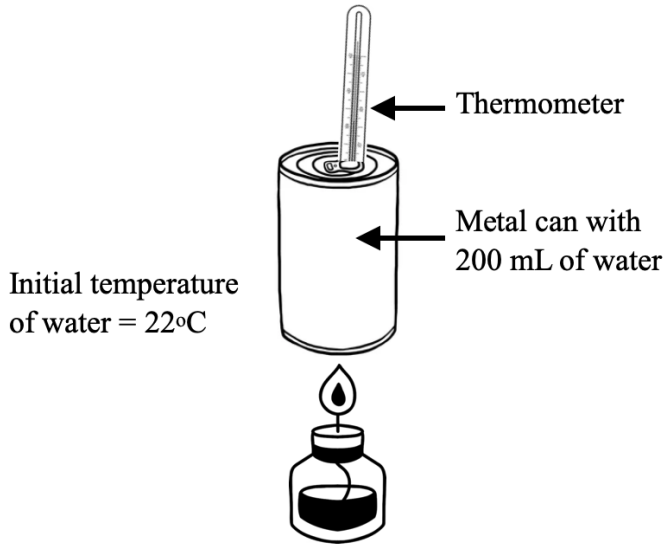
(A) 1.88%

(B) 0.766%

(C) 0.465%

(D) 0.220%

18. A student carried out an experiment, using the apparatus shown, to find the heat of combustion of ethanol.



When 1.80 g of ethanol was burnt, the temperature of the water increased to 48°C. Calculate the energy released, in kJ, when 1.50g of ethanol was burnt.

(A) 21.74 kJ

(B) 18.11 kJ

(C) 4.803 kJ

(D) 4.353 kJ

19. The pH of pure water at 50°C ($K_w = 5.5 \times 10^{-14}$) is:

(A) 6.63

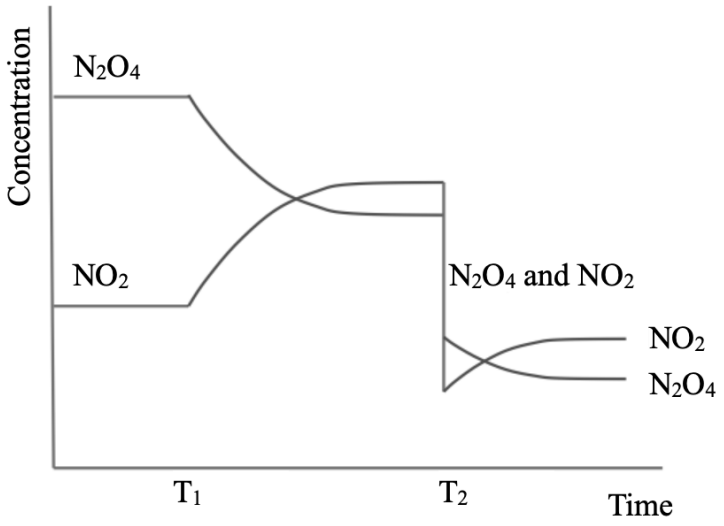
(B) 7

(C) 13.2

(D) 13.6

20. The graph shows the concentrations over time for the equilibrium system:

$2NO_2\,(g) \rightleftharpoons N_2O_4\,(g)$ $\Delta H = -58\ kJ.mol^{-1}$



What has happened to the temperature at T_1 and to the volume at T_2?

(A) Temperature ***decreased*** at T_1 and volume ***increased*** at T_2

(B) Temperature ***increased*** at T_1 and volume ***decreased*** at T_2

(C) Temperature ***decreased*** at T_1 and volume ***decreased*** at T_2

(D) Temperature ***increased*** at T_1 and volume ***increased*** at T_2

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Student Number

Chemistry

2023 TRIAL EXAMINATION

Section II
80 marks

Attempt Questions 21- 36
Allow about 2 hour and 25 minutes for this part.

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 21 (3 marks)

How did Aboriginal and Torres Strait Islander peoples use their knowledge of solubility equilibria to remove toxins in cycad fruit? **3**

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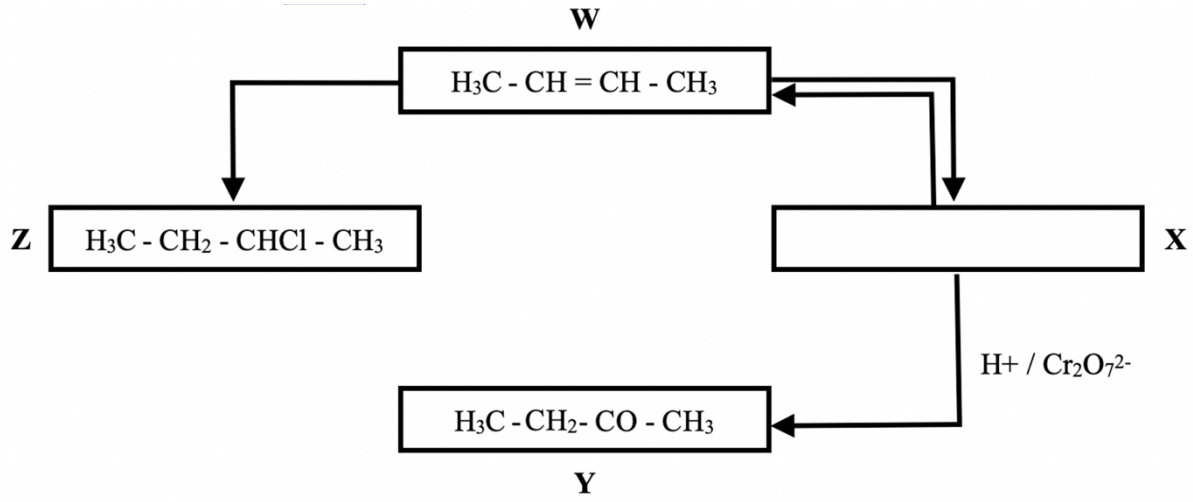
Question 22 (6 marks)

Consider the reactions below.



(a) Identify the name of the compound in Z. **1**

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(b) Name and draw the structural formula of the compound in X. **2**

Name:

(c) Identify another condition that can assist the conversion of X into Y. **1**

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(d) Draw the reaction of compound W with bromine water, using structural formulae, and name the product formed. **2**

Name:

Question 23 (6 marks)

A farm is situated close to a nearby stream. A group of environmental science students were curious to determine if any barium ions are present in the stream.

(a) Describe a method these students could use to determine the presence of barium ions, using a flame test on the water. **2**

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(b) Discuss the limitations of using a flame test for the identification of barium ions. **2**

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(c) Suggest an alternative method for testing for the presence of barium ions in the water. **2**

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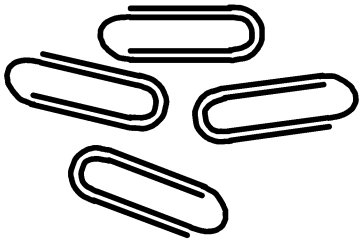
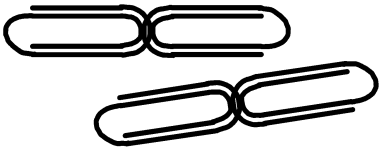
Question 24 (5 marks)

Two students set up a simple game involving 40 paper clips. Student **X** was responsible for connecting individual paper clips into pairs, whist student **Y** was responsible for taking apart the connected paper clips. Both students remained blindfolded during the game.

Individually separated paper clips



Connected pairs of paper clips



After a while, the amount of individual and connected paper clips became constant.

(a) How does this model relate to the essential features of a dynamic equilibrium reaction? **2**

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(b) A third student added another pile of individual paper clips to the game. After a while, the amount of individual and connected paper clips became constant again. **3**

By referring to the collision theory, explain how the addition of more paperclips to the game simulates the effect of concentration on a chemical equilibrium.

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Question 25 (7 marks)

A buffer solution has the property of resisting changes in pH even when small amounts of acid or alkali are added to it.

(a) Compare the change in pH of a 1:1 molar solution of $CaCl_2$/HCl and a 1:1 molar solution of $NaH_2PO_4^-/Na_2HPO_4$ when a small amount of acid is added to the mixture using equilibrium principles and the Brönsted-Lowry theory. **5**

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(b) Provide reasons why the Arrhenius theory is inadequate in explaining the differences in behaviour of the substances in part (a). **2**

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Question 26 (3 marks)

Nylon 6-6 is a condensation polymer formed from the reaction between hexane-1,6-diamine (NH_2-C_6H_{12}-NH_2) and hexanedioic acid (COOH-C_4H_8-COOH). The polymer is formed according to the chemical equation shown below.

$$n\text{NH}_2\text{-C}_6\text{H}_{12}\text{-NH}_2 + n\text{COOH-C}_4\text{H}_8\text{-COOH} \rightarrow$$
$$n\text{COOH-C}_4\text{H}_8\text{-CO- NH-C}_6\text{H}_{12}\text{-NH}_2 + (2n\text{-}1)\ \text{H}_2\text{O}$$

The molar masses of some species are shown in the table below.

Species	Molar mass ($g.mol^{-1}$)
hexane-1,6-diamine	116.20
hexanedioic acid	146.14
Nylon 6-6	244.31

If 220.0 g of hexanedioic acid and 280.0 g of hexan-1,6-diamine are reacted together in a vessel, what mass of nylon 6-6 is produced if the reaction goes to completion?

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Question 27 (4 marks)

Three solutions of citric acid, hydrochloric acid and acetic (ethanoic) acid each have a concentration of 0.1 $mol.L^{-1}$ and a pH of 2.1, 1.0 and 2.9, respectively.

(a) Why are the pH values different even though the acid concentrations are the same? **2**

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(b) A student dilutes the acetic (ethanoic) acid in part (a) by dissolving 10 mL in 100 mL of water. The pH of the diluted solution was then measured to be 3.4. **2**

They expect that decreasing the concentration of hydrogen ions by a factor of 10 will increase the pH by one unit.

Account for the increase in pH of only 0.5 units.

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Question 28 (5 marks)

Look at the following equation for the manufacture of soap.

Oil + 3*X* $\leftrightharpoons$ $3CH_3(CH_2)_{14}COONa$ + *Y*

(a) Identify the components *X* and *Y*. **1**

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(b) Account for the cleaning action of this soap by describing its structure and interaction with water (use diagrams to support your answer). **4**

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Question 29 (5 marks)

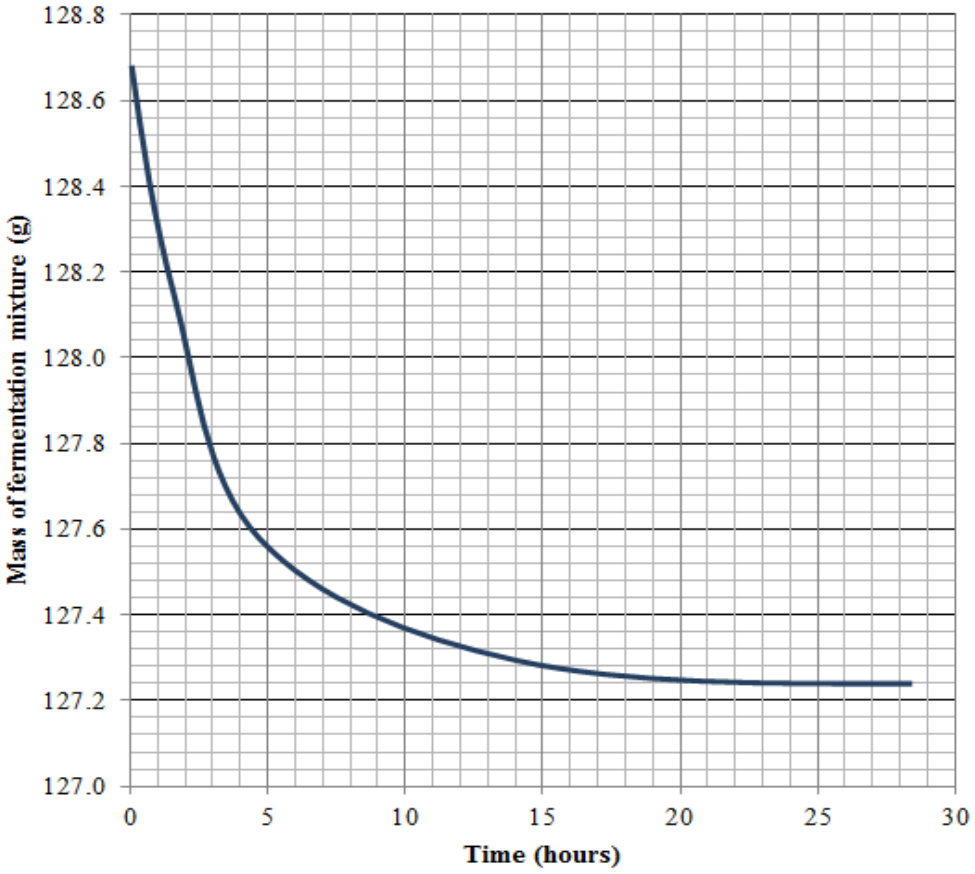
The production of alcohol can be achieved in the school laboratory by the fermentation of glucose according to the equation below:

$$C_6H_{12}O_6\,(aq) \xrightarrow{\text{yeast}} 2C_2H_5OH\,(aq) + 2CO_2\,(g)$$

A student added 12g of glucose to a conical flask along with 1g of yeast and 50 mL of water at 37°C.

The conical flask was placed on a balance that was connected to a computer to monitor mass changes in the reaction vessel.

The graph below shows how the mass of the reaction mixture changed over a 24 hour period.



(a) Calculate the mass change in the conical flask by referring to the graph. **1**

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Question 29 continues on the next page

Question 29 continued

(b) Calculate the mass of ethanol produced by the reaction and compare this to the theoretical yield of ethanol. **4**

Show all working.

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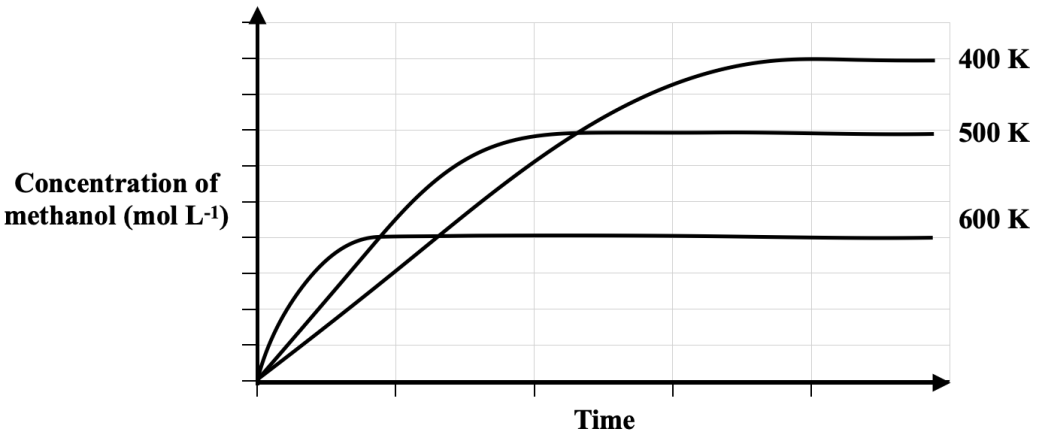
Question 30 (5 marks)

Hydrogen and carbon monoxide react as gases as follows.

$2H_2\,(g) + CO\,(g) \rightleftharpoons CH_3OH\,(g)$



(a) Write the equilibrium expression for this reaction. **1**

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(b) State one way that the equilibrium constant for this reaction could be increased. **1**

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(c) 1.0 mol of H_2 and 1.0 mol of CO were placed into a 4.0 L container at 298 K. When the system had reached equilibrium, it was found that 0.2 mol of CH_3OH had been formed.

Calculate the equilibrium constant for the reaction under these conditions.

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Question 31 (5 marks)

A sample of lemon juice was analysed in the laboratory to calculate the concentration of citric acid present. A student took 25.00 mL of the juice and diluted it to 250.00 mL. Exactly 25.00 mL of the diluted lemon juice was titrated with a standardised 0.1245 $mol.L^{-1}$ sodium hydroxide solution using phenolphthalein as the indicator. An average titre of 23.95 mL of sodium hydroxide was required.

Assuming that the lemon juice contained only citric acid, a triprotic acid ($C_6H_8O_7$), calculate the concentration in mol L^{-1} of citric acid in the undiluted lemon juice.

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Question 32 (7 marks)

The properties of three organic compounds, Q, R and S, are given in the table.

Compound	**Q**	**R**	**S**
Example	CH_3CH_2COOH	$CH_3CH_2CH_2CH_2NH_2$	$CH_3CH_2CONH_2$
Molecular weight ($g.mol^{-1}$)	74.08	73.14	73.09
Boiling Point (°C)	141.2	78	213
pK_a	4.88	10.21	0.42

(a) Name the three compounds tabulated above: **3**

Q …….

R …….

S …….

(b) Write TWO balanced chemical equations to compare the reactions that occur when compounds **Q** and **R** are individually added to water. **2**

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(c) Provide reasons for the variation in boiling points between the carboxylic acid and the amine or the amide, given that all three compounds have very similar molecular masses. **2**

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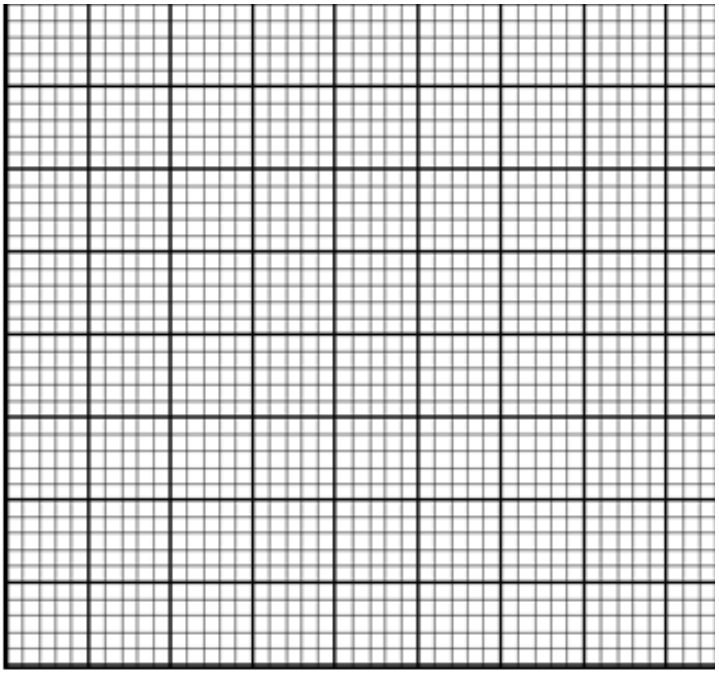
Question 33 (7 marks)

The boiling points of organic acids increases with increase in Molar Mass.

Organic acid	Molar mass (amu)	Boiling point (^{0}C)
Methanoic acid	46	101
Ethanoic acid		118
Propanoic acid	74	?
Butanoic acid	88	163
Pentanoic acid	102	186

(A) Plot graph using the data given in the table. **3**



(B) Using the graph, predict the boiling point of Propanoic acid. 1

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Question 33 continues on the next page

Question 33 continued

(C) To compare the boiling points of organic acids shown above and alcohols with the same number carbon atoms, Kevin plotted a similar graph for molar mass and boiling point of alcohols.

Predict the trend that Kevin should record for the boiling points of alcohols, compare that with the organic acids under investigation. Explain your answer. **3**

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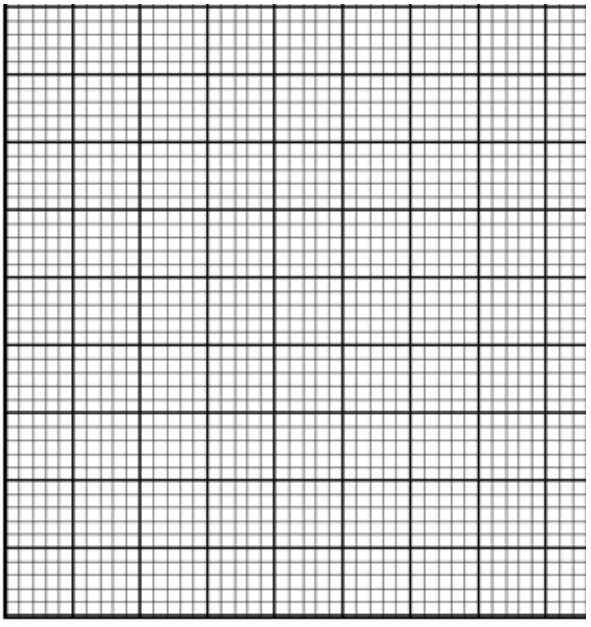
Question 34 (5 marks)

A sample of tuna was analysed to determine its mercury concentration. A 1.00 g sample was broken down with dilute acid and made up to 10.00 mL of solution. This was analysed using an atomic absorption spectrometer, and the amount of light absorbed at the selected wavelength of 254 nm was found to be 0.600. **5**

Industry standards recommend a concentration of no more than 1.05×10^{-6} mol.L^{-1} of mercury to be classified as safe for human consumption.

From the following measurements and using the grid, determine the concentration of mercury and justify if the tuna satisfies the industry standard.

Concentration of Hg (ppm)	Absorbance
0.1	0.260
0.2	0.510
0.3	0.760
0.4	1.100



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Question 35 (5 marks)

A 40.0 mL solution of 2.00 x 10^{-3} mol.L^{-1} sodium sulfate is added to a 200 mL solution of 2.00 x 10^{-3} mol.L^{-1} lead (II) nitrate. Calculate whether a precipitate of lead (II) sulfate will form. **5**

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Question 36 (2 marks)

Photosynthesis is an example of a non-equilibrium system. **2**

The following values occur for the photosynthesis reaction at 25°C.
$\Delta H^o = +2803\ kJ.mol^{-1}$
$\Delta S^o = -212\ J.mol^{-1}.K^{-1}$

Calculate the Gibbs free energy for photosynthesis at 25°C and determine whether this reaction is spontaneous or non-spontaneous in nature.

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End of paper

2023 Year 12 Chemistry Trial Examination - Marking Guidelines and Sample Answers.

Section I Multiple Choice

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B	A	A	B	C	C	B	C	A	B	**B**	D	A	C	C	D	C	B	A	D

Section II

Question 21 (3 marks)

Criteria	Marks
● Clearly outlines how Aboriginal and Torres Strait Islander peoples removed toxins from cycad fruit	3
● Provides some detail on how Aboriginal and Torres Strait Islander peoples removed toxins from cycad fruit	2
● Provides some relevant information	1

Sample Answer:
Aboriginal and Torres Strait Islander peoples used **leaching** to remove toxins from cycad fruit. The seeds of the cycad are used for making bread but contain the toxin cycasin. To remove the toxin, the seeds were crushed and put in a woven bag or basket and placed in **running water**.
The toxin is very **water-soluble so the running water removed** the toxins over several hours or days.

Another method was ageing, where the seeds were left under trees or buried for several months. The chemical structure of the toxin changed over time and was rendered harmless.

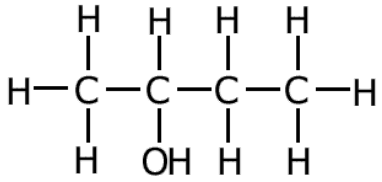
Question 22a (1 mark)

Criteria	Marks
● Identifies 2-chlorobutane	1

Question 22b (2 marks)

Criteria	Marks
● Names and draws correct structure of butan-2-ol	2
● Addresses ONE of the above	1

Sample Answer:



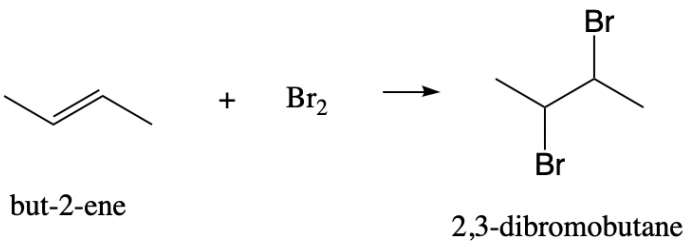
Question 22c (1 mark)

Criteria	Marks
● Acidified potassium permanganate or conc sulfuric and heat	1

Question 22d (2 marks)

Criteria	Marks
● Writes the correct equation using structural formulae and correctly names the organic product. ● OR Reaction with HOBr	2
● Addresses ONE of the above	1

Sample Answer:



Question 23a (2 marks)

Criteria	Marks
● Gives a correct method for carrying out a flame test on a solution. ● Correctly states the expected results	2
● Provides some relevant information	1

Sample Answer:
A nichrome wire loop should be placed in a sample of the water. The wire loop is placed in the blue flame of a Bunsen burner and the colour produced observed. A pale green flame should be produced.

Question 23b (2 marks)

Criteria	Marks
● Discusses at least two limitations of the flame test for the confirmation of barium ions in the water	2
● Identifies one limitation	1

Sample Answer:
The limitations could include:
- Other ions may be in the sample so the colour of the flame will not give accurate results that can be used to identify the presence of barium ions.
- The concentration of barium ions in the sample may be too low to be identified using this method.

Question 23c (2 marks)

Criteria	Marks
● Describe at least one other method to identify barium ions in water **including** a confirmation test	2
● Identifies one method to identify barium ions in water	1

Sample Answer:
Mix the sample with sulphate ions. If a white precipitate is formed, Ba2+ may be present.
To confirm, add fluoride ions in to a sample, which results in no precipitate.

Question 24a (2 marks)

Criteria	Marks
● Explains TWO features of a dynamic equilibrium with reference to the game	2
● Provides some relevant information	1

Sample Answer: Any TWO points from below

- The connecting of individual paper clips by student X represents the forward reaction and the taking apart of paper clips by student Y represents the reverse reaction.

- The use of 40 paperclips further represents a closed system
- The constant number of both individual and connected paperclips reflect equilibrium concentrations of products and reactants.

Question 24b (3 marks)

Criteria	Marks
• Explains the change in reactants and products as a result of an increase in concentration with **reference** to the paper clip game • Addresses collision theory in response • Describes why a new equilibrium will be produced	3
• Addresses TWO of the above criteria	2
• Provides some relevant information	1

Sample Answer:

- In general, increasing the concentration of reactants in a chemical reaction increases the rate of the forward reaction, which can lead to the establishment of a new equilibrium.

When the concentration of reactants is increased, there are more reactant molecules present in the system. This means that there are more opportunities for the reactant molecules to collide with each other and react, which increases the rate of the reaction.

- Thus, an increase in paper clips to the game increases the success and probability of connecting individual paperclips, leading to a higher rate of producing connected paper clips (products).

As the concentration of reactants decreases due to the formation of products, the rate of the forward reaction slows down until it reaches a point where the rate of product formation equals the rate of reactant depletion.

- At this point, a new equilibrium is established.

Thus, as the number of individual paperclips decreases due to the formation of connected paperclips, the rate of the reaction decreases. This will eventually reach a new constant amount of both individual and connected paperclips, reflecting a new equilibrium.

Question 25a (5 marks)

Criteria	Marks
• Makes a general statement summarising the buffering ability of the two pairs of reagents (1) • Compares the reactions of the ions $H_2PO_4^-$, HPO_4^{2-} and Cl^- with water (1) • And relates these to their relative strengths as bases compared with water (1) • Includes an appropriate equation (1) to illustrate the shift in equilibrium required to maintain the pH when an acid is added (1)	5
• Any one point is missing	4
• Any two points missing	3
• Any three points missing	2
• Provides some relevant information	1

Sample Answer:

The capacity of a solution to resist changes in pH upon addition of an acid or a base relies on the existence of compounds that can react with the acid or the base. Specifically, both an acid and a base must be present in the mixture to combine with any added base or acid and preserve the pH. In contrast, a strong acid like HCl, which fully ionises in an aqueous medium, generates a weak conjugate base, Cl^-, that cannot bind to any added acid (proton). Consequently, in the absence of a buffering system, an acid added to the $CaCl_2$/HCl solution will significantly decrease the pH.

The $NaH_2PO_4^-/Na_2HPO_4$ mixture exhibits an equilibrium between $H_2PO_4^-$ and HPO_4^{2-} ions in the presence of water, generating H_3O^+ ions according to the equation below:

$H_2PO_4^-\ (aq) + H_2O\ (l) \leftrightharpoons H_3O^+\ (aq) + HPO_4^{2-}\ (aq)$

In the case of the weak acid $H_2PO_4^-$, the proton remains bound to its conjugate base, the HPO_4^{2-} ion, until it encounters a stronger base, such as the OH^- ion, with which it combines.

In general, buffer solutions resist changes in pH by having both a weak acid and its conjugate base (or a weak base and its conjugate acid) present in the solution. The acid and its conjugate base can react with added H^+ or OH^- ions to maintain the pH of the solution within a certain range. In this example, the phosphate equilibrium is the only one that can act as a buffer.

Question 25b (2 marks)

Criteria	Marks
● States that the Arrhenius concept does not relate the idea of strong and weak acids to the position of equilibrium when an acid is placed in water ● States that the Arrhenius concept has not considered the role of the solvent in acid-base reactions	2
● Addresses one of the above.	1

Sample Answer:
The Arrhenius theory is insufficient to account for the variation in behaviour because it only defines acids as substances that dissociate in water to produce H^+ ions and bases as substances that dissociate in water to produce OH^- ions. This definition does not encompass all acid-base reactions and fails to explain the behaviour of substances that do not ionise in water or do not produce H^+ or OH^- ions. It does not account for acid/base strength as shown by the relative tendency of the species present to accept or donate protons compared with each other and compared with the solvent. To account for the variation in behaviour, the Brönsted-Lowry definition of acids as proton donors and bases as proton acceptors is necessary.

Question 26 (3 marks)

Criteria	Mark
• Correctly calculates the number of moles of each reactant present • Identifies the limiting reagent and uses it to calculate the mass of nylon produced • Correctly calculates the mass of nylon produced	3
• Correctly calculates the number of moles of each reactant present • Calculates the mass of nylon produced without identifying and using the limiting reagent	2
• Correctly calculates the number of moles of each reactant present	1

Sample Answer:

n(hexandioic acid) = $\frac{m}{Mm}$ = $\frac{220\ g}{116.20\ g.mol^{-1}}$ = 1.89328 mol

n(hexan-1,6-diamine) = $\frac{m}{Mm}$ = $\frac{280\ g}{146.14\ g.mol^{-1}}$ mol = 1.9159 mol ~~2.40963~~

n(hexandioic acid is the limiting reagent (1:1)

∴ n(nylon) = 1.89328 mol

m = n x Mm
= 244.31 g.mol^{-1} x 1.89328 mol
= 462.547 g
= 462.5 g (4.s.f)

Question 27a (2 marks)

Criteria	Mark
• Relates hydrogen ion concentration to the extent of degree of ionisation of the strong acid and weak acids • Relates pH to hydrogen ion concentration of monoprotic strong acid, monoprotic weak acid and triprotic weak acid	2
• Provides some relevant information	1

Sample Answer:
HCl is a strong acid and its ionisation is 100%. Citric and acetic acids are weak acids, and their ionisation is partial.
The concentration of hydrogen ions in a solution is used to measure its pH. Since dissociation of HCl 100%, [H3O+] is 0.1 M and it gives the pH value of 1. 0.1M triprotic citric acid has 3 times higher hydrogen ion concentration in a solution compared to 0.1 M acetic acid.
Hence, the pH of HCl is the lowest, citric acid has the next lower pH but acetic acid has a higher pH

Question 27b (2 marks)

Criteria	Mark
• Identifies a weak acid solution as an equilibrium system, uses Le Châtelier's Principle to account for the increase in hydrogen ion concentration • AND Links it to the pH change	2
• Identifies a weak acid solution as an equilibrium system and uses Le Châtelier's Principle to account for the increase in hydrogen ion concentration	1

Sample Answer:
According to the pH equation, pH = -log[H^+], a ten-fold change in the concentration of hydrogen ions results in a one unit change in pH. Thus, diluting an acid by a factor of 10 should increase the pH by one unit, meaning that it should increase to 3.9.
However, in the case of a weak acid, the solution is in equilibrium, and dilution will cause a decrease in the concentration of hydrogen ion concentration. This shifts the equilibrium in favour of the products, leading to an

increase in hydrogen ion concentration and a decrease in pH. Consequently, the net effect of dilution results in an increase of 0.5 pH units instead of one.

Question 28a (1 mark)

Criteria	Mark
● Correctly identifies X and Y	1

Sample Answer:
X and Y are sodium hydroxide and glycerol respectively.

Question 28b (marks)

Criteria	Marks
● Describes the structure of soap ● Clearly accounts for the cleaning action of soap, referring to key terms ● Fully labelled diagram of a soap molecule showing the anion head	4
● Identifies the structure of soap ● Accounts for the cleaning action of soap ● Fully labelled diagram of a soap molecule showing the anion head	3
● Identifies the structure of soap OR describes the cleaning action of soap ● Diagram of a soap molecule showing the anion head	2
Any relevant information	1

Sample Answer:
A soap molecule is composed of a **lengthy hydrocarbon chain with a charged carboxylate group situated at one end**, attached to a sodium ion. Notably, the sodium ion, Na^+, does not contribute to the cleaning action of soap.

The reaction when soap dissolves in water is $CH_2(CH_2)_{15}CH_2COONa\ (s) \rightarrow CH_3(CH_2)_{15}CH_2COO^-\ (aq) + Na^+\ (aq)$

The soap's hydrocarbon **chain is non-polar, rendering it soluble in oil,** and is referred to as the hydrophobic tail, as it repels water. **Water is a polar molecule capable of forming hydrogen bonds with ions in a solution.** The carboxylate group is negatively-charged and is classified as hydrophilic. It possesses a dipole that attracts it to the positive end of the water molecule.

When the material is agitated, the oil soap layer separates from it and the oil gets trapped and dispersed in microscopic droplets known as micelles. **The water then carries these micelles away.**

Question 29a (1 mark)

Criteria	Mark
● Correctly calculates the mass change in the conical flask.	1

Sample Answer:

128.68 g – 127.24 g = 1.44 g ± 0.2

Question 29b (4 marks)

Criteria	Marks
● Correctly calculates moles of carbon dioxide using mass lost. ● Calculates correct mass of ethanol produced ● Calculates the theoretical yield of ethanol ● Makes a comparison of actual and theoretical mass of ethanol produced	4
● Addresses THREE of the above criteria	3
● Addresses TWO of the above criteria	2
● Addresses ONE of the above criteria	1

Sample Answer:
Actual mass of ethanol produced:

$$n(CO_2) = \frac{1.44\ g}{44.01\ g.mol^{-1}}$$

= 0.032 mol

$n(C_2H_5OH)$ = 0.0327 mol (1:1 ratio)
$m(C_2H_5OH)$ = 0.0327 mol x 46.068 $g.mol^{-1}$
= 1.5 g

theoretical mass of ethanol produced:
$n(C_6H_{12}O_6)$ = $\frac{12\ g}{180.156\ g.mol^{-1}}$
= 0.0666 mol

$n(C_2H_5OH)$ = 0.0666 mol x 2 (1:2 ratio)
= 0.1332 mol
$m(C_2H_5OH)$ = 0.1332 mol x 46.068 $g.mol^{-1}$
= 6.1 g

Mass difference = 6.1-1.5g = 4.6g

The actual mass of ethanol produced is 4.6g *lower* than the theoretical mass of ethanol.

Or

the Yield = (1.5 x100)/6.1= 24.59% %

Question 30a (1 mark)

Criteria	Marks
• Correctly writes the equilibrium expression	1

Sample Answer:

$K = \frac{[CH_3OH]}{[H_2]^2[CO]}$

Question 30b (1 mark)

Criteria	Marks
• Correctly identifies decreasing temperature as a means of increasing K	1

Sample Answer:

The value of the equilibrium constant K can only be altered by changes in temperature. Given that the forward reaction is exothermic, a decrease in the reaction temperature would shift the equilibrium in the forward direction, to produce more heat and counteract the temperature change. This would increase the concentration of products, resulting in an increase in the value of K.

Question 30c (3 marks)

Criteria	Marks
• Determines equilibrium concentrations of reactant and products • Use RICE table • Calculates the value of K	3
• Addresses TWO of the above criteria	2
• Addresses ONE of the above criteria	1

Sample Answer:

	H_2	CO	CH_3OH
Initial	0.25	0.25	0

Change	- 0.10	- 0.05	+ 0.05
Equilibrium	0.15	0.20	0.05

$$K = \frac{[CH_3OH]}{[H_2]^2[CO]} = \frac{[0.05]}{[0.15]^2[0.20]} = 11.11 = 10 \text{ (2 s.f.)}$$

Question 31 (5 marks)

Criteria	Marks
● Provides a balanced chemical equation OR evidence of correct stoichiometry ● Calculates correct moles of citric acid ● Calculates correct concentration of diluted citric acid ● Calculates correct concentration of undiluted citric acid ● States answer to four significant figures	5
● Addresses FOUR of the above criteria	4
● Addresses THREE of the above criteria	3
● Addresses TWO of the above criteria	2
● Provides any relevant calculation	1

Sample Answer:

$C_6H_8O_7$ *(aq)* + 3NaOH *(aq)* □ $Na_3C_6H_5O_7$ *(aq)* + 3H_2O *(l)*

n(NaOH) = cv
= 0.1245 mol.L^{-1} x 0.02395 L
= 2.981 x 10^{-3} mol

$\therefore$ n($C_6H_8O_7$) = 2.981 x 10^{-3} mol x 1/3
= 9.93925 x 10^{-4} mol (1:3 ratio)

$$\therefore c(C_6H_8O_7) = \frac{9.93925 \times 10^{-4} \text{ mol}}{0.025 \text{ L}}$$
= 3.975 x 10^{-3} mol.L^{-1} (diluted) /10
= 0.03976 mol.L^{-1} (undiluted)

Question 32a (3 marks)

Criteria	Marks
● Correctly names all three compounds	3
● Correctly names one or two compounds	1-2

Sample Answer:
Q – propanoic acid
R – butan-1-amine
S – propanamide

Question 32b (2 marks)

Criteria	Marks
● Gives two correct equations showing acidic behaviour of Q and basic behaviour of R	2
● Gives one correct equation showing acidic behaviour of Q or basic behaviour of R	1

Sample Answer:
Propanoic acid donates a proton to water
CH_3CH_2COOH*(aq)* + H_2O*(l)* ⇋ $CH_3CH_2COO^-$*(aq)* + H_3O^+*(aq)*

Butan-1-amine receives a proton from water

$CH_3CH_2CH_2CH_2NH_2\ (l) + H_2O(l) \rightleftharpoons CH_3CH_2CH_2CH_2NH_3^+(aq) + OH^-\ (aq)$

Question 32c (2 marks)

Criteria	Marks
● Explains the variation in boiling points between carboxylic acid and amine or amide in terms of the strength of the intra-molecular forces involved due to different functional groups present	2
● Provides some relevant information	1

Sample Answer:

The boiling point of the carboxylic acid (acetic acid) is higher than that of the amine (butan-1-amine) due to the highly polar -COOH functional group, which is more polar than the $-NH_2$ group. Although both functional groups can form hydrogen bonds, the O-H bond in the carboxylic acid is more polar than the N-H bond in the amine because oxygen is more electronegative than nitrogen.

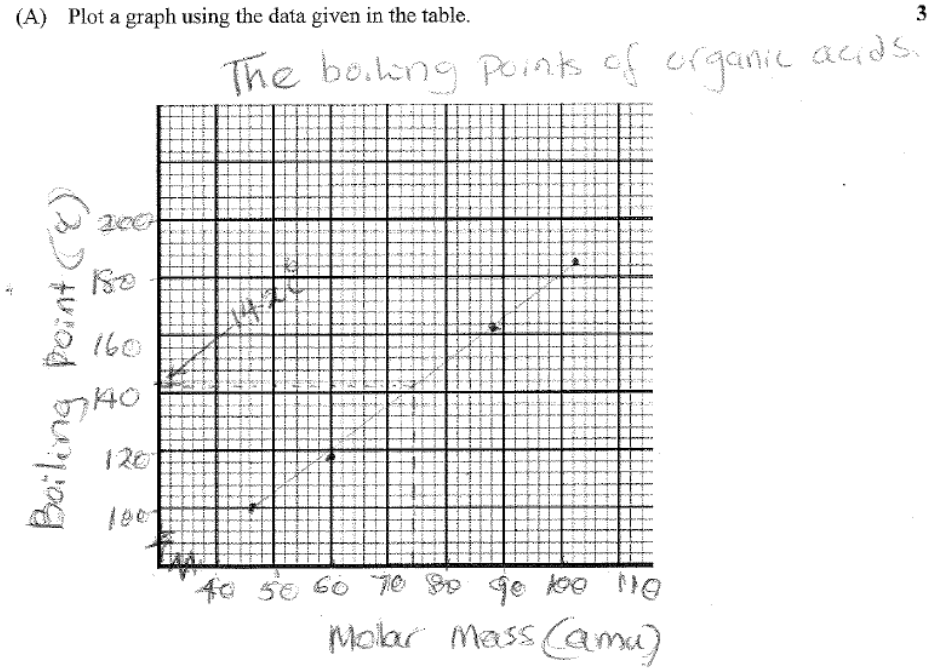
Question 33 (7 marks)

The boiling points of organic acids increases with increase in Molar Mass.

Organic acid	Molar mass (amu)	Boiling point (^{0}C)
Methanoic acid	46	101
Ethanoic acid		118
Propanoic acid	74	?
Butanoic acid	88	163
Pentanoic acid	102	186

Question 33a

(A) Plot a graph using the data given in the table. 3



Criteria	Marks
• Correct X and Y scale and correct labels	1
• Title (correct) and 'Line of best fit'	1
• **All points** plotted correctly	1
OR • Any relevant information	1

(B) Using the graph, predict the boiling point of Propanoic acid. 1

142 ^{0}C +/- 1

(C) To compare the boiling points of organic acids shown above and alcohols with the same number carbon atoms, Kevin plotted a similar graph for molar mass and boiling point of alcohols.

Predict the trend that Kevin should record for the boiling points of alcohols, compare that with the organic acids under investigation. Explain your answer. 3

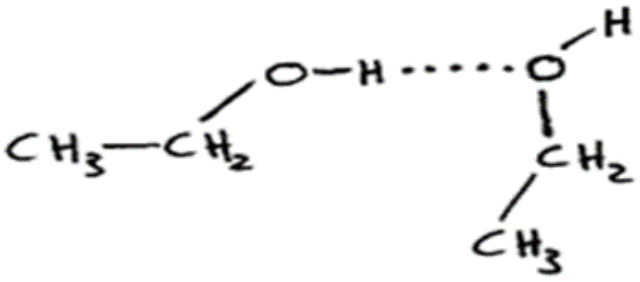
Criteria	Marks
• Identify that carboxylic acids have higher boiling points than alcohols hence the data of the graph should be slightly lower for alcohols	1
• Explain the formation of hydrogen bonds (alcohols + carboxylic acids: due to –OH functional group) and dipole-dipole bonds (carboxylic acids due to – C=O functional group)	1

• Compare the bp of alcohols and carboxylic acids related intermolecular forces and heat energy needed to break bonds to change state (liquid – gas)	1
OR • Provides some relevant information	1

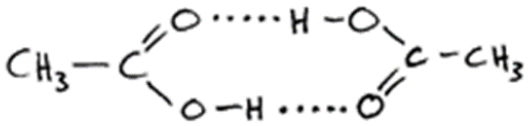
Sample Answer:

- Due to high ratio of hydrogen bonds oresent in carboxylic acids compared to alcohols with similar carbon atoms, more energy is needed to break them when the liquid changes in to gas, hence carboxylic acids have higher boiling points.

- Alkanol is a polar molecules due to its highly polar –OH group. The high melting points and boiling points in alkanols is due to hydrogen bonding between the O of an –OH group in one molecule and the H of an-OH group in a nearby molecule.



- Alkanoic acids have two polar groups (eg. –OH group as well as the –C=O group). Hence each molecule can produce 2 hydrogen bonds between nearby molecules
- The ability of the-COOH group to be involved in two hydrogen bonds gives an alkanoic acid an even higher boiling point than that of a similar sized alkanol. Two hydrogen bonds can occur between a pair of alkanoic acid molecules as shown below.



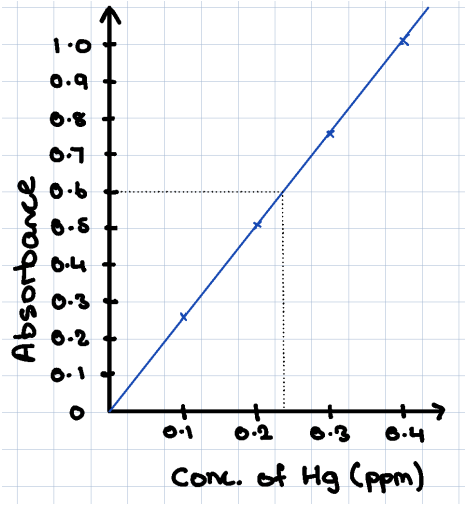
Hence more heat energy is needed to break 'high density of strong intermolecular forces' in carboxylic acids.

Question 34 (5 marks)

Criteria	Marks
• Correctly draws a line graph (axes correct and labeled, correct points) to plot standards	5

• Correctly calculates concentration of Hg in $mol.L^{-1}$ • Provides justification for tuna not meeting industry standards	
• Provides a correct graph and calculations but does not provide justification	4
• Correctly graphs standards but has incorrect calculations	2-3
• Provides some relevant information	1

Sample Answer:



Absorbance of 0.600 = 0.24 ppm
$= 0.24 \times 10^{-4}\ g.L^{-1}$

$$= \frac{0.24 \times 10^{-4}\ g.L^{-1}}{200.6\ g.mol^{-1}}$$

$= 1.20 \times 10^{-6}\ mol.L^{-1}$

The concentration of mercury in the tuna exceeds 1.05×10^{-6} $mol.L^{-1}$ so the tuna does not meet the industry standard and is not safe for human consumption.

Question 35 (5 marks)

Criteria	Marks
● Provides a correct balanced equation ● Correctly calculates moles of both reactants ● Correctly calculates concentrations of $[SO_4^{2-}]$ and $[Pb^{2+}]$ ● Correctly calculates the ion product (Q) ● Correctly states whether a precipitate will form	5
● Addresses THREE to FOUR of the above criteria	3-4
● Addresses TWO of the above criteria	2
● Provides some relevant information	1

Sample Answer:

$Na_2SO_4\ (aq) + Pb(NO_3)_2\ (aq) \rightleftharpoons PbSO_4\ (s) + 2NaNO_3\ (aq)$

$n(Na_2SO_4) = cv$
$= 2 \times 10^{-3}\ mol.L^{-1} \times 0.04\ L$
$= 8 \times 10^{-5}\ mol$
$n(Pb(NO_3)_2) = 2 \times 10^{-3}\ mol.L^{-1} \times 0.2\ L$
$= 4 \times 10^{-4}\ mol$
Total volume $= 0.240\ L$

$$[SO_4^{2-}] = \frac{n}{v} = \frac{8 \times 10^{-5}\ mol}{0.240\ L}$$
$$= 3.33 \times 10^{-4}\ mol.L^{-1}$$

$$[Pb^{2+}] = \frac{4 \times 10^{-4}\ mol}{0.240\ L}$$
$$= 1.67 \times 10^{-3}\ mol.L^{-1}$$

$[Pb^{2+}][SO_4^{2-}] = 3.33 \times 10^{-4} \times 1.67 \times 10^{-3}$
$= 5.56 \times 10^{-7}$

K_{sp} (from data sheet) $= 2.53 \times 10^{-8}$

IP $>$ K_{sp} so a precipitate will form.

Question 36 (2 marks)

Criteria	Marks
● Correctly calculates Gibbs free energy ● Determines the reaction is non-spontaneous	2
● Provides some relevant information	1

Sample Answer:

$\Delta H^o = +2803\ kJ.mol^{-1}$
$\Delta S^o = -212\ J.mol^{-1}.K^{-1}$
$\Delta G^o = \Delta H^o - T\Delta S^o$
$= +2803 - (298 \times -0.212)$
$= +2803 + 63.18$
$= +2866\ kJ.mol^{-1}$

Since ΔG is positive, this is a non-spontaneous system. The reaction will only proceed when a significant amount of energy is supplied or a catalyst is used (with a lesser amount of energy being supplied). Photosynthesis is a non-spontaneous reaction that requires a catalyst in nature.