Student Number _____

Caringbah High School
Course Chemistry
Trial Exam 2023

Write all your answers in this answer booklet.

Use pen for written responses and pencil for diagrams and graphs.

Total Marks: 100

Task Length: 3 hour + 5 minutes reading time

PART A: Multiple Choice Questions (20 marks)

PART B: Longer Response Questions (80 marks)

Task Prepared by: S. Tudberry

OUTCOME	*MARK*
Knowledge and Understanding	*/ 74*
Working Scientifically *Q27,q30,q31,q32,q33,q36*	*/ 26*
Total	*/100*

PART A: Answer the multiple choice questions HERE. Circle the letter of the BEST answer.

Do NOT detach this page from the rest of the task.

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

PART A: Circle the letter of the BEST answer on the grid (20 marks)

1.	*The equilibrium constant of a reaction is 300. If the volume of reaction flask is tripled the equilibrium constant is:* *A. 300* *B. 600* *C. 900* *D. 100*	
2.	*0.1 moles of each of the following substances is dissolved in 1 L of water. For which substance would the pH of the resultant solution be closest to 14?* *A. NH_4Cl* *B. CH_3CH_2OH* *C. $Ca(OH)_2$* *D. $NaCH_3COO$*	
3.	*Also known as PVC, polyvinylchloride is a polymer made of which of the following monomers?* *A. Chloroethene* *B. Chloroethane* *C. Chloropropane* *D. Chloropropene*	
4.	*A student carried out an experiment to measure the enthalpy change of combustion of methanol. The energy from the combustion of methanol was used to heat a beaker containing water. The student's calculated enthalpy change of combustion was more exothermic than the value in data books. Which factor could have caused this difference?* *A. Some methanol had evaporated from the wick before the final weighing* *B. In the calculation, the student used the molar mass of ethanol instead of methanol.* *C. There was incomplete combustion.* *D. The water boiled for 5 minutes before the final temperature was taken.*	
5.	*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*	
6.	*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.*	

7. *The forward reaction in the equilibrium shown below is endothermic.*

$OCl^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + OH^-_{(aq)}$

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

A. Adding a small amount of hydrochloric acid.
B. Removing water.
C. Increasing the pH.
D. Lowering the temperature.

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

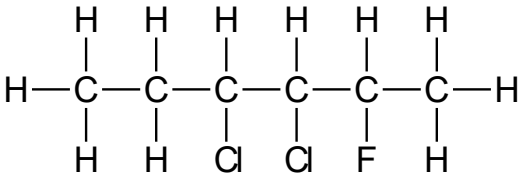
$2O_{3(g)} \rightleftharpoons 3O_{2(g)}$

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?

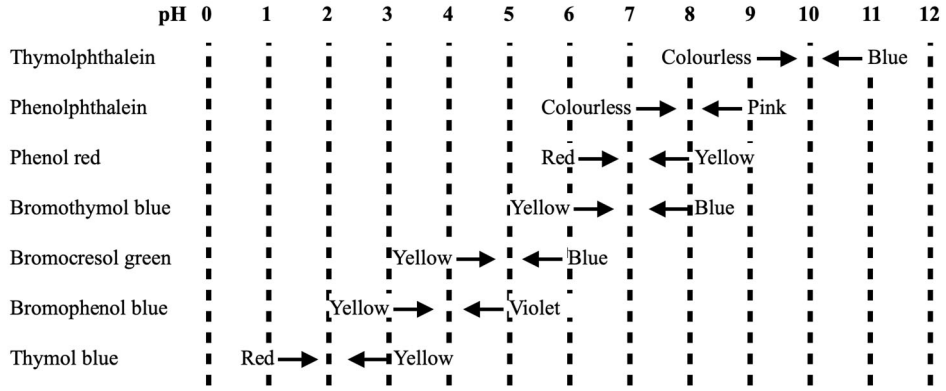
	Direction favoured	***Reason***
A.	*Left*	$Q < K_{eq}$
B.	*Left*	$Q > K_{eq}$
C.	*Right*	$Q < K_{eq}$
D.	*Right*	$Q > K_{eq}$

9. *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.

10. *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?

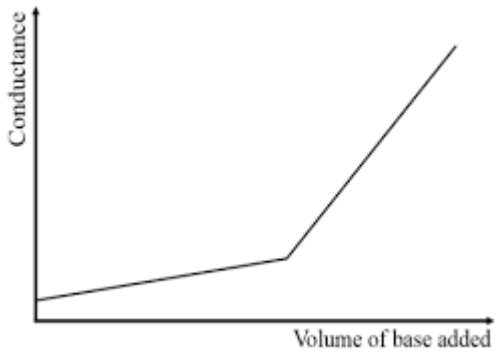
A. Bromocresol green, phenol red and phenolphthalein.
B. Thymol blue, bromophenol blue and phenolphthalein.
C. Thymol blue, bromothymol blue and thymolphthalein.
D. Thymol blue, bromophenol blue and bromocrescol green.

11. *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%

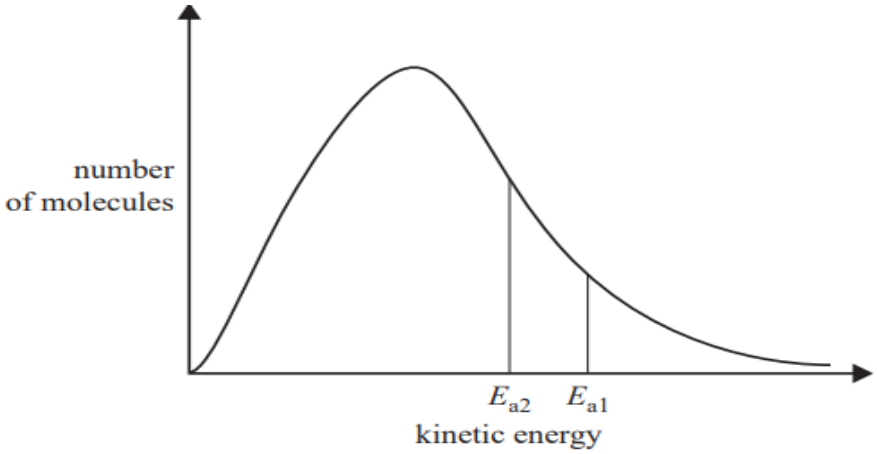
12. *A conductometric titration was carried out using an acid and a base of similar concentration and the graph below was recorded.*



The acid and base used could have been:
A. H_2SO_4 and $Ba(OH)_2$
B. H_2SO_4 and NH_3
C. CH_3COOH and NH_3
D. CH_3COOH and KOH

13. *The diagram below represents the distribution of kinetic energy in a sample of gaseous reactant molecules.*

The activation energy E_{a1} has been changed to activation energy E_{a2}. This change increases the reaction rate.



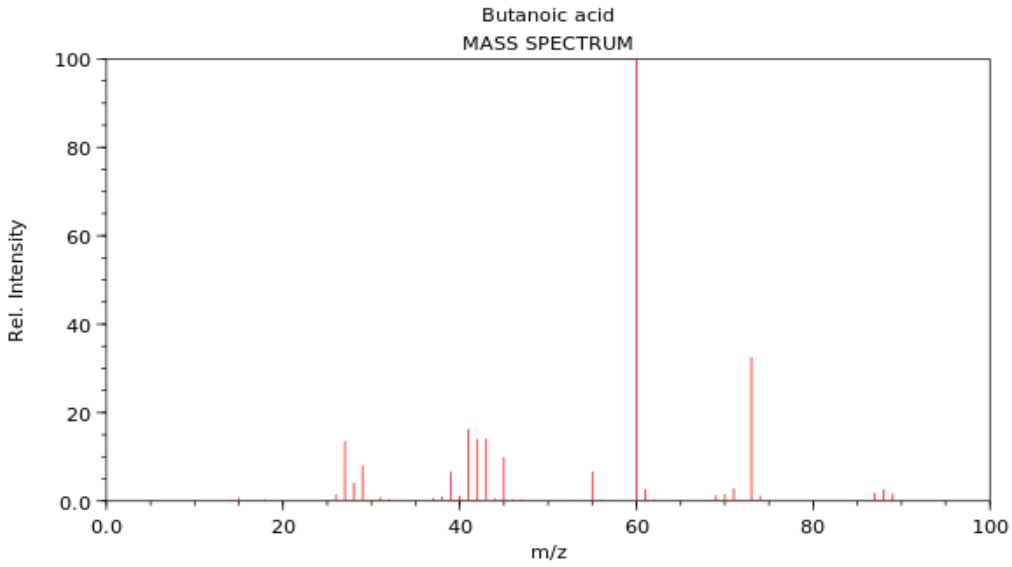
Which of the following gives the most likely cause of the change from E_{a1} to E_{a2} and explains why the reaction rate would increase?

	Cause of the change	***Why the reaction rate increases***
A.	*Catalyst added*	*Molecules move faster, resulting in more successful collisions*
B.	*Catalyst added*	*Greater proportion of reactants collide with sufficient energy to react*
C.	*Temperature increased*	*Greater proportion of reactants collide with the correct orientation to react*
D.	*Concentration of reactants increased*	*Greater frequency of collisions, resulting in more successful collisions*

14. *Iodine monochloride (ICl) reacts with carbon-carbon double bonds (one ICl per double bond). If 0.105 g of a molecule of molar mass 304.5 g mol^{-1} reacts with exactly 0.224 g of ICl, how many carbon-carbon double bonds are present in the molecule?*

A. 3
B. 4
C. 5
D. 8

15. *An unidentified organic substance with the molecular formula $C_4H_8O_2$ is found to react with a base. Mass spectrometry shows the parent molecular ion has a mass-to-charge ratio, m/z, of 88.*



Which one of the following species is consistent with a peak on the mass spectrum at m/z = 45?

A. $COOH^+$
B. $CH_3CH_2O^+$
C. $CH_3CH_2OH^+$
D. $CH_3CH_2CH_2COOH^+$

16. *The pH of pure water at 0°C ($K_w = 1.15\times10^{-15}$)is:*

A. 6.63
B. 7
C. 7.47
D. 13.2

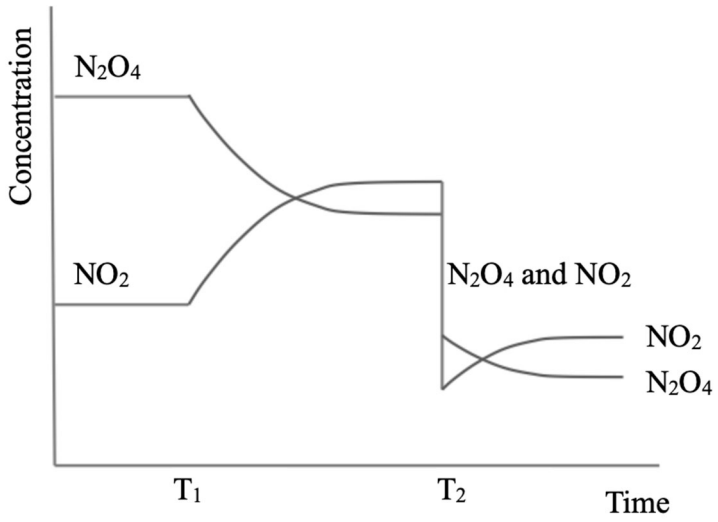
17. *In which solution will AgBr have the lowest molar solubility? (K_{sp} AgBr = 5 x 10^{-13})*

$$AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$$

A. 0.5 M $AgNO_3$ solution
B. 0.5 M NaBr solution
C. 0.5 M $AgClO_4$ solution
D. 0.5 M $MgBr_2$ solution

18. *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 time T_1 and to the volume at time 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*

19. *Calculate the pH of a solution prepared by mixing 300 mL of 0.10 M HF and 200 mL of 0.10 M KOH. The Ka of HF at 25°C is 6.8×10^{-4}.*
A. 2.82
B. 2.96
C. 2.43
D. 3.44

20. *A 20.00 mL sample of vinegar is placed in a volumetric flask. The volumetric flask is then filled up to the line marking its designated volume. Then a 20.00 mL aliquot of the diluted sample of vinegar is titrated against a 0.102 M solution of potassium hydroxide, KOH, using a phenolphthalein indicator. If the undiluted sample of vinegar has a concentration of 3.16% m/v acetic acid, CH_3COOH, which volumetric flask should be selected to be able to dilute the original sample of vinegar and obtain titres of about 20 mL?*

A. 100 mL volumetric flask
B. 200 mL volumetric flask
C. 250 mL volumetric flask
D. 1000 mL volumetric flask

PART B: Longer Answers (80 marks)

21. *The concentration of reactants and products in a chemical reaction carried out at 25°C for the dissociation of NH_3 are as follows:* **3**

Reactant/product	***Concentration***
$[N_2]$	*0.1M*
$[H_2]$	*0.2M*
$[NH_3]$	*0.3M*

Calculate the equilibrium constant for this reaction. (Show all relevant steps in your answer).

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22. *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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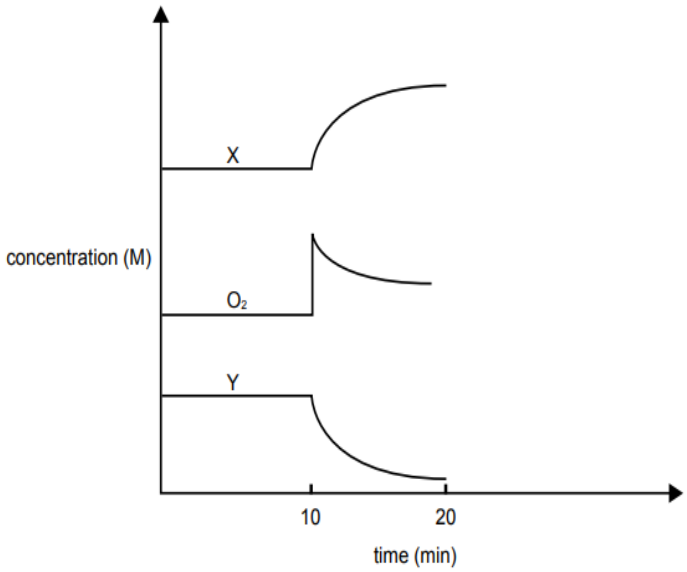
23. *Part of the contact process for the manufacture of sulfuric acid involves the conversion of sulfur dioxide to sulfur trioxide, as shown by the equation:*

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -192\ kJ\ mol^{-1}$$

As part of a laboratory study of this process, a container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide, and oxygen in the presence of a catalyst. The container was initially at 450°C. Concentrations during the following experiment are shown in the diagram below.



a. *What change occurred at the 10-minute point?* **1**

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b. *Which components of the equilibrium mixture are represented by X and Y?* **1**

X: ……*Y:* ……

c. *Give explanations, using Le Chatelier's principle, for the changes in concentration that occurred in X, Y and O_2 between 10 and 20 minutes.* **2**

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	d. Account for TWO changes to the reaction conditions that would increase the rate of formation of SO_3 gas and explain why the industrial production of SO_3 occurs at 450°C and not at a lower or higher temperature. …… …… …… …… …… ……	**3**
24.	*Two students set up a simple game involving 40 individual 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 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.* *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.* …… …… …… …… …… …… …… …… …… …… ……	***4***

25. *A student was given 4 colourless liquids that were labelled **A**, **B**, **C** and **D**. They were known to be ethanol, ethanoic acid, pentane and hex-3-ene, but the exact identity of each liquid was unknown.*

The student tested the properties of each liquid and obtained the following results.

	A	***B***	***C***	***D***
Solubility in water	*insoluble*	*soluble*	*soluble*	*insoluble*
Addition of red-coloured bromine solution (aq)	*colour disappears*	*no immediate reaction*	*no immediate reaction*	*no immediate reaction*
Addition of sodium carbonate solution (aq)	*no reaction*	*gas evolved*	*no reaction*	*no reaction*

a. Identify each of the liquids. **2**

A:……. B: ……

C: ……. D: ……

*b. Identify the type of reaction occurring between **compound A** and bromine solution, write a balanced equation and draw the structure(s) of the compound(s) formed.* **3**

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*c. Identify the type of reaction occurring between **compound B** and Na_2CO_3 solution, write a balanced equation and draw the structure of the anion formed.* **3**

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	d. Discuss the different solubilities of the 4 compounds in water. …… …… …… …… …… …… …… …… …… …… …… …… …… …… ……	**3**
26.	*The white smoke reaction is a neutralisation reaction between the vapours of concentrated solutions of hydrochloric acid and ammonia. It is given its name due to the production of fine white salt crystals that are momentarily suspended in air when the vapours react, giving the appearance of white smoke.* *Justify why this reaction can only be explained by the Brønsted-Lowry definition of acids and bases and not the Arrhenius definition. Include a chemical equation in your answer.* …… …… …… …… …… …… …… …… …… …… …… …… ……	**3**

27. *A small organic molecule contains carbon, hydrogen, oxygen and chlorine atoms. A pH probe was inserted into a dilute aqueous solution of this compound and the pH was 4.5.*

The mass spectrum, infrared spectrum, ^{1}H NMR spectrum and ^{13}C NMR spectrum of this compound are provided on pages 15 and 16.

a. ***On the infrared spectrum**, on page 15, label the peaks that correspond to the presence of two functional groups involving carbon, hydrogen and/or oxygen atoms in this compound.*
Please note that the peak due to the C-Cl stretch has been labelled. **1**

b. *What information is provided by the pH of the aqueous solution?* **1**

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c. *What information is provided by the mass spectrum?* **1**

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d. *What specific information about the structure of the compound is provided by the splitting pattern in the ^{1}H NMR spectrum and the data table on page 16* **2**

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e. *Use the data provided to determine the number of carbon and hydrogen atoms in a molecule of this compound. Explain your reasoning.* **2**

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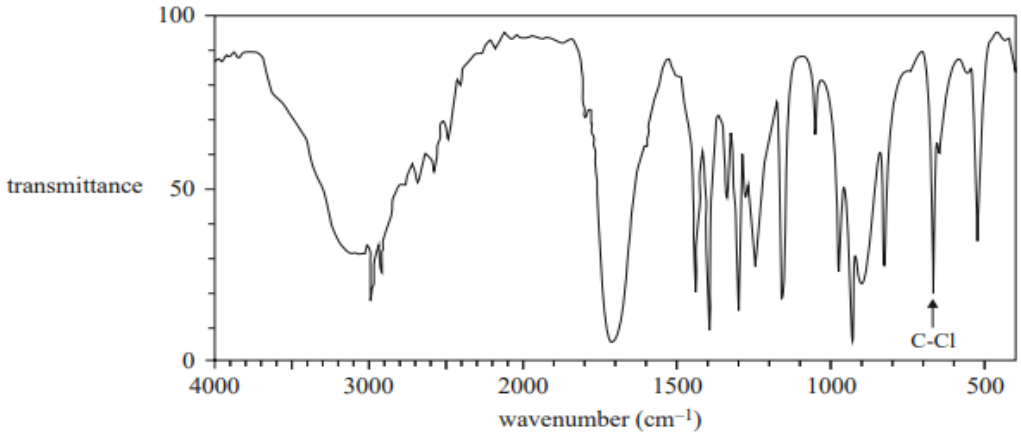
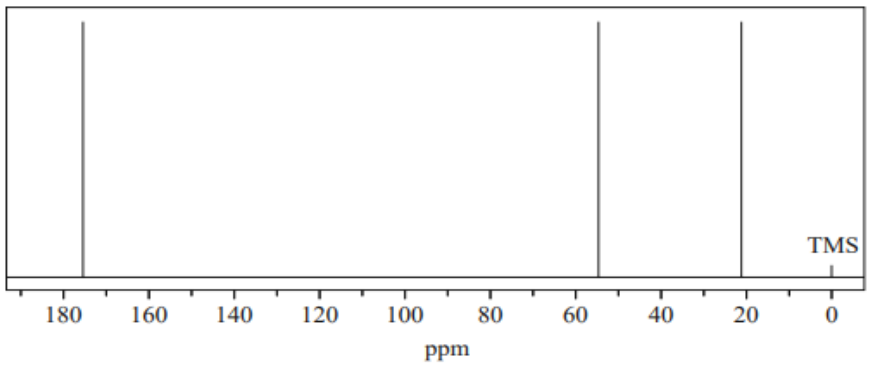
f. *Draw a molecular structure for this molecule.* **1**

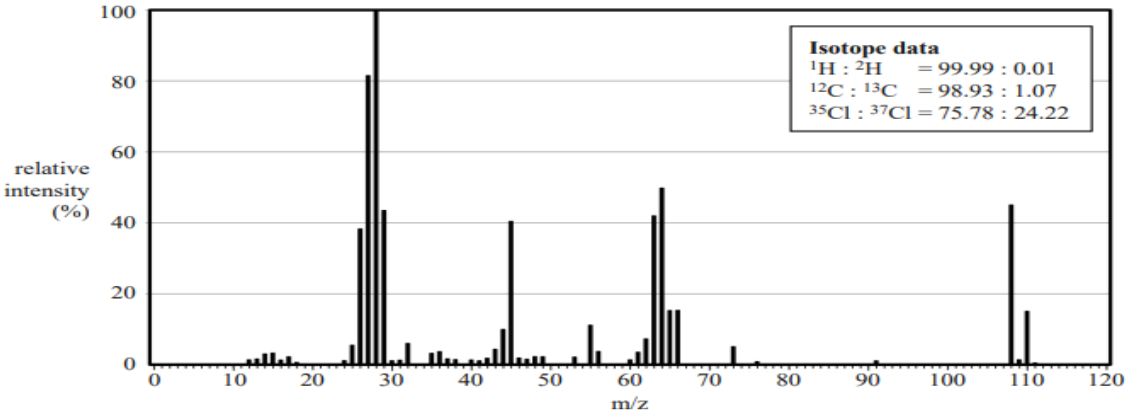
IR spectrum



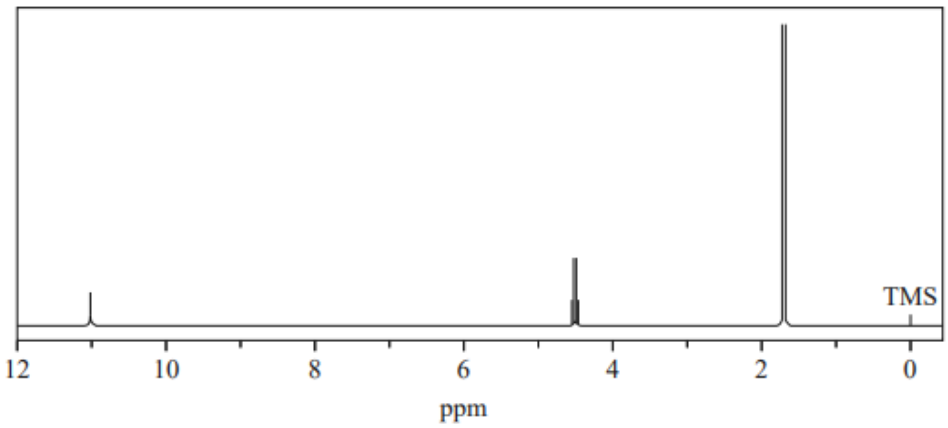
^{13}C NMR spectrum



$C_xH_yO_2Cl$ mass spectrum



^{1}H NMR spectrum



^{1}H NMR data

Chemical shift (ppm)	Peak splitting	Relative peak area
1.7	doublet (2 peaks)	3
4.5	quartet (4 peaks)	1
11.2	singlet (1 peak)	1

28. *Account for the cleaning action of soap by describing its structure and interaction with water.* **3**

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29.	*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?* …… …… …… …… …… …… *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.* *They expect that decreasing the concentration of hydrogen ions by a factor of 10 will increase the pH by one unit.* *b. Account for the increase in pH of only 0.5 units. Use a chemical equation to support your answer.* …… …… …… …… …… ……	**2** **3**

30.	*Hydrogen and carbon monoxide react as gases as follows.* *$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$* *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.* …… …… …… …… …… ……	**2**
31.	*An investigation was carried out to analyse a commercial lawn fertiliser. A sample of 1.00 g of fertiliser containing 24.0% sulfur (S) in the form of sulfate (SO_4^{2-}) was dissolved in water.* *100 mL of 0.20 mol.L^{-1} barium chloride solution was then added and a precipitate formed.* *Calculate the theoretical percentage by mass of sulfate (SO_4^{2-}) in the fertiliser.* …… …… …… …… …… ……	**3**

32. *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.*

nNH_2-C_6H_{12}-NH_2 + nCOOH-C_4H_8-COOH $\rightarrow$

$$nCOOH\text{-}C_4H_8\text{-}CO\text{-}\ NH\text{-}C_6H_{12}\text{-}NH_2 + (2n\text{-}1)\ H_2O$$

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? **3**

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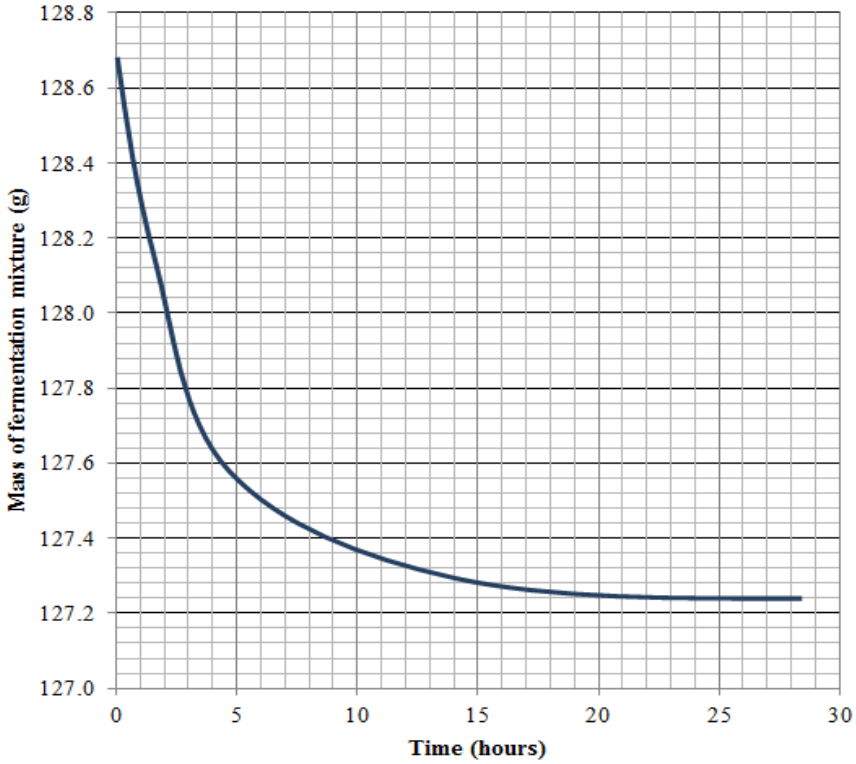
33. *The production of alcohol can be achieved in the school laboratory by the fermentation of glucose according to the equation below:*

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

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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b. *Calculate the mass of ethanol produced by the reaction and compare this to the theoretical yield of ethanol. Show all working.* **4**

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34. *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 compounds shown in the table above: **3**

Q:……

R:……

S:……

b. Explain the variations in boiling points between Compounds Q, R and S. **3**

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35. *The phosphate buffer system operates in the internal fluid of cells. The pH of an equimolar solution of sodium dihydrogen phosphate, NaH_2PO_4, and disodium hydrogen phosphate, Na_2HPO_4, is 6.8.*

a. Write a chemical equation that represents the equilibrium system described. **1**

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b. Explain how this system operates as a buffer and account for what would happen if a small volume of 0.1 mol.L^{-1} carbonic acid, H_2CO_3 was added to the solution. **3**

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36. *A sample of lemon juice was analysed in the laboratory. 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 ($C_6H_8O_7$), calculate the concentration in mol.L^{-1} of citric acid in the undiluted lemon juice. Note: Citric acid is a triprotic acid. **5**

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37.	*Compare the molar solubility of solid CaF_2 (K_{sp} = 4 x 10^{-11}) in a 0.025M NaF solution to the solubility in distilled water.* …… …… …… …… …… …… …… …… …… …… ……	**5**

Task Evaluation ***Name: _____***

Total Mark: *_____ out of _____*

Mark sub-totals

Multiple choice mark: _____ out of _____

Knowledge and understanding mark: _____ out of _____

Working Scientifically mark: _____ out of _____

Circle the number that best matches. Key: 1– never 2-occasionally 3-sometimes 4-mostly 5- always

Aspect	*never*	*occasionally*	*sometimes*	*mostly*	*always*
I pay attention in class	*1*	*2*	*3*	*4*	*5*
I complete all my classwork	*1*	*2*	*3*	*4*	*5*
I ask the teacher when I need help	*1*	*2*	*3*	*4*	*5*
I make summary notes to study	*1*	*2*	*3*	*4*	*5*
I get distracted in class	*1*	*2*	*3*	*4*	*5*
I keep my OneNote book up to date	*1*	*2*	*3*	*4*	*5*
I provide sufficient detail in my OneNote responses/notes	*1*	*2*	*3*	*4*	*5*
I completed past papers to prepare for the test	*1*	*2*	*3*	*4*	*5*
I can communicate my understanding in tests	*1*	*2*	*3*	*4*	*5*

Questions:

1. *Do you feel that your performance in this task represents your understanding of Science?*

   _____

2. *What does your teacher do that helps you understand in Science?*

   _____

3. *What can your teacher do to improve your understanding in Science?*

   _____

4. *What do you do to maximise your results in Science?*

   _____

5. *What could you do better/differently to improve your results in Science?*

   _____

6. *Is there anything else you want your teacher to know?*

Student Number _____

Caringbah High School
Course Chemistry
Trial Exam 2023

Marking Criteria

Write all your answers in this answer booklet.

Use pen for written responses and pencil for diagrams and graphs.

Total Marks: 100

Task Length: 3 hour + 5 minutes reading time

PART A: Multiple Choice Questions (20 marks)

PART B: Longer Response Questions (80 marks)

Task Prepared by: S. Tudberry

OUTCOME	*MARK*
Knowledge and Understanding	*/ 74*
Working Scientifically *Q27,q30,q31,q32,q33,q36*	*/ 26*
Total	*/100*

PART A: Answer the multiple choice questions HERE. Circle the letter of the BEST answer.

Do NOT detach this page from the rest of the task.

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

PART A: Circle the letter of the BEST answer on the grid (20 marks)

1.	*The equilibrium constant of a reaction is 300. If the volume of reaction flask is tripled the equilibrium constant is:* *A. 300* *B. 600* *C. 900* *D. 100*	
2.	*0.1 moles of each of the following substances is dissolved in 1 L of water. For which substance would the pH of the resultant solution be closest to 14?* *A. NH_4Cl* *B. CH_3CH_2OH* *C. $Ca(OH)_2$* *D. $NaCH_3COO$*	
3.	*Also known as PVC, polyvinylchloride is a polymer made of which of the following monomers?* *A. Chloroethene* *B. Chloroethane* *C. Chloropropane* *D. Chloropropene*	
4.	*A student carried out an experiment to measure the enthalpy change of combustion of methanol. The energy from the combustion of methanol was used to heat a beaker containing water. The student's calculated enthalpy change of combustion was more exothermic than the value in data books. Which factor could have caused this difference?* *A. Some methanol had evaporated from the wick before the final weighing* *B. In the calculation, the student used the molar mass of ethanol instead of methanol.* *C. There was incomplete combustion.* *D. The water boiled for 5 minutes before the final temperature was taken.*	
5.	*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* *% ionised = [H3O+][A-]/[HA]* *4% = [H3O+][A-]/0.01 [H3O+] = 0.04 x 0.01 = 0.0004* *pH = 3.40*	
6.	*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.*	

7. *The forward reaction in the equilibrium shown below is endothermic.*

$OCl^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + OH^-_{(aq)}$

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

A. Adding a small amount of hydrochloric acid.
B. Removing water
C. Increasing the pH.
D. Lowering the temperature.

8. *At a certain temperature, the Keq 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*	$Q > K_{eq}$

$C(O_3) = 0.3/4 = 0.075\ M$

$C(O_2) = 1.5/4 = 0.375\ M$

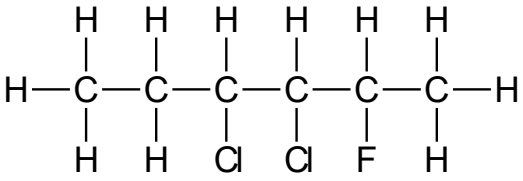
$Q = (0.375)^3/(0.075)^2$

$= 9.375$

Therefore Q<Keq

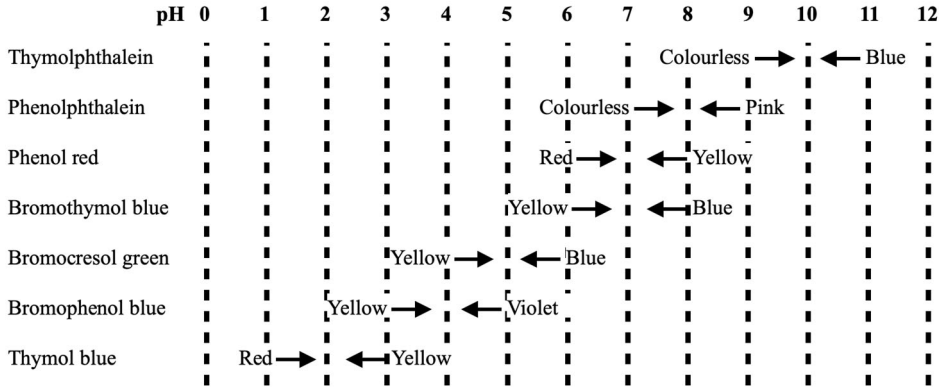
And system will shift to right

9. *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.

10. *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.

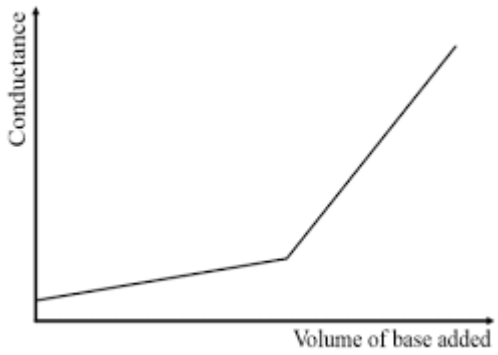
11. *A food critic noticed their specialty chicken dish was extremely bland and requested that analysis be carried out to measure the sodium chloride concentration. This was achieved by dissolving the food sample in water and the chloride ion being precipitated by adding an excess of silver nitrate solution.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

M(food) = 10.0g m ppt AgCl = 0.188g MM = 143.35 g.mol-1
N(AgCl) = 0.188/143.35 = 0.00131147541 mol = n(NaCl) = n (Cl-)
M (NaCl) = n x MM = 0.0013 x 58.44 = 0.07664262295g
therefore %(NaCl) = 0.0766/10.0 x 100 = 0.766%

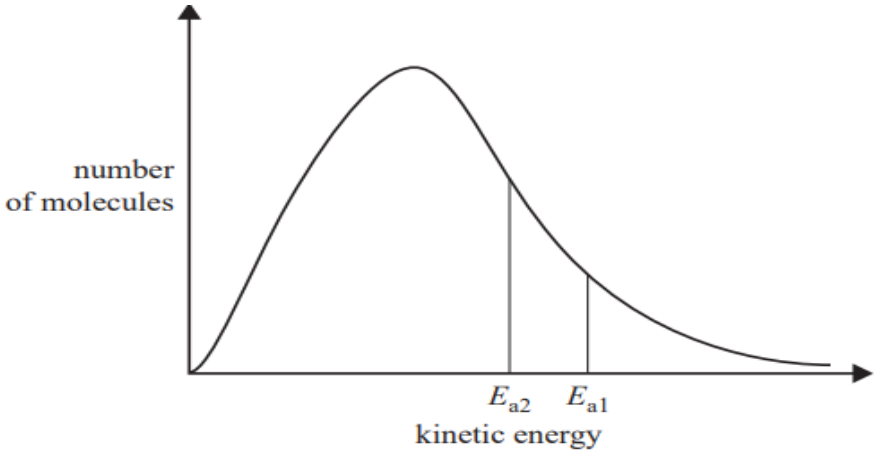
12. *A conductometric titration was carried out using an acid and a base of similar concentration and the graph below was recorded.*



The acid and base used could have been:
A. H_2SO_4 and $Ba(OH)_2$
B. H_2SO_4 and NH_3
C. CH_3COOH and NH_3
D. CH_3COOH and KOH

13. *The diagram below represents the distribution of kinetic energy in a sample of gaseous reactant molecules.*

The activation energy E_{a1} has been changed to activation energy E_{a2}. This change increases the reaction rate.



Which of the following gives the most likely cause of the change from E_{a1} to E_{a2} and explains why the reaction rate would increase?

	Cause of the change	***Why the reaction rate increases***
A.	*Catalyst added*	*Molecules move faster, resulting in more successful collisions*
B.	*Catalyst added*	*Greater proportion of reactants collide with sufficient energy to react*
C.	*Temperature increased*	*Greater proportion of reactants collide with the correct orientation to react*
D.	*Concentration of reactants increased*	*Greater frequency of collisions, resulting in more successful collisions*

14. *Iodine monochloride (ICl) reacts with carbon-carbon double bonds (one ICl per double bond). If 0.105 g of a molecule of molar mass 304.5 g mol^{-1} reacts with exactly 0.224 g of ICl, how many carbon-carbon double bonds are present in the molecule?*

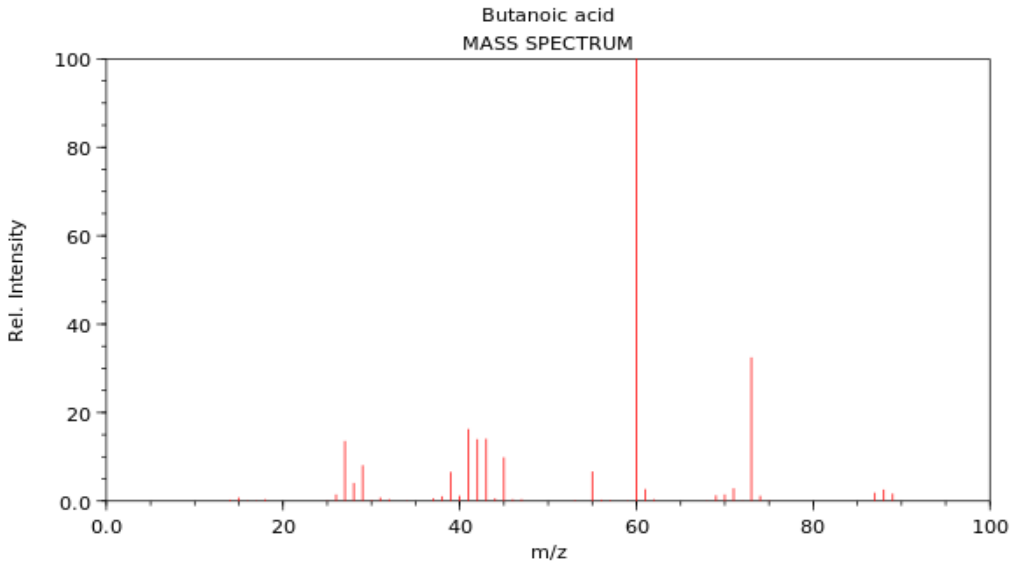
A. 3
B. 4
C. 5
D. 8

n moles = 0.105/304.5 = 3.4487 x 10^{-4}

n(ICl) = 0.224 / (35.45 + 126.9) = 1.379735 x 10^{-3}

n Cl / n (molecule) = 4

15. *An unidentified organic substance with the molecular formula $C_4H_8O_2$ is found to react with a base. Mass spectrometry shows the parent molecular ion has a mass-to-charge ratio, m/z, of 88.*



Which one of the following species is consistent with a peak on the mass spectrum at m/z = 45?

A. $COOH^+$
B. $CH_3CH_2O^+$
C. $CH_3CH_2OH^+$
D. $CH_3CH_2CH_2COOH^+$

16. *The pH of pure water at 0°C ($Kw = 1.15 \times 10^{-15}$) is:*

A. 6.63
B. 7
C. 7.47
D. 13.2

$1.15 \times 10^{-15} = [H^+][OH^-]$

$X = 3.3391 \times 10^{-8}$

$pH = 7.47$

17. *In which solution will AgBr have the lowest molar solubility? ($Ksp\ AgBr = 5 \times 10^{-13}$)*

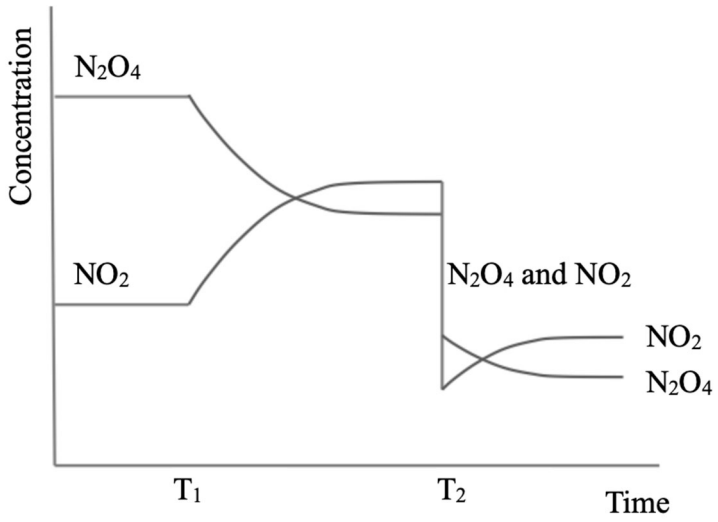
$AgBr(s) \leftrightarrow Ag^+(aq) + Br^-(aq)$

A. 0.5 M $AgNO_3$ solution
B. 0.5 M NaBr solution
C. 0.5 M $AgClO_4$ solution
D. 0.5 M $MgBr_2$ solution

D is the answer as there will be twice as many Br^- ions in solution therefore it will impact the solubility of AgBr the most

18. *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*

19. *Calculate the pH of a solution prepared by mixing 300 mL of 0.10 M HF and 200 mL of 0.10 M KOH. The Ka of HF at 25°C is 6.8×10^{-4}.*

A. 2.82
B. 2.96
C. 2.43
D. 3.44

nHF = 0.1 x 0.300 = 0.03 nKOH = 0.1 x 0.2 = 0.02

HF in excess by 0.01 mol and [HF] = 0.01/0.5 = 0.02 mol.L-1

$6.8 \times 10^{-4} = (x^2)/0.02$ $x = 0.003687 = [H^+]$ pH = 2.4

20. *A 20.00 mL sample of vinegar is placed in a volumetric flask. The volumetric flask is then filled up to the line marking its designated volume. Then a 20.00 mL aliquot of the diluted sample of vinegar is titrated against a 0.102 M solution of potassium hydroxide, KOH, using a phenolphthalein indicator. If the undiluted sample of vinegar has a concentration of 3.16% m/v acetic acid, CH_3COOH, which volumetric flask should be selected to be able to dilute the original sample of vinegar and obtain titres of about 20 mL?*

A. 100 mL volumetric flask
B. 200 mL volumetric flask
C. 250 mL volumetric flask
D. 1000 mL volumetric flask

n(KOH) in 20 mL titre = $0.102 \times 20 \times 10^{-3} = 0.00204$ mol

$n(CH_3COOH)$ in 20 mL diluted = 0.00204 mol

$m(CH_3COOH)$ in 100 mL = $5 \times 0.00204 \times 60 = 0.612$ g in 100 mL; i.e. 0.612% m/V

So, vinegar has to be diluted by a factor of 3.16 / 0.612 = 5.2

This can be achieved by diluting 20 mL original sample to 100 mL.

PART B: Longer Answers (80 marks)

21. *The concentration of reactants and products in a chemical reaction carried out at 25°C for the dissociation of NH_3 are as follows:* **3**

Reactant/product	*Concentration*
$[N_2]$	*0.1M*
$[H_2]$	*0.2M*
$[NH_3]$	*0.3M*

Calculate the equilibrium constant for this reaction? (Show all relevant steps in your answer).

3 marks: Chemical equation, Expression, Correct calculation. Ignore sig figs.
2 marks: 2 of above
1 mark: 1 of above

$2NH_3 <-> N_2 + 3H_2$
$K = [N_2][H_2]^3 / [NH3]^2$
$= (0.1)(0.2)^3 / (0.3)^2$
= 0.0088…. (0.009 to 1 sig fig.)
FB: Some student reversed K (it is dissociation). Must use equilibrium arrow. Take care with calc errors.

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

Criteria	*Marks*
• *Clearly outlines how Aboriginal and Torres Strait Islander peoples removed toxins from cycad fruit, referencing equilibria*	*3*
• *Provides some detail on how Aboriginal and Torres Strait Islander peoples removed toxins from cycad fruit with a link to equilibria*	*2*
• *Provides some relevant information*	*1*

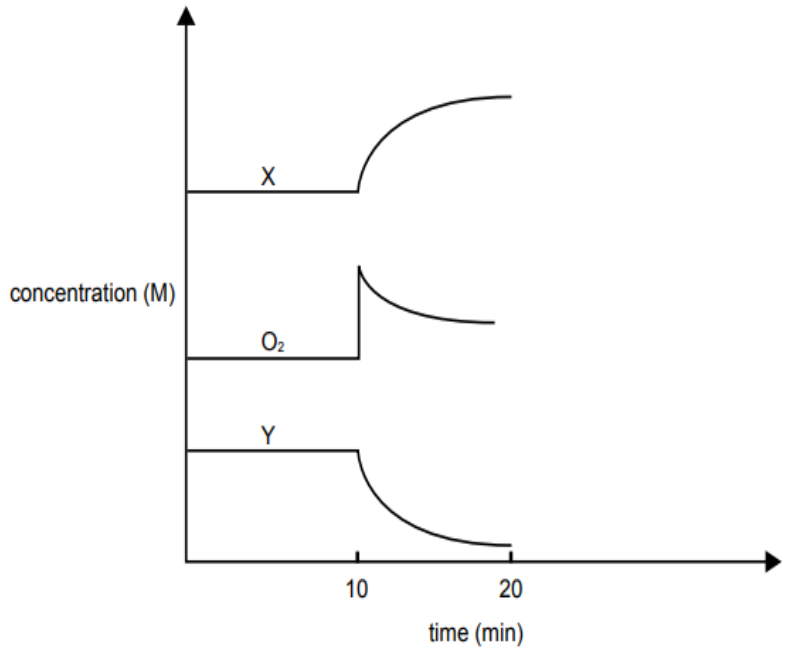
Sample Answer: *Aboriginal and Torres Strait Islander peoples used leaching to remove toxins from cycad fruit. The seeds of the cycad are used for making bread but contain the toxin cycasin. The seeds are sliced or crushed to increase the surface area. To remove the toxin, the seeds were then put in a woven bag or basket and placed in running water. The toxin is water-soluble, so the running water removed the toxins over several hours or days. The seeds were in an open system so equilibrium cannot be achieved and all the cycasin will eventually dissolve into the water therefore being removed from the fruit.*

FB: some omitted that the fruit was cut/sliced/crushed etc. Need to include terms like open system. Good to see equations.

23. *Part of the contact process for the manufacture of sulfuric acid involves the conversion of sulfur dioxide to sulfur trioxide, as shown by the equation:*

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -192\ kJ\ mol^{-1}$$

As part of a laboratory study of this process, a container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide, and oxygen in the presence of a catalyst. The container was initially at 450°C. Concentrations during the following experiment are shown in the diagram below.



a. What change occurred at the 10-minute point? **1**

Only Answer – Identifies the addition of oxygen into the container

b. Which components of the equilibrium mixture are represented by X and Y? **1**

Correctly identifies:

SO_3 as X and SO_2 as Y

c. Give explanations, using Le Chatelier's principle, for the changes in concentration that occurred in X, Y and O_2 between 10 and 20 minutes. **2**

2 marks

- *Explains or defines Le Chatelier's principle AND*
- *Explains the changes in $[SO_3(g)]$, $[SO_2(g)]$ and $[O_2(g)]$ between 10 and 20 minutes.*

1 mark

- *student only partially answers the question but still shows an understanding of LCP (by example).*

Sample Answer: *When a system is at equilibrium and a change is imposed on the system, the equilibrium will shift in a direction to compensate for, or counteract, that imposed change.*

Upon addition of O_2 at 10 minutes, there is an immediate spike in the concentration of oxygen. To compensate for this extra oxygen, the position of equilibrium moves to the right. Hence the amount of SO_3 (or X) will increase and the amount of SO_2 (or Y) will decrease. Because the forward reaction rate has temporarily increased, some of the added O_2 will be consumed in the reaction to form additional SO_3. Hence $[O_2(g)]$ will fall after the spike. The falls in $[O_2(g)]$ and $[SO_2(g)]$ and the increase in $[SO_3(g)]$ continue until a new equilibrium is reached at 20 minutes.

FB: Main omission was restored equilibrium at t=20 min. Some forgot to say oxygen decreased after initial spike.

5/9/23

d. *Account for TWO changes to the reaction conditions that would increase the rate of formation of SO_3 gas and explain why the industrial production of SO_3 occurs at 450°C and not at a lower or higher temperature.* **3**

• *Accounts for TWO changes to the reaction conditions that would increase the rate of formation of sulfur trioxide* • *Explains why the industrial production of SO_3 occurs at 450°C , not higher nor lower, by referring to Le Chatelier's principle*	*3*
• *Accounts for ONE changes to the reaction conditions that would increase the rate of formation of sulfur trioxide AND* *Explains why the industrial production of SO_3 occurs at 450°C not higher nor lower, by referring to Le Chatelier's principle* ***OR*** • *Accounts for TWO changes to the reaction conditions that would increase the rate of formation of sulfur trioxide*	*2*
• *Accounts for ONE changes to the reaction conditions that would increase the rate of formation of sulfur trioxide* ***OR*** • *Explains why the industrial production of SO_3 occurs at 450°C, not higher nor lower, by referring to Le Chatelier's principle* ***OR*** • *Identifies TWO changes to the reaction conditions that would increase the rate of formation of sulfur trioxide*	*1*

Sample answer:

Increasing the pressure *would increase the concentration of all gases and increase the chance of successful collisions and by LCP drive the equilibrium reaction to the right, according to mole ratio.* ***Decreasing the temperature*** *would increase the formation of the product as the reaction is exothermic, hence favouring the right forward reaction by LCP. (Other answers could include addition of a* ***catalyst*** *or* ***increasing the concentration of the reactants****, or* ***removal of the product****).*

Note: Raising the temperature would increase the 'rate' of the reaction (not the yield) because reactant particles gain kinetic energy and have a greater chance of collisions

This reaction is exothermic so by LCP a ***higher*** *temperature would* ***decrease the yield*** *even though it would* ***increase the rate of the reaction****. At 450°C the reaction produces a sufficiently high yield. A* ***lower*** *temperature would* ***improve on this yield but it would take an unacceptably long time to obtain the product****.*

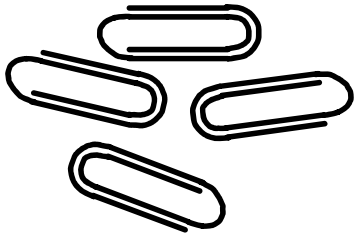
FB: A 2 part question, so you need to address both to the level of the verbs used. Second part done poorly. If you need more space, then use a booklet (and direct the marker to the booklet!!). Don't stop or cut your answer short because you have ran out of space.

Vol/pressure – same, so not counted as TWO separate changes.

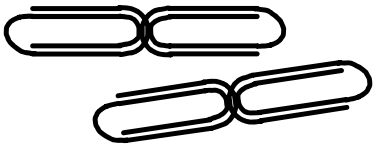
Also, it is a waste of time and space rewording the question.

24. *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 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.

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. **4**

4 marks

- *Explains the general effect of concentration on the rate of reaction.*
- *Explains the change in reactants and products because 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 marks

Weak in one or 2 minor aspects but still shows a good understanding of collision theory and links this to the model.

2 marks

2 of the 4 areas addressed thoroughly.

1 mark

Any relevant information

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 forward 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.

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 and the constant number of both individual and connected paperclips reflect equilibrium concentrations of products and reactants.

FB: Avoid general/vague responses (generalisations). Use the paper clip game to illustrate specific changes that occurred that modelled dynamic equilibrium. Mostly done well by students.

25. *A student was given 4 colourless liquids that were labelled **A**, **B**, **C** and **D**. They were known to be ethanol, ethanoic acid, pentane and hex-3-ene, but the exact identity of each liquid was unknown.*

The student tested the properties of each liquid and obtained the following results.

	A	**B**	**C**	**D**
Solubility in water	*insoluble*	*soluble*	*soluble*	*insoluble*
Addition of red-coloured bromine solution (aq)	*colour disappears*	*no immediate reaction*	*no immediate reaction*	*no immediate reaction*
Addition of sodium carbonate solution (aq)	*no reaction*	*gas evolved*	*no reaction*	*no reaction*

a. *Identify each of the liquids.* **2**

All correct for 2 marks, 2 correct for 1 mark
***A** = hex-3-ene*
***B** = ethanoic acid*
***C** = ethanol*
***D** = pentane*

b. *Identify the type of reaction occurring between **compound A** and bromine solution, write a balanced equation and draw the structure(s) of the compound(s) formed.* **3**

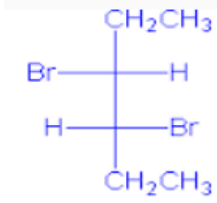
- *Identifies the reaction between **A** and bromine as an addition reaction.*
- *Writes a balanced equation. (States not needed)*
- *Draws the structure of the compound formed 3,4-dibromohexane.*

All correct for 3, 2 correct for 2 marks, Any relevant information for 1 mark

Sample answer:

The reaction between hex-3-ene and bromine solution is addition.

$C_6H_{12}(l) + Br_2(aq) \rightarrow C_6H_{12}Br_2(l)$



FB: Must say addition. (Halogenation can also be a substitution rxn)

Take care with states (not penalised)

Structure drawn well.

c. *Identify the type of reaction occurring between **compound B** and Na_2CO_3 solution, write a balanced equation and draw the structure of the anion formed.* **3**

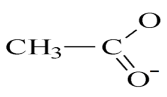
- *Identifies the reaction between **B** and sodium carbonate solution as an acid-base reaction or an acid-carbonate reaction.*
- *Writes a balanced equation **with states.***
- *Draws the structure of the ethanoate ion.*

3 marks all correct. 2 marks if missing 1 aspect. 1 mark for any relevant information.

Sample Answer: An acid-base reaction occurs.

$2CH_3COOH(aq)or(l) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l) + 2CH_3COO^-(aq)$

$2CH_3COOH(aq)\ or\ (l) + Na_2CO_3(aq) \rightarrow CO_2(g) + H_2O(l) + 2NaCH_3COO$



FB: Poorly completed. May also include Na in eqn. States were marked here. Few successfully drew the anion. "Carbonation" is not the same as acid + carbonate.

d. Discuss the different solubilities of the 4 compounds in water. **3**

*3 marks - Discusses the **solubilities** of the 4 substances **in water** by correctly identifying:*
*-the **structures** and **polarity** of each of the 4 substances **AND***
*-the **strength of the intermolecular (or ionic) forces** between the **substances** and **water**.*

(Diagrams are optional but can be used as part of an explanation).

2 marks – demonstrates an understanding of intermolecular forces and mostly links this to solubilities.

1 mark – any relevant information.

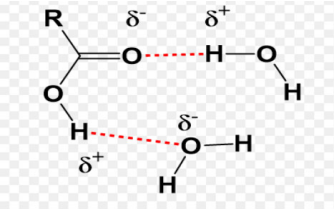
Sample answer

***A** = hex-3-ene and **D** = pentane*

These are non-polar covalently bonded molecules, while water is polar. The liquids do not form a solution as the water molecules are strongly attracted to other water molecules by hydrogen bonding. These strong intermolecular forces mean that water and hex-3-ene or pentane form immiscible layers. Hex-3-ene or pentane molecules are only attracted to each other by weak temporary dipole-dipole forces/dispersion forces.

***B** = ethanoic acid*

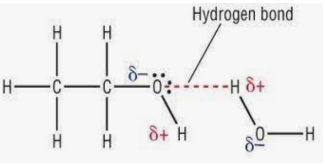
This covalently bonded molecule dissolves in water because the polar part of the molecule, the –COOH group, is attracted to water by strong intermolecular hydrogen bonding between the H of the –COOH group (which has a δ+ charge due to the polar bond with oxygen of the –OH group) and the O of water.



(In addition, ethanoic acid is a weak acid and partially ionises in water to form hydronium and ethanoate ions. These dissolve in water due to the attraction between the charged ions and polar water molecules- optional). As a result, ethanoic acid dissolves readily in water and does not form layers.

***C** = ethanol*

Ethanol is a polar molecule. It is described as having a "dual" nature, as it has both polar and non-polar parts to the molecule. The polar –OH end of the molecule forms strong hydrogen bonding, allowing ethanol to be totally miscible in water. No layers form. The strength of hydrogen bonding and the small hydrocarbon chain (which has no attraction for water) means that the net result is ethanol and water are completely miscible.



FB: Key point bolded in the criteria. Some students didn't mention 'polarity' or discuss bonding between water molecules. Students either new this or they didn't. Some students need to invest time to revise bonding. It is important!

……

……

26. *The white smoke reaction is a neutralisation reaction between the vapours of concentrated solutions of hydrochloric acid and ammonia. It is given its name due to the production of fine white salt crystals that are momentarily suspended in air when the vapours react, giving the appearance of white smoke.*
Justify why this reaction can only be explained by the Brønsted-Lowry definition of acids and bases and not the Arrhenius definition. Include a chemical equation in your answer.

3

• *Correctly justifies why the white smoke reaction is explained using the Brønsted-Lowry definition of acids and bases, while the Arrhenius definition cannot be used. Must reference the in Arrhenius' defn water is required.* • *Includes a correct chemical equation that describes the white smoke reaction* ***with correct state for ammonium chloride salt.***	*3*
• *Correctly outlines the reason why the white smoke reaction is* ***explained*** *using the Brønsted-Lowry definition of acids and bases. AND* • *Includes a correct chemical equation that describes the white smoke reaction.* • ***OR outlines why*** *the white smoke reaction meets the Brønsted-Lowry definition of acids and bases, while the Arrhenius definition cannot be used with specific reference to the species involved.*	*2*
• *Provides a correct reason why the white smoke reaction occurs using the Brønsted-Lowry definition of acids and bases.*	*1*

Sample answer

$HCl_{(aq)} + NH_{3(aq)} \rightarrow NH_4Cl_{(s)}$

The white smoke reaction involves a transfer of protons from the hydrochloric acid to the ammonia molecule resulting in the formation of the ammonium chloride salt. This process is explained by the Brønsted-Lowry definitions of acids and bases, which defines acids as proton donors, and bases as proton acceptors. In this ***reaction HCl donates a proton to NH_3****. The Arrhenius definition of acids and bases* ***requires a solvent to create a solution*** *in which acids can donate hydrogen ions and bases hydroxide ions.* ***The white smoke reaction does not involve an ionising solvent and NH_3 does not dissociate into OH^- ions so cannot be explained by the Arrhenius definition of acids and bases.***

NOTE: THIS QUESITON WAS ANSWERED POORLY. STUDENTS NEEDED TO PAY ATTENTION TO STATES AND INCLUDE THE NEED FOR WATER IN THE ARRHENIUS DEFINITION.

27. *A small orga*

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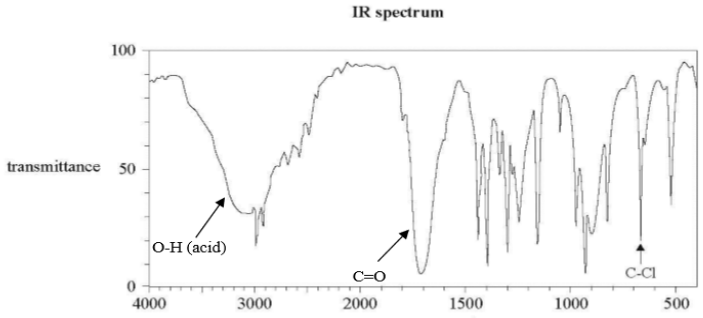
are provided

Identifies correctly 2 peaks on the infrared spectrum as an –OH from an acid AND a carbonyl group (C=O).



a. ***On the ir***

functiona

Please no

1

b. What information is provided by the pH of the aqueous solution? **1**

- *Identifies the compound as acidic* ***OR*** *Concludes that the compound contains a –COOH group.*

...

c. What information is provided by the mass spectrum? **1**

Identifies that the molecular mass is approximately 110 or 108 because of the m/z ratio of the parent peak(s).
Sample answer *The mass spectrum indicates that there are 2 parent peaks, at m/z ratios of 108 and 110 – hence the molecular mass will be 108 or 110 depending on which chlorine isotope is present.*

...

...

d. What specific information about the structure of the compound is provided by the splitting pattern **2**

- Indicates there are three hydrogen environments in the molecule.

AND

- Indicates (from the splitting patterns) that:

From the quartet/ four peaks-one hydrogen environment has three neighbouring H atoms,
From the doublet/two peaks-one hydrogen environment has one neighbouring H atom, and
From the singlet/ single peak-one hydrogen environment has no neighbouring H atoms.
AND Hence, the environments are CH_3, CH and COOH
Only 1 mark if just identifies 3 hydrogen environments or only partially interprets the splitting pattern.

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2

2 marks - *Uses the data from the mass spectrum, ^1H NMR spectrum and the ^{13}C NMR spectrum to conclude that there are 3 carbon atoms, 5 hydrogen atoms (and 1 chlorine atom) in the molecule.*
1 mark - *Uses the data from the spectra to make a correct conclusion about either the number of carbons* ***OR*** *the number of hydrogen atoms.*
Since the molecular mass is approximately 110/108 and assuming only 1 chlorine is present, the total mass of carbon, oxygen and hydrogen is close to 73.
The chlorine atom must be attached to a carbon atom (see IR spectrum).
This would correspond to 3 carbons, 2 oxygens and 5 hydrogens (36 + 32 + 5)
The conclusion from part (b) is that the compound is an acid.
The conclusions from the ^{13}C NMR and ^1H NMR spectra and splitting patterns is that there are at least 3 carbons and 5 hydrogens. A chlorine is attached to the carbon of the –CH group.

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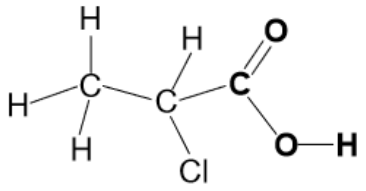
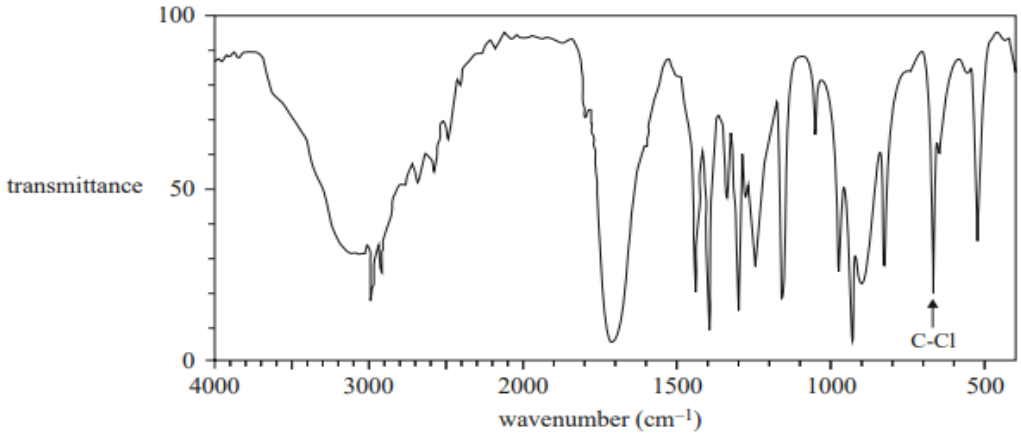
f. Draw a molecular structure for this molecule. **1**

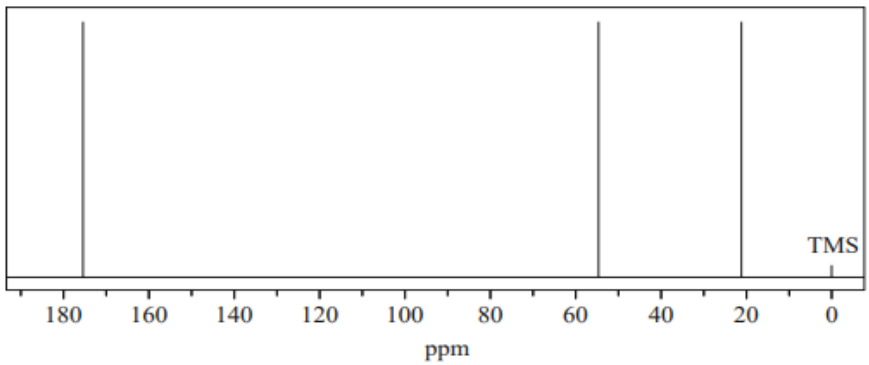
1 mark for structure supported by prior responses, i.e. allow carry through error



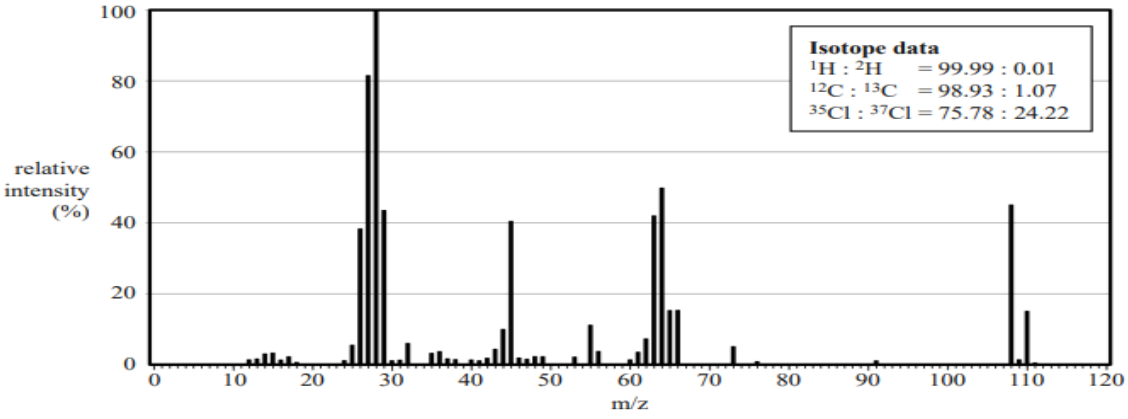
IR spectrum



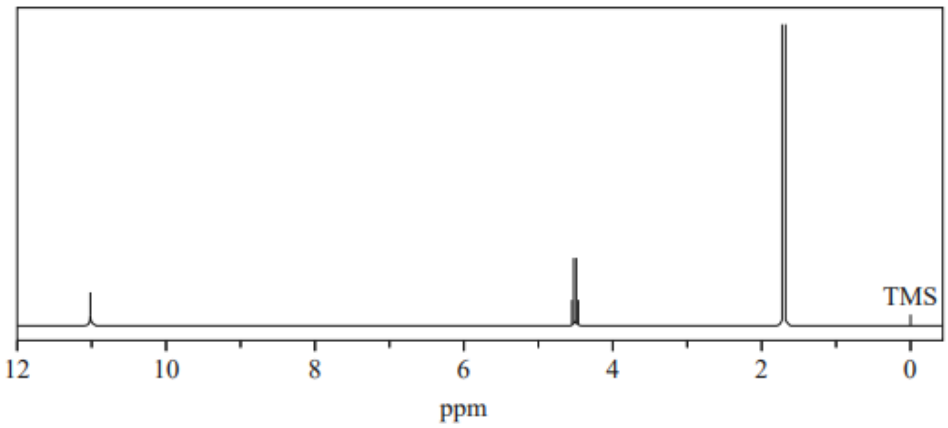
^{13}C NMR spectrum



$C_xH_yO_2Cl$ mass spectrum



^{1}H NMR spectrum



^{1}H NMR data

Chemical shift (ppm)	Peak splitting	Relative peak area
1.7	doublet (2 peaks)	3
4.5	quartet (4 peaks)	1
11.2	singlet (1 peak)	1

28. *Account for the cleaning action of soap by describing its structure and interaction with water.* **3**

• *Describes the structure of soap (hydrocarbon tail and carboxylate head)* • *Clearly accounts for the cleaning action of soap, referring to key terms (H-bonds, hydrophilic, hydrophobic, micelle formation)*	*3*
• *Identifies the structure of soap* • *Accounts for the cleaning action of soap*	*2*
• *Identifies the structure of soap OR describes the cleaning action of soap*	*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 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.

Note: A diagram is not needed but it could be used to support an answer.

29. *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**

• *Relates hydrogen ion concentration to the extent of ionisation of each of the acids* • *Relates pH to hydrogen ion concentration*	*2*
• *Provides some relevant information e.g relates pH to hydrogen ion concentration or refers to percentage ionisation*	*1*

Sample Answer:

The concentration of hydrogen ions in a solution of an acid is used to measure its pH. As each acid ionizes to a different degree, this results in a different hydrogen ion concentration. Hence, the pH of each acid will be distinct.

HCl is a strong acid and ionises completely hence the lowest pH. Citric acid and acetic acids are weak acids and only partially ionise therefore have higher pH's.

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.

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

b. Account for the increase in pH of only 0.5 units. Use a chemical equation to support your **3**

• *Identifies a weak acid solution as an equilibrium system, uses Le Châtelier's Principle via equilibrium shift to counteract change to account for the increase in hydrogen ion concentration and links it to the pH change* • *Provides a suitable equation (with or without water)*	*3*
• *Weak in one aspect*	*2*
• *Any relevant information*	*1*

Sample Answer:

$CH_3COOH_{(aq)}$ <-> $CH_3COO^-_{(aq)}$ + $H^+_{(aq)}$

OR $HA_{(aq)}$ <-> $A^-_{(aq)}$ + $H^+_{(aq)}$

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 ions. 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.

30. *Hydrogen and carbon monoxide react as gases as follows.* **2**

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

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.

• *Determines equilibrium concentrations of reactant and products* • *Calculates the value of K from the expression*	*2*
• *Shows relevant steps with a minor error*	*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*

$$K = \frac{[CH_3OH]}{[H_2]^2[CO]} = \frac{[0.05]}{[0.15]^2[0.20]} = 11.11$$

31.	*An investigation was carried out to analyse a commercial lawn fertiliser. A sample of 1.00 g of fertiliser containing 24.0% sulfur (S) in the form of sulfate (SO_4^{2-}) was dissolved in water.* *100 mL of 0.20 mol.L^{-1} barium chloride solution was then added and a precipitate formed.* *Calculate the theoretical percentage by mass of sulfate (SO_4^{2-}) in the fertiliser.*	**3**

3 marks – calculates the correct percentage by mass of sulfate

2 marks – uses a correct process to calculate a percentage by mass of sulfate

*1 mark – provides **a correct calculation or process** to calculate a percentage by mass of sulfate*

Sample:

$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$

Mass S = 0.24 g

Therefore nS = m/MM = 0.24/32.07 = 7.48×10^{-3}

$nSO_4^{2-} = 7.40 \times 10^{-3}$

Mass SO_4^{2-} = n x M = 7.48×10^{-3} x (32.07 + 64) = 0.7186036

% mass SO_4^{2-} = (0.7186036/1.00) x 100 = 71.9%

Alternatively, if the student correctly calculates the experimental percentage of sulfate MAXIMUM of 2 marks

Moles sulfate = 0.020 mol

Mass sulfate = 1.92g

% Mass = 192%

32. *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.*

$nNH_2\text{-}C_6H_{12}\text{-}NH_2 + nCOOH\text{-}C_4H_8\text{-}COOH \rightarrow$

$nCOOH\text{-}C_4H_8\text{-}CO\text{-}NH\text{-}C_6H_{12}\text{-}NH_2 + (2n-1)\ H_2O$

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? **3**

...
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3

1) *Correctly calculates the number of moles of each reactant present*
2) *Calculates the mass of nylon produced without identifying and using the limiting reagent OR 1 error as per 3 marks* — *2*
3) *Correctly calculates the number of moles of each reactant present* — *1*

Sample Answer: ***This was answered well***

n(hexandioic acid) = $\frac{m}{Mm} = \frac{220\ g}{146.14\ g.mol^{-1}}$ *= 1.505405775 mol*

n(hexan-1,6-diamine) = $\frac{m}{Mm} = \frac{280\ g}{116.20\ g.mol^{-1}}$ *= 2.40963 mol*

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

∴ n(nylon) = 1.50540 mol

m = n x Mm

= 244.31 g.mol^{-1} x 1.50540 mol

= 367.784 g

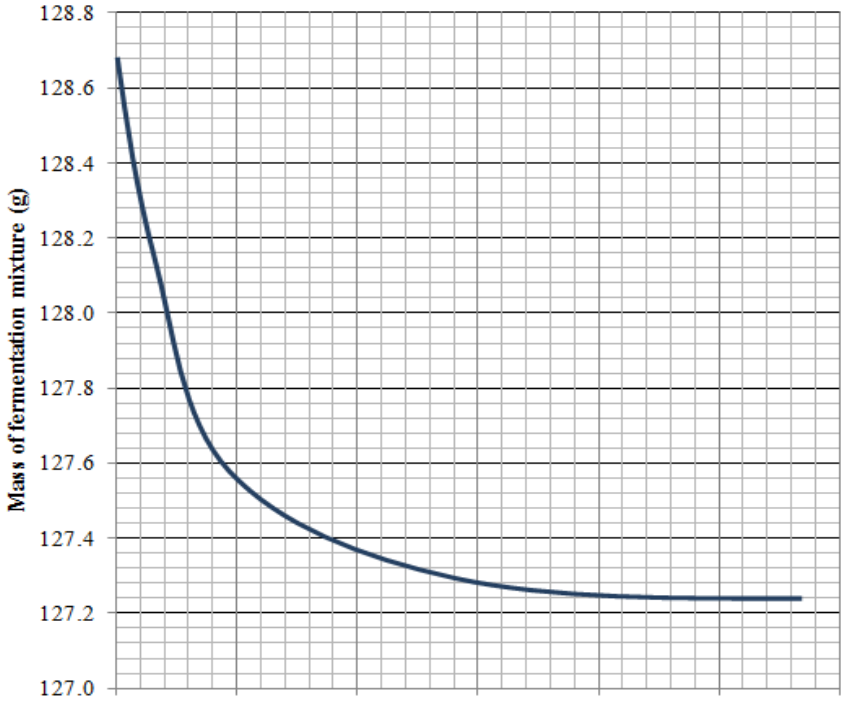
= 367.8 g (4.s.f)

5/9/23

33. *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.



Correctly calculates the mass change in the conical flask.
Sample Answer:
128.68 g – 127.24 g = 1.44 g ±0.04g

1

• *Correctly calculates moles of carbon dioxide using mass lost.* • *Calculates correct mass of ethanol produced* • *Calculates the theoretical yield of ethanol* • *Makes a comparison to the theoretical mass produced*	*4*
• *Addresses THREE of the above criteria OR 1 error as above*	*3*
• *Addresses TWO of the above criteria*	*2*
• *Addresses ONE of the above criteria*	*1*

Sample Answer:

Actual mass of ethanol produced:

n(CO2) = 1.44 g/44.01 g.mol-1 = 0.0327 mol

n(C2H5OH) = 0.0327 mol (1:1 ratio)

m(C2H5OH) = 0.0327 mol x 46.068 g.mol-1 = 1.5 g

theoretical mass of ethanol produced:

$n(C_6H_{12}O_6)$ = 12 g / 180.156g.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

The actual mass of ethanol produced is lower than the theoretical mass of ethanol

34. *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

3

a. Name the compounds shown in the table above:

Q:.....

R:.....

S:.....

Sample Answer: 1 mark each correct name

Q – propanoic acid R – butan-1-amine S – propanamide (propan-1-amide was also accepted although not needed)

3

b. Explain the variations in boiling points between Compounds Q, R and S.

• *Thoroughly explains the variation in boiling points between carboxylic acid, amine and amide in terms of the strength of the intra-molecular forces involved due to different functional groups present* • *Makes the clear link between strength of IM forces and temperature of boiling point to overcome these forces(better answers referred to energy)*	*3*
• *Explains the variation in boiling points between **TWO OF** carboxylic acid, amine and amide in terms of the strength of the intra-molecular forces involved due to different functional groups present OR* • *Identifies the intermolecular forces for all three substances AND links strength of IMF to BP*	*2*
• *Provides some relevant information*	*1*

Sample Answer:

The stronger the intermolecular forces, the more energy needed to overcome these and therefore the higher the boiling point.

All molecules have a similar MM so dispersion forces are similar.

Amides have two very polar bonds, the N-H and the C=O. This means they can form hydrogen bonds between molecules. They also form dimers with the hydrogen bonds forming between N-H on one molecule and the C=O of a different molecule. The dimer formation caused tighter packing of molecules and stronger H-bonds. The strong H-bonds between molecules results in amides having the highest boiling point of the 3 molecules.

The boiling point of the carboxylic acid (propanoic 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.

35. *The phosphate buffer system operates in the internal fluid of cells. The pH of an equimolar solution of sodium dihydrogen phosphate, NaH_2PO_4, and disodium hydrogen phosphate, Na_2HPO_4, is 6.8.*

a. Write a chemical equation that represents the equilibrium system described. **1**

Correct equation

$H_2PO_4^-{}_{(aq)} + H_2O_{(l)} <-> H_3O^+{}_{(aq)} + HPO_4^{2-}{}_{(aq)}$

b. Explain how this system operates as a buffer and account for what would happen if a small volume of 0.1 mol.L^{-1} carbonic acid, H_2CO_3 was added to the solution. **3**

• *Gives reasons why this system operates as a buffer (links to weak acid and conjugate base)* • *Explains why the addition of carbonic acid will not significantly change the pH of the solution by referring to Le Chatelier's principle (or shift in equilibrium position to counteract/minimise change)*	*3*
• *Gives a reason why this system operates as a buffer* • *Describes how the addition of carbonic acid initially increases the concentration of H_3O^+ OR causes a shift in the equilibrium position of the system.*	*2*
• *Provides a relevant piece of information relating to buffering. Can't just define a buffer.*	*1*

Sample answer:

The mixture of sodium dihydrogen phosphate and disodium hydrogen phosphate is an example of a buffer system because it regulates blood and cell pH by resisting changes to pH when small amounts of acid or base are added. These changes are based on Le Chatelier's principle that says if a chemical system at equilibrium is disturbed, the system will adjust itself to minimise the disturbance.

Consequently, the addition of a small volume of 0.1 mol L^{-1} carbonic acid would initially increase the concentration of H_3O^+ but will force the equilibrium to shift left to favour the reactants to counteract the change, resulting in a reduction in H_3O^+ concentration. The pH of the solution will thus be maintained/ not significantly changed.

36. *A sample of lemon juice was analysed in the laboratory. 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 ($C_6H_8O_7$), calculate the concentration in mol.L^{-1} of citric acid in the undiluted lemon juice. Note: Citric acid is a triprotic acid.

5

• *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 (accept 3-5 sig figs)*	*5*
• *Addresses FOUR of the above criteria*	*4*
• *Addresses THREE of the above criteria (max 3 marks if used 1:1 ratio)*	*3*
• *Addresses TWO of the above criteria / 2 correct steps*	*2*
• *Provides any relevant calculation / 1 correct step*	*1*

Sample Answer:

$C_6H_8O_7\ (aq) + 3NaOH\ (aq) \rightarrow Na_3C_6H_5O_7\ (aq) + 3H_2O\ (l)$

$n(NaOH) = cv$

$= 0.1245\ mol.L^{-1} \times 0.02395\ L$

$= 2.981 \times 10^{-3}\ mol$

$\therefore n(C_6H_8O_7) = 2.981 \times 10^{-3}\ mol \times 1/3$

$= 9.93925 \times 10^{-4}\ mol$ (1:3 ratio)

$$\therefore c(C_6H_8O_7) = \frac{9.93925 \times 10^{-4}\ mol}{0.025\ L}$$

$= 0.03976\ mol.L^{-1}$ (diluted) / (1 in 10 dilution)

$= 0.3976\ mol.L^{-1}$ (undiluted)

	• *Uses correct equations* • *Substitutes values correctly* • *Calculates the number of moles of CaF_2 that will dissolve accurately in both situations* • *Makes a comparison statement between the different solubilities*	***5***
	• *One error from above*	***4***
	• *Uses a correct equation* • *Substitutes values correctly* • *Calculates the number of moles of CaF_2 that will dissolve but with errors* ***Students receive 3 marks if correctly calculate 1 solubility***	***3***
	• *Uses correct equation* • *Substitutes values correctly*	***2***
	• *Any reasonable attempt such as a step in the calculation or writes a correct equation for dissociation.*	***1***

37. 5

Sample Answer:

Solubility equilibrium for CaF_2 is:

$CaF_{2\,(s)} \rightarrow Ca^{2+}_{(aq)} + 2F^-_{(aq)}$

$K_{sp} = 4 \times 10^{-11} = [Ca^{2+}][F^-]^2 = (x)(2x)^2$

$4 \times 10^{-11} = 4x^3$

Note: Many students used the wrong expression here e.g. $2x^2$ or $2x^3$ or just x^2

$X = 2.2 \times 10^{-4}$ (2.154×10^{-4})*this is the concentration of calcium ions in solution and therefore the same as the solubility of calcium fluoride.*

Solubility in 0.025 M NaF:

substituting values:

$4 \times 10^{-11} = (x)(0.025 + 2x)^2$

2x is negligible compared with 0.025 since Ksp is small.

So, $x = 6.4 \times 10^{-8}$

So, more of solid CaF_2 will dissolve in a litre of water than in 0.025M NaF solution.

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Task Evaluation ***Name: _____***

Total Mark: *_____ out of _____*

Mark sub-totals

Multiple choice mark: _____ out of _____

Knowledge and understanding mark: _____ out of _____

Working Scientifically mark: _____ out of _____

Circle the number that best matches. Key: 1– never 2-occasionally 3-sometimes 4-mostly 5- always

Aspect	*never*	*occasionally*	*sometimes*	*mostly*	*always*
I pay attention in class	*1*	*2*	*3*	*4*	*5*
I complete all my classwork	*1*	*2*	*3*	*4*	*5*
I ask the teacher when I need help	*1*	*2*	*3*	*4*	*5*
I make summary notes to study	*1*	*2*	*3*	*4*	*5*
I get distracted in class	*1*	*2*	*3*	*4*	*5*
I keep my OneNote book up to date	*1*	*2*	*3*	*4*	*5*
I provide sufficient detail in my OneNote responses/notes	*1*	*2*	*3*	*4*	*5*
I completed past papers to prepare for the test	*1*	*2*	*3*	*4*	*5*
I can communicate my understanding in tests	*1*	*2*	*3*	*4*	*5*

Questions:

1. *Do you feel that your performance in this task represents your understanding of Science?*

   _____

2. *What does your teacher do that helps you understand in Science?*

   _____

3. *What can your teacher do to improve your understanding in Science?*

   _____

4. *What do you do to maximise your results in Science?*

   _____

5. *What could you do better/differently to improve your results in Science?*

   _____

6. *Is there anything else you want your teacher to know?*