Exam Choice

Student Number

2023 | TRIAL EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes.
- Working time – 3 hours.
- Write using black pen.
- Draw diagrams using pencil.
- For questions in Section II, show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

Total marks: 100

Section I – 20 marks (pages 3 – 14)

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

Section II – 80 marks (pages 15 – 35)

- Attempt questions 21 – 33
- Allow about 2 hours and 25 minutes for this section.

Section I – 20 marks

Attempt Questions 1-20

Allow about 35 minutes for this section

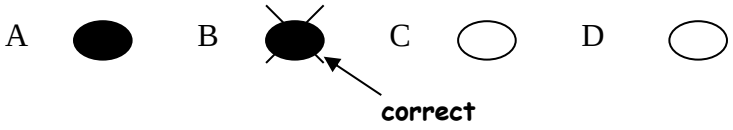
Use the multiple-choice answer sheet.

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.



1. According to the Arrhenius theory of acids, which species is produced when acids dissolve in water?

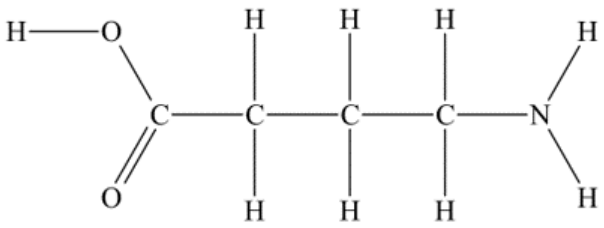
(A) H

(B) H^+

(C) H^-

(D) OH^-

2. The compound shown below plays an important role in the brain, where it inhibits transmission of chemical signals.



Which option below names TWO functional groups present in this molecule?

(A) amide and ester

(B) amide and carbonyl

(C) carboxyl and amine

(D) alkene and amine

3. Which reactants and/or conditions can be used to produce butanoic acid?

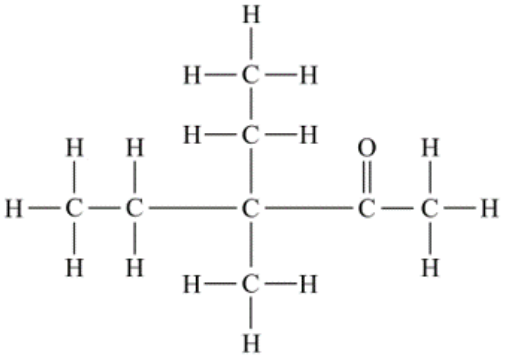
(A) butanal and acidified potassium permanganate

(B) 2-butanol and acidified potassium dichromate

(C) 1-propanol and methanal

(D) ethyl butanoate and concentrated sulfuric acid

4. What is the systematic name for the compound below?



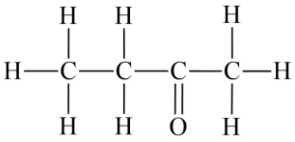
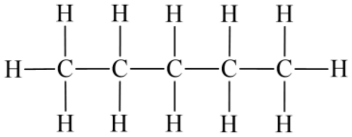
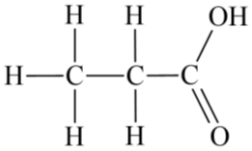
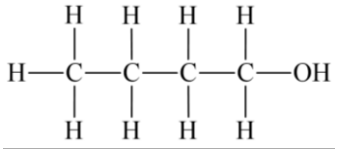
(A) 3-ethyl-3-methyl-2-pentanone

(B) 3-ethyl-3-methyl-4-pentanone

(C) 2,2-diethyl-3-butanone

(D) 3-methyl-3-ethanone pentane

5. At 50°C, three of the compounds below are liquids and one is a gas.

A	**B**
	
C	**D**
	

Identify the compound which must be the gas at this temperature?

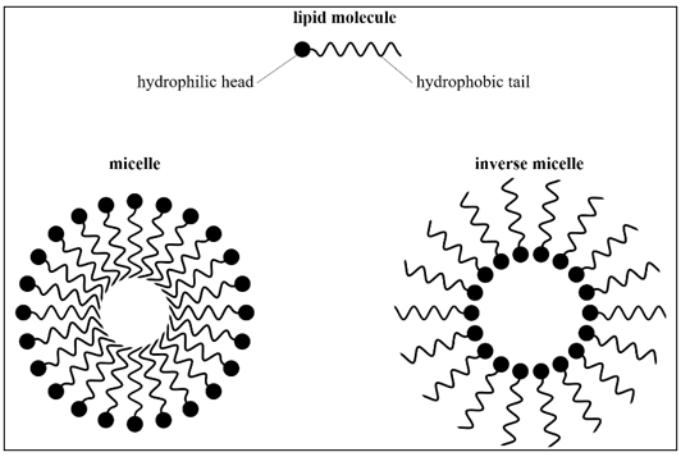
(A) A

(B) B

(C) C

(D) D

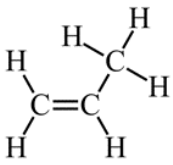
6. Interactions between lipid and solvent molecules can result in the formation of micelles and inverse micelles as shown in the diagrams below.



Which alternative below shows the correct polarity of a solvent which would form each type of micelle?

	Micelle	**Inverse micelle**
(A)	polar	polar
(B)	polar	non-polar
(C)	non-polar	polar
(D)	non-polar	non-polar

7. Polypropylene is produced in an addition reaction from the monomer unit below.



In a single molecule of this polymer, the longest continuous carbon chain contains 52000 carbon atoms.

What is the approximate relative mass of this molecule?

(A) 7.3×10^5

(B) 1.0×10^6

(C) 1.1×10^6

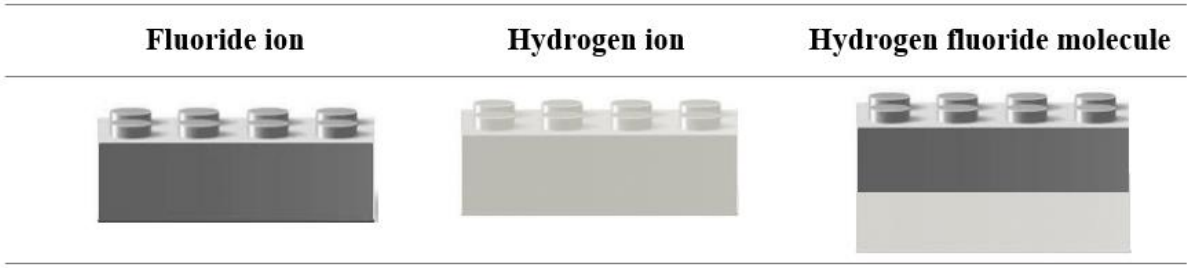
(D) 2.2×10^6

Questions 8 and 9 refer to the information below.

A student was required to construct a model to help others visualise the composition of a solution of 0.1 M hydrofluoric acid. They were told this acid had a K_a value of 6.7×10^{-4}.

The student had access to children's building blocks of various colours, like those shown in the image.

The student counted out 25 dark blocks and 25 light blocks and created the following key.



The student used the K_a value provided to determine, via calculation, the appropriate number of dark and light blocks to join to make the number of 'HF molecules' in the model consistent with the K_a value for the acid.

After joining the calculated number of blocks, they finally placed all single and joined blocks into a large beaker. This was presented as the final model.

8. How many separate dark blocks should the student have placed into the beaker to make the model show the correct % ionization for the acid?

(A) 2

(B) 6

(C) 12

(D) 23

9. Other students assessed the model and were asked to state some of its limitations based on the aim of the modelling exercise.

Four statements made are shown below.

I *The model should have included some different coloured blocks to represent the proportion of hydroxide ions also present in the solution.*

II *The building blocks used were too big to represent actual ions and molecules.*

III *It did not include the most common chemical present in the 0.1M HF being modelled.*

IV *The true nature of the hydrogen ion in aqueous solution is not shown by the model.*

Given the aim of the exercise, which of the above statements are significant limitations of the final model presented?

(A) I and IV

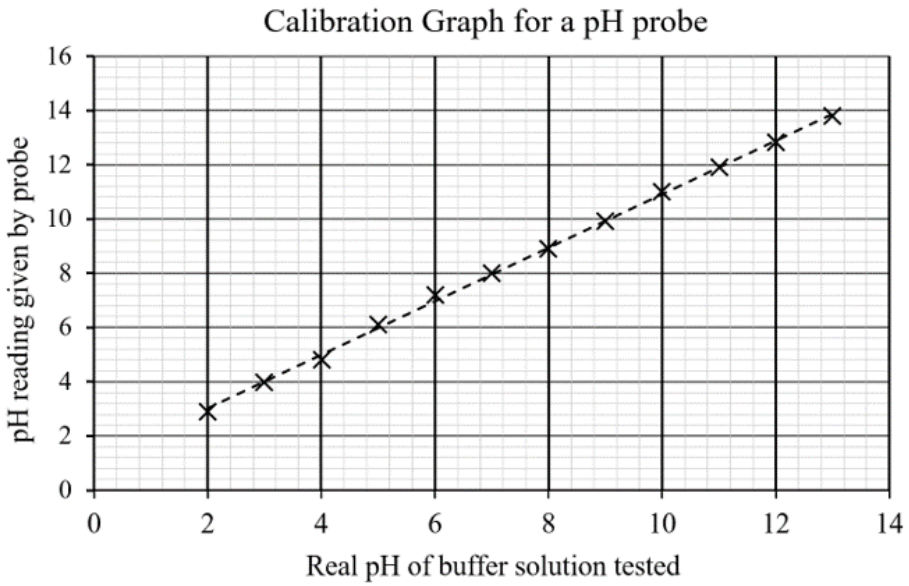
(B) I and II

(C) II and III

(D) III and IV

10. A pH probe is used to measure the pH of several buffers of known pH values to determine if the meter required calibration.

The graph below shows the pH readings given by the probe for each of the known (real) pH values of each buffer.



Which of the following statements is true, based on the data provided in the calibration graph shown.

(A) Using the probe without calibration will affect the reliability of data it gathers.

(B) If the probe were to be placed in a solution with $[OH^-] = [H^+]$ it would read 6.

(C) The equivalent point in a titration, as determined using this probe, will occur approximately one pH unit lower the actual equivalence point.

(D) The $[H^+]$ of a solution, as determined from its pH measured using this probe, will be 10 times lower than the actual $[H^+]$ in the same solution.

11. The table below shows some data on four acid-base indicators.

Indicator name	pH range	Colour range
methyl orange	3.1−4.4	red−yellow
bromophenol red	3.8−5.4	yellow−blue
methyl red	4.2−6.3	red−yellow
phenol red	6.8−8.4	yellow−red

A solution, labelled **X,** is made by mixing equal volumes of 0.0002 mol L^{-1} sodium hydroxide and 0.0004 mol L^{-1} HNO_3.

Which indicator shown would turn pure yellow when added to a sample of **X**?

(A) methyl orange

(B) bromophenol red

(C) methyl red

(D) phenol red

12. A metal hydroxide has a formula $X(OH)_2$, where X represents the symbol of the metal.

The pH of a saturated solution of $X(OH)_2$, as measured by a pH probe, was found to be 12.3.

Based on this measurement, metal X is likely to be:

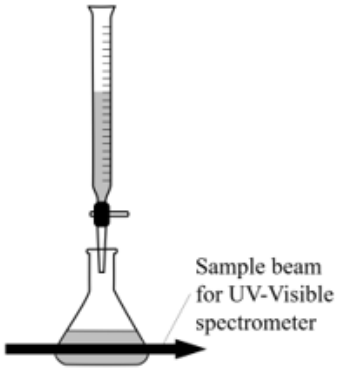
(A) barium.

(B) calcium.

(C) iron.

(D) lead.

13. A chemist sets up a UV-Visible spectrometer to automatically monitor the progress of a titration as shown in the diagram below, alongside a colour wheel.



The appropriate indicator for this titration is phenolphthalein. What colour should the spectrometer beam be set to?

(A) Orange

(B) Green

(C) Pink

(D) Blue

14. The Solvay process is an industrial method to produce sodium carbonate. It involves several steps, and the net reaction is:

$$2NaCl(s) + CaCO_3(s) \longrightarrow Na_2CO_3(s) + CaCl_2(s)$$

The molar masses of sodium chloride and sodium carbonate are given in the table.

Compound	**Mass of one mole (g)**
NaCl	58.44
Na_2CO_3	105.99

If the percentage yield is 95%, what is the mass of sodium carbonate produced from 180 kg of sodium chloride?

(A) 155 kg

(B) 163 kg

(C) 171 kg

(D) 310 kg

15. A sample of Compound X is divided into three parts. Each is tested with a different reaction.

- **Reaction 1:** Compound X produces an alkene and water upon reaction with hot concentrated sulfuric acid.
- **Reaction 2:** Compound X reacts rapidly with hydrochloric acid to produce an alkyl chloride.
- **Reaction 3:** Compound X does not react with acidified potassium permanganate.

Which row of the table below shows a possible identification of Compound X and Reactions 1 and 2?

	Compound X	**Reaction 1**	**Reaction 2**
(A)	butan-2-ol	oxidation	elimination
(B)	ethyl ethanoate	substitution	addition
(C)	ethanol	addition	oxidation
(D)	2-methylpropan-2-ol	dehydration	substitution

16. Butyl propanoate can be synthesised from 1-butanol and one another reactant.

Compared to 1-butanol, the other reactant has:

(A) fewer double bonds

(B) longer carbon chain length

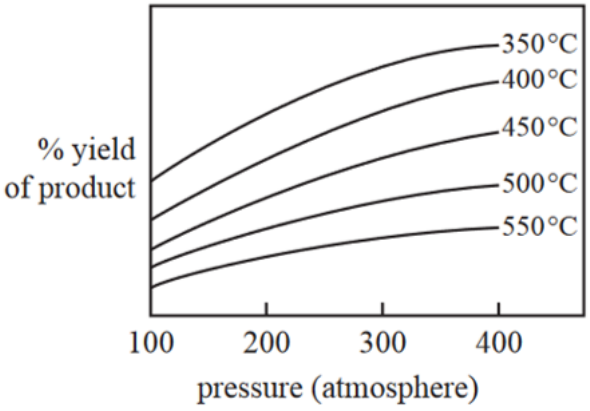
(C) more peaks in its ^{13}C NMR spectrum

(D) the same parent ion peak in its mass spectrum

17. The graph below refers to the following gaseous reaction.

$$aA(g) + bB(g) \rightarrow cC(g) + dD(g)$$

The effect of increasing pressure and temperature on the equilibrium yield of the products is shown in the graph below.

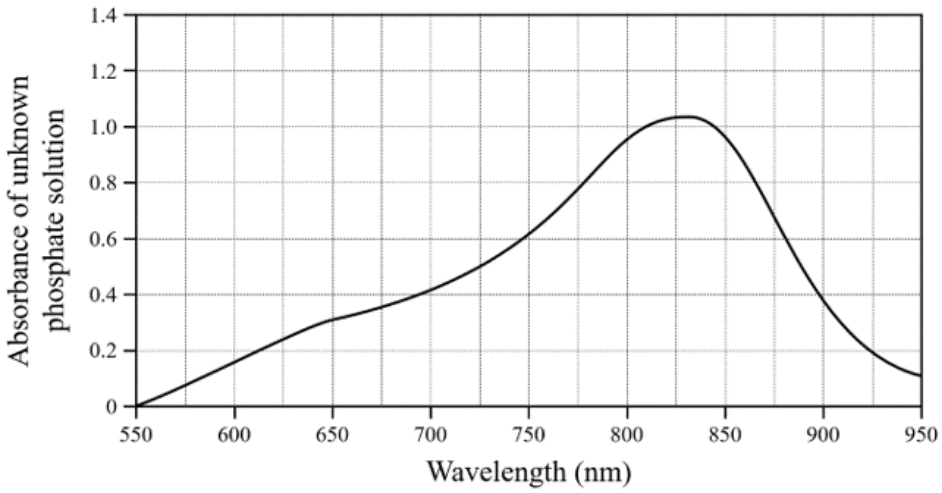


Which of the following alternatives regarding the chemical system is consistent with the data above?

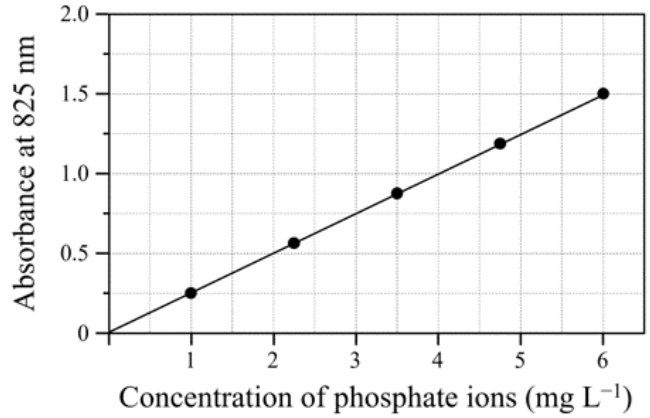
	Relative numbers of moles of products and reactants	ΔH
(A)	$a + b < c + d$	−
(B)	$a + b < c + d$	+
(C)	$a + b > c + d$	−
(D)	$a + b > c + d$	+

18. A student wishes to find the concentration of phosphate ions in a sample.

Its UV absorbance spectrum is shown below.



The student prepares a set of phosphate standards and measures their absorbance at 825 nm to produce the calibration curve shown below.



What is the concentration of phosphate ions in the unknown solution?

(A) 1.1×10^{-5} M

(B) 4.0×10^{-5} M

(C) 4.4×10^{-5} M

(D) 5.1×10^{-5} M

19. The following equation describes the equilibrium system between dichromate and chromate ions.

$$Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons CrO_4^{2-}(aq) + 2H^+(aq)$$

50 mL of an orange solution of potassium dichromate ($K_2Cr_2O_7$) is mixed with 50 mL of a yellow solution of potassium chromate (K_2CrO_4) in a 100mL bottle. The resulting mixture is light orange in colour. A lid is placed on the bottle, which comes to the laboratory temperature of 25.5°C. This solution is labelled "**X**".

10 mL of solution "X" is poured into a second bottle. 20 drops of 10 M sodium hydroxide are added. The resulting solution is allowed to re-establish equilibrium in the sealed bottle, at the same temperature. This solution is labelled "**Y**".

Which alternative shows the changes in solution "**Y**" compared to "**X**"?

	$[Cr_2O_7^{2-}]$	**pH**	**Colour change**
(A)	no change	higher	no change
(B)	lower	higher	more yellow
(C)	no change	no change	no change
(D)	lower	lower	more yellow

20. 1.23 g of a pure acid, $H_2X(s)$, is added to exactly 250.0 mL of 0.100 M NaOH(*aq*).

A reaction occurs according to the equation:

$$H_2X(s) + 2NaOH(aq) \rightarrow Na_2X(aq) + 2H_2O(l)$$

The NaOH is in excess. This excess NaOH requires 27.50 mL of 0.20 M HCl(*aq*) for neutralization.

What is the molar mass of the acid?

(A) 31.5 g mol^{-1}

(B) 63.0 g mol^{-1}

(C) 98.0 g mol^{-1}

(D) 126 g mol^{-1}

2023 | TRIAL EXAMINATION

Chemistry

Section II
Answer Booklet

80 marks

Attempt Questions 21 – 33

Allow about 2 hours and 25 minutes for this part

Instructions

- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which questions you are answering.

Marks

Question 21 (3 Marks)

Account for any expected differences in the solubility of $PbCl_2$ in each of the solvents below (all solubilities measured at 25°C). **3**

- distilled water
- 1 M lead(II) nitrate
- 1 M iron(III) chloride

Include a relevant balanced equation in your answer. No calculations are necessary.

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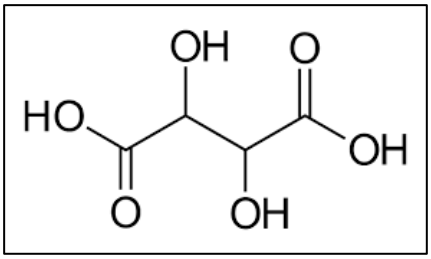
Marks

Question 22 (7 marks)

Tartaric acid is a highly soluble, white, crystalline organic acid occurring naturally in many fruits. The skeletal formula for the acid is shown below.



(a) On the diagram, circle the atoms lost upon complete ionisation of this acid. **1**

(b) The potassium salt of tartaric acid is called potassium bitartrate ($KC_4H_5O_6$), familiar to cooks as 'cream of tartar'.

Write an equation for a reaction between tartaric acid and a suitable base which would produce this salt. **1**

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(c) A student tests a solution of 'cream of tartar' ($KC_4H_5O_6$) in the school laboratory using red and blue litmus paper. The results are shown below.

Effect of 'cream of tartar' solution on red litmus paper	Effect of 'cream of tartar' solution on blue litmus paper
Stays red	Turns red

Apply the Brønsted-Lowry theory of acids and bases to explain the acid/base nature of cream of tartar solution as demonstrated by its effect on litmus paper above. Include a relevant ionic equation to support your answer. **3**

Write your answer to 22 (c) on page 18, overleaf.

Marks

Question 22 (c) (continued)

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(d) Demonstrate an understanding of the term ‘amphiprotic’, using the salt potassium bitartrate as an example to support your answer. **2**

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Marks

Question 23 (4 marks)

K_w (the ionisation constant of water) is 5.50×10^{-13} at 373 K.

(a) Calculate the pH of water at this temperature. **2**

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(b) Deduce whether the self-ionisation of water is an exothermic or endothermic process. **2**

Justify your answer.

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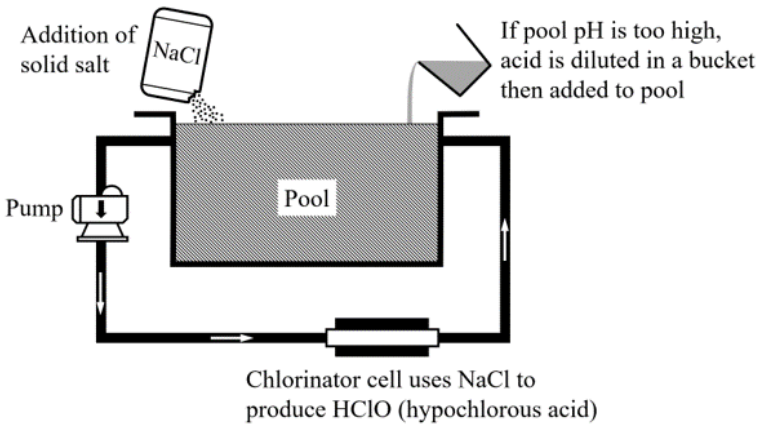
Marks

Question 24 (5 marks)

A saltwater swimming pool contains a balanced mixture of chemicals that kills bacteria and provides a safe pH for swimming. From time to time, different actions must be taken to maintain the balance.



- Salt (NaCl) is added to the pool.
- The pump moves the water through the chlorinator cell.
- The chlorinator cell electrolyses the NaCl and produces HClO (hypochlorous acid).
- HClO kills bacteria, keeping the pool safe for swimming.
- Hypochlorous acid is in equilibrium with the hypochlorite ion:

$$HClO + H_2O \rightleftharpoons H_3O^+ + OCl^-$$

(a) Sunlight breaks down hypochlorite ions to release chloride ions and oxygen gas. Fill in the boxes to write a balanced ionic equation for this process. **1**

$$\square \xrightarrow{\text{sunlight}} \square + \square$$

(b) Would you expect an increase in chloride ion concentration to significantly change the pH of the pool? Justify your answer. **2**

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Question 24 continues on page 21.

Marks

Question 24 (continued)

(c) When the pH of the pool is too high, acid is added. Because a pool contains a large volume of water, the acid must be highly concentrated. The bottle has a safety warning that includes handling instructions and this symbol:

Outline how one litre of concentrated hydrochloric acid can be diluted safely in a 5-litre bucket. **2**

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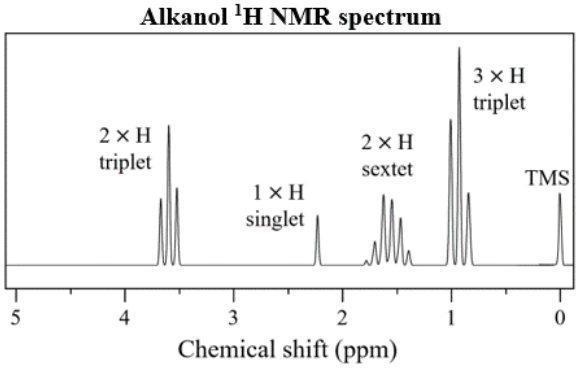
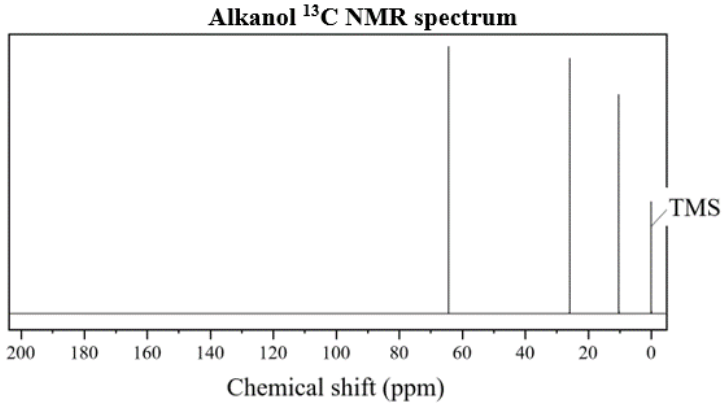
Marks

Question 25 (9 marks)

Scientists are investigating the properties of an alkanol. They recorded a ^{1}H NMR spectrum and a ^{13}C NMR spectrum.





(a) What is the role of TMS in NMR spectroscopy? **1**

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(b) What information is given by the *number* of signals in the ^{13}C NMR spectrum? **1**

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Question 25 continues on page 23.

Marks

Question 25 (continued)

(c) Use both spectra to identify the alkanol. Justify your identification. **3**

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(d) A different compound, Alcohol X, undergoes complete oxidation to form Compound Y.

Outline how an identified spectroscopic test on Compound Y could be used to deduce whether X was a primary or a secondary alcohol. **4**

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Question 26 (7 marks)

Two groups of students in a Chemistry lesson were asked to analyse a solution of H_2SO_4 to determine its concentration within ± 0.02 mol L^{-1} of the accepted value, which would be revealed to the students upon completion of their experimental work. Each group followed a different method, as outlined in the table below.

Group A	**Group B**
Gravimetric analysis • 100.0 mL sample of H_2SO_4 measured with measuring cylinder. • Excess warm 1.00 M barium chloride solution slowly added to unknown acid, with constant stirring, until no further precipitate appears to form. • Precipitate filtered with standard laboratory filter paper. • Filter paper and residue left overnight to dry. • Mass of filter paper used subtracted to determine the mass of dried precipitate. • Three trials completed.	**Volumetric analysis** • Standard titration of unknown carried against 0.200 M sodium carbonate solution. • Methyl orange selected as indicator. • Volumetric pipette rinsed with distilled water and unknown acid. • Burette rinsed with distilled water and then sodium carbonate. • Three titres recorded.

The raw data taken by the groups are shown below.

Group A

	Trial		
	1	**2**	**3**
Volume of H_2SO_4 (mL)	100.0	100.0	100.0
Mass of filter paper (g)	1.26	1.26	1.26
Mass of dried filter paper and precipitate (g)	3.75	2.40	3.32

Group B

	Titre		
	1	**2**	**3**
Volume of H_2SO_4 (mL)	25.00	25.00	25.00
Initial burette reading (mL)	0.00	18.15	0.00
Final burette reading (mL)	18.15	35.55	17.50

At the conclusion of the experimental work, the teacher revealed the accepted value for the acid concentration, which was 0.155 mol L^{-1}.

Question 26 continues on the page 25.

Marks

Question 26 (continued)

Complete the tables below to assess each investigation, providing justifications based on the information provided and your knowledge of these techniques. **7**

Group A	Group B
Accuracy (include suitable calculations to support assessment)	
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Reliability	
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Validity of method carried out in analysis	
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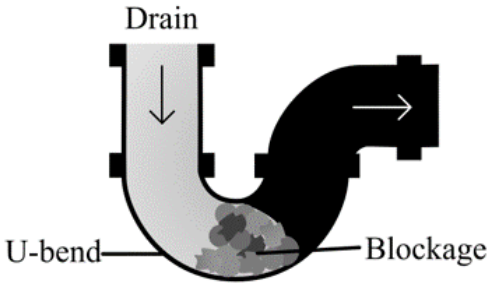
Question 27 (7 marks)

Kitchen sinks can become blocked by solidified fat and cooking oil deposits.



A YouTube vlogger claiming to be an expert in home cleaning included the following tip to deal with this problem.

> *"A cheap and effective fix for a blocked sink is to pour one cup of sodium bicarbonate solid down the drain. Then pour two cups of white vinegar into the drain and let chemistry do the rest. The two chemicals combine to produce a large volumes of gas which fizzes and bubbles to break down the blockage. It also makes a salt solution which helps to dissolve the fat/oil blockage."*

A viewer of the clip wrote the following in the comment section under the video.

> *"Doing this would have to be the worst way to fix a fat-blocked sink. The reaction would definitely make a gas, but it would not break up the solid significantly. The only other product is a solution that contains no surfactant. Anyone who has studied a little bit of chemistry knows the best thing to do is to pour caustic soda (sodium hydroxide) powder down the sink."*

Apply your knowledge of chemistry to critically analyse both the vlogger's advice and the viewer's comment shown, including an assessment on whether caustic soda would be more effective at removing the blockage.

Support your answer with correct and relevant chemical vocabulary, appropriate definitions, and relevant diagrams.

Write your answer to Question 27 on page 27.

Marks

Question 27 (continued)

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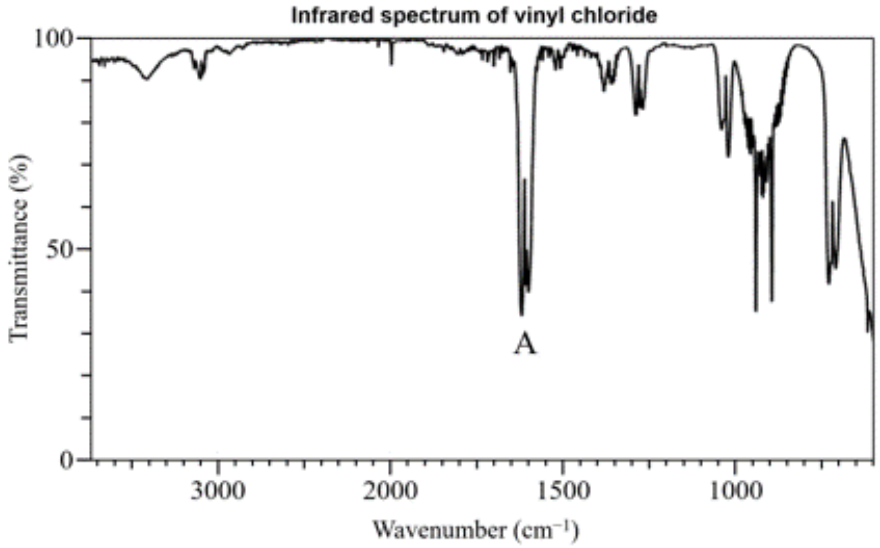
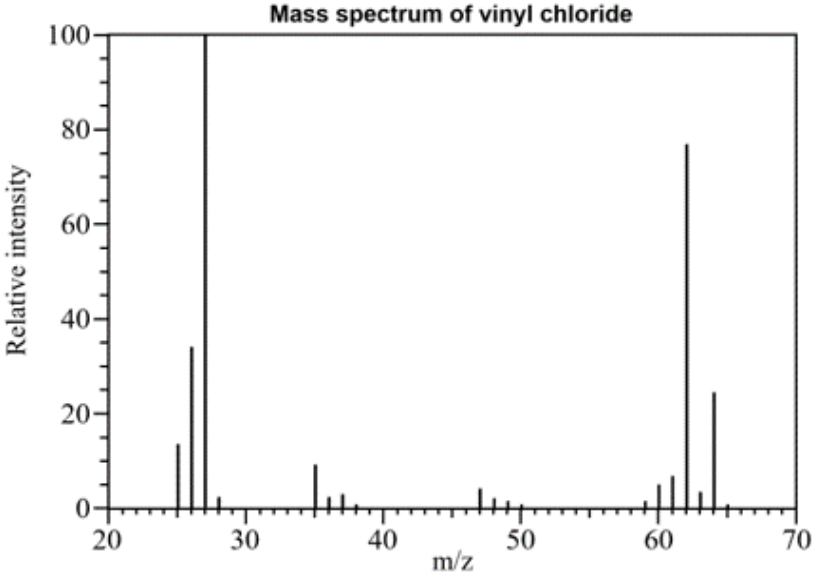
Question 28 (6 marks)

In February 2023, a train derailment in the United States resulted in the spill of many hazardous substances including hundreds of thousands of litres of vinyl chloride. The systematic name for vinyl chloride is chloroethene. It is used to produce the polymer, poly(vinyl chloride) (PVC).

The infrared and mass spectra of vinyl chloride are shown below.





Question 28 continues on page 29.

Marks

Question 28 (continued)

(a) Explain why the peak labelled **A** in the infrared spectrum of vinyl chloride is not present in the infrared spectrum (not shown) of poly(vinyl chloride). **2**

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(b) In the mass spectrum, the peak at m/z = 62 belongs to the unfragmented vinyl chloride ion. Explain why there is a large peak at m/z = 64. **2**

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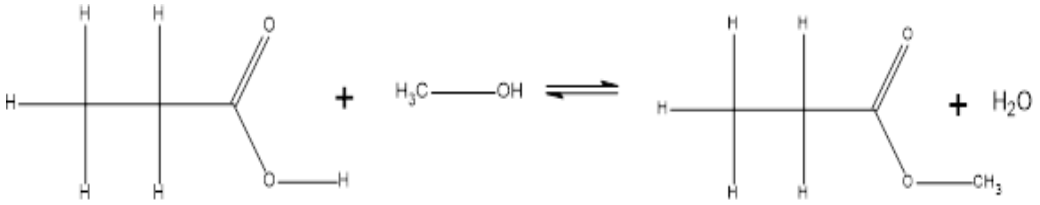
(c) Draw the structure of a chemical species that could be responsible for the base peak. **2**

Marks

Question 29 (9 marks)

A first-hand investigation was carried out to determine the value of K_{eq} for the reaction represented by the equation below.



(a) What is the IUPAC name of the organic product in the reaction being investigated? **1**

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(b) 15.00 g of propanoic acid was added to a round-bottomed flask, to which 4.00 g of methanol and 1.00 g of concentrated sulfuric acid were added. The mixture was heated under reflux for 1 hour.
Upon cooling, the flask was stoppered and placed into a water bath maintained at a constant temperature of 25°C.

After 24 hours, the concentration of methanol in the mixture was analysed spectroscopically and found to be 15% w/w.

Use the data provided to determine the experimental value of K_{eq} at 25°C, showing all working. **4**

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Question 29 continues on page 31.

Marks

Question 29 (continued)

(c) The experiment as outlined above was repeated without the addition of the sulfuric acid.

i. Explain how this change would affect the measured concentration of methanol. **2**

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ii. Would this affect the estimate for K_{eq} ? Justify your answer. **2**

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Question 30 (4 marks)

Isotopically pure samples of a substance are composed of only one isotope of each type of atom.

Account for similarities and differences in the mass spectra of isotopically pure samples of $^{13}CH_4$ and $^{14}NH_3$. (Assume all hydrogen atoms are ^{1}H.) **4**

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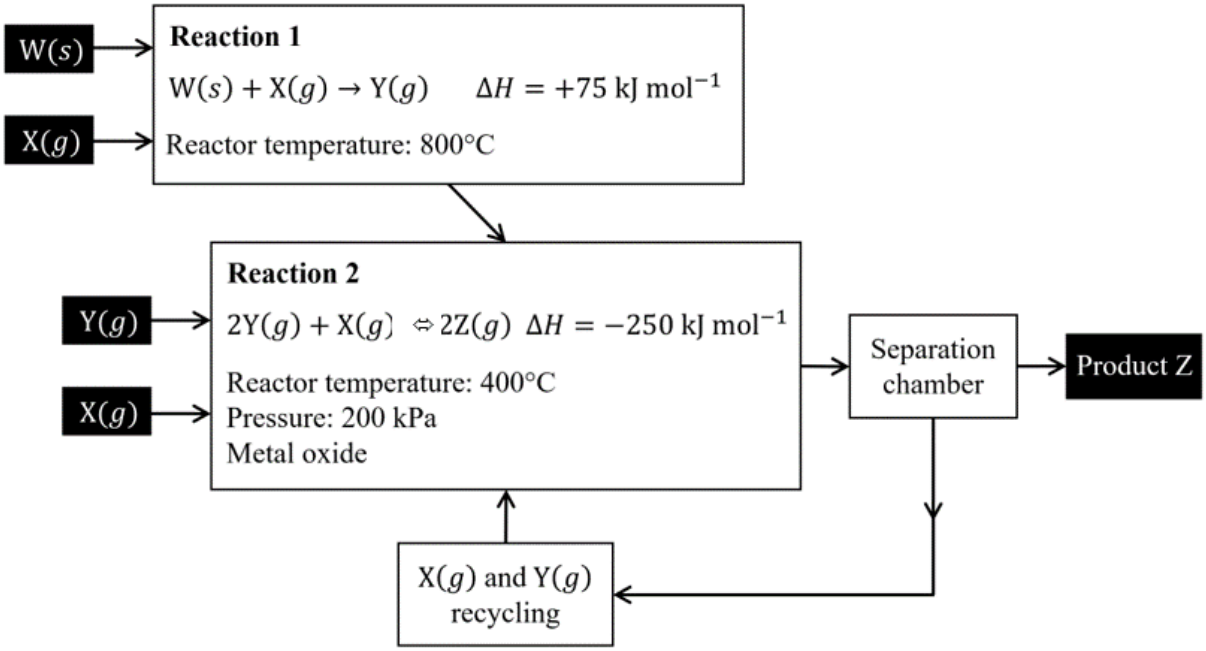
Question 31 (8 marks)

The design of a synthesis process to make an industrially useful product, "Z" from a solid raw material "W", is outlined in the diagram below.

Some information relating to the chemicals involved is shown in the table below.

W	X	Y	Z
Solid chemical, toxic upon inhalation	*Non-toxic, strong oxidising agent*	*Toxic, acidic gas*	*Highly corrosive and flammable liquid*



Question 31 continues on page 33.

Marks

Question 31 (continued)

(a) Justify the design and reactor conditions as outlined in the diagram. **5**

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(b) Evaluate factors that should be considered when choosing a location to build this industrial plant. **3**

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Marks

Question 32 (6 marks)

A solution of an unknown salt is analysed. It is known to contain either Zn^{2+}, Cu^{2+}, or Ca^{2+} as its cation, and either SO_4^{2-} or Cl^- or CO_3^{2-} as its anion.

Outline a method that could be used to identify the unknown salt solution. Include relevant observations which would confirm the ions present. **6**

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Marks

Question 33 (5 marks)

Some thermochemical data relating to potassium hydroxide are shown below.

$\mathrm{KOH}(s) \longrightarrow \mathrm{K^+}(aq) + \mathrm{OH^-}(aq) \qquad \Delta H = -57.6 \text{ kJ mol}^{-1}$

$\mathrm{KOH}(aq) + \frac{1}{2}\mathrm{H_2SO_4}(aq) \longrightarrow \frac{1}{2}\mathrm{K_2SO_4}(aq) + \mathrm{H_2O}(l) \qquad \Delta H = -59.1 \text{ kJ mol}^{-1}$

An 80.0 mL sample of 0.50 mol L^{-1} H_2SO_4 was poured into a polystyrofoam cup. A temperature probe placed into the acid recorded an initial temperature of 24.3°C.

5.00 g of KOH was then added to the acid and completely dissolved in it. The probe was used to determine the highest temperature reached upon this dissolution.

(a) Show by calculation which is the limiting reagent in the reaction between potassium hydroxide and sulfuric acid. **2**

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(b) Calculate the highest theoretical temperature which could be measured by the probe. **3**

Show working and state any assumptions made to calculate your answer.

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Section II extra writing space.

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Exam Choice

2023 Chemistry Trial Examination.

Marking Guidelines and Model 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	C	A	A	B	B	C	A	D	D	D	B	B	A	D	D	C	C	B	D

Section II

21.

Marking Criteria	Marks
• States the correct order of the solubility of $PbCl_2$ in each solvent. • Gives the equation for the dissociation of $PbCl_2$ • Explains the trend in solubility in terms of the common ion effect and Le Chatelier's Principle.	**3**
• States the correct order of the solubility of $PbCl_2$ in each solvent. • Gives the equation for the dissociation of $PbCl_2$ • Provides some explanation for the trend in solubility in terms of the common ion effect and/or Le Chatelier's Principle.	**2**
• Provides some relevant information.	**1**

Sample Answer:

$PbCl_2$ is extremely insoluble (as demonstrated by its very low K_{sp} value of…., but it will have an even lower solubility in the lead(II) nitrate and an even lower solubility in iron(III) chloride solution.

The reason for its lower solubility in both $Pb(NO_3)_2$ (aq) and $FeCl_3$ (aq) is that these solutions contain a common ion, the Pb^{2+} and Cl^- ions respectively. The presence of these ions already in the solution favours the reverse reaction as shown in the equation for the dissociation of lead(II) chloride, thus favouring the removal of the ions from solution, forming more undissolved solid.

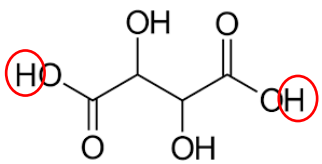
Since the $FeCl_3$ solution contains 3 Cl^-, the concentration of this common ion is 3 times that of the Pb^{2+} in $Pb(NO_3)_2$, hence more collisions increase the rate of the reverse reaction, having the greatest effect on the solubility of lead(II) chloride.

$PbCl_2$ (s) ⇔ Pb^{2+} (aq) + $2Cl^-$ (aq)

22 (a)

Marking Criteria	Marks
• Circles the two correct H atoms which are lost upon complete ionisation of the acid (those from carboxyl groups)	**1**

Sample answer:



22(b)

Marking Criteria	Marks
• Writes a possible correctly balanced equation for the formation of the salt. No states required.	**1**

Sample answer:

$C_4H_6O_6$ (s) + KOH (aq) → $KC_4H_5O_6$ (aq) + H_2O (l)

22(c)

Marking Criteria	Marks
• Explains the acidic nature of a cream of tartar solution, recognised by its effect on litmus paper, by application of the Bronsted-Lowry Theory AND • Includes a balanced ionic equation to support the answer.	**3**
• Defines an acid using the Bronsted-Lowry Theory and relates this to the colour change in the litmus AND • Includes a balanced ionic equation to support the answer OR • Provides a sound explanation of the effect of cream of tartar solution on litmus paper demonstrating a good understanding of the Bronsted-Lowry Theory	**2**
• Provides some relevant information.	**1**

Sample answer:

The results from the litmus paper test indicate that cream of tartar is acidic, as blue litmus turns red. The B/L theory states that acids act as proton donors and lose a proton, accepted by the other reactant, which acts as a base. From this, we can infer the following reaction must occur when cream of tartar dissolves in water:

$KC_4H_5O_6$ (s) → K^+(aq) + $C_4H_5O_6^-$ (aq)

The K^+ is a stable ion which will not hydrolyse.

$C_4H_5O_6^-$ (aq) + H_2O (l) ⇔ $C_4H_4O_6^-$ (aq) + H_3O^+ (aq)

The formation of the H_3O^+ is what changes the colour of the blue litmus paper.

22(d)

Marking Criteria	Marks
• Demonstrates an understanding of the term 'amphiprotic', using potassium tartrate as an example.	**2**
• Provides some relevant information eg a definition of the term 'amphiprotic'.	**1**

Sample answer:

An amphiprotic species can act as both a proton donor and a proton acceptor. The chemical formula for potassium tartrate ($KC_4H_5O_6$) shows that is has 1 proton which can be donated upon reaction with a substance acting as a base (eg water as shown in part (c).

It could also accept a H^+ upon reaction with a substance which is a stronger acid, re-forming tartaric acid. In this reaction it reacts as a base.
e.g. $C_4H_5O_6^-$ (aq) + HCl (aq) → $C_4H_6O_6$ + Cl^-

23 (a)

Marking Criteria	Marks
• Calculates the pH of water at 373K	**2**
• Provides one step in the calculation or writes the expression of K_w	**1**

Sample answer:

$K_w = [H_3O^+] \times [OH^-] = 5.50 \times 10^{-13}$ (at 373K)

$[H_3O^+] = \sqrt{5.50x10^{-13}}$
$= 7.45 \times 10^{-7}$

$pH = -\log [H_3O^+]$
$= -\log 7.45 \times 10^{-7}$
$= 6.13$

23 (b)

Marking Criteria	Marks
• Deduces the endothermic nature of the self-ionisation of water by comparing the size of K_w at 273K and 373K and by applying knowledge of Le Chatelier's Principle and the nature of K.	**2**
• Provides some relevant information.	**1**

Sample answer:

Higher temperatures favour the endothermic reaction in an equilibrium system, as the endothermic reaction absorbs some heat from the environment and thereby minimises the effect of the higher temperature (by Le Chatelier's Principle).
Since the value of K_w at 373K is higher than that at 273K (1.0×10^{-14}), the higher temperatures must have favoured the forward reaction, increasing the $[H_3O^+]$ and $=[OH^-]$, as this would increase K (products/reactants). Therefore the data suggests the self-ionisation of water is an endothermic process.

24 (a)

Marking Criteria	Marks
• Correct balanced equation	1

$2OCl^-(aq) \longrightarrow 2Cl^-(aq) + O_2(g)$

24(b)

Marking Criteria	Marks
• Identifies chloride ions as a weak base • Draws a conclusion	2
• Identifies a relationship between chloride and pH	1

Sample answer:

The chloride ion is the conjugate base of a strong acid, HCl. Therefore, it is a weak base. An increase in its concentration would have an insignificant effect on the pH of a pool.

24 (c)

Marking Criteria	Marks
• Outlines two safety measures including one specific to dilution of acid	2
• Outlines safety measures without reference to dilution	1

Sample answer:

- 3 or more litres of water put in bucket first, before carefully adding acid.
- Wear gloves and safety goggles to prevent skin and eye injury

25 (a)

Marking Criteria	Marks
• Provides the role of TMS in NMR spectroscopy.	1

Sample answer:

TMS is an internal reference with a strong signal at a chemical shift of zero, allowing for calibration of the chemical shifts.

25 (b)

Marking Criteria	Marks
• Identifies information	1

Sample answer:

The number of different chemical environments for carbon atoms in the molecule.

25 (c)

Marking Criteria	Marks
• Identifies alkanol • Justifies identification using information from both spectra	3
• Identifies alkanol • Justifies identification using information from one spectrum OR: • incorrect alkanol is identified using information from both spectra but a subsequent error is made.	2
• Some relevant information identified from either spectrum	1

Sample answer:

There are 8 H atoms (2+1+2+3) and three carbon environments (3 signals in ^{13}C NMR).
Alkanol, so must have −COH. Singlet at ~2.25 ppm in ^{1}H NMR, and ~64 ppm in ^{13}C NMR confirm this.
Triplet due to 3H suggests CH_3-CH_2. But there is no corresponding 2H signal split into 4. This means the sextet is the result of further splitting from the other 2 H atoms.
$CH_3CH_2CH_2OH$ propan-1-ol is consistent with all data.

25 (d)

Marking Criteria	Marks
• Identifies products of complete oxidation of primary and secondary alcohols • Identifies spectroscopic test • Relates feature of spectroscopic test to product of complete oxidation of each alcohol	4
• Identifies products of complete oxidation of primary and secondary alcohols • Identifies spectroscopic test • Relates feature of spectroscopic test to product of complete oxidation of one alcohol	3
• Identifies relationship between a feature of spectrum and a product of alcohol oxidation	2
• Some relevant information about oxidation of alcohols	1

Sample answer:
Primary alcohol → carboxylic acid (via aldehyde)
Secondary alcohol → ketone
^{13}C NMR sample answer
If the ^{13}C NMR spectrum of Compound Y shows a signal at:

- 50−90 ppm, it is a carboxylic acid and Compound X was a primary alcohol.
- 160−185 ppm, it is a ketone and Compound X was a secondary alcohol.

Infrared sample answer

If the infrared spectrum of Compound Y shows a broad feature around 2500−3000 cm^{-1}, indicating the presence of OH, Compound Y is a carboxylic acid and Compound X was a primary alcohol. If the infrared spectrum does not have the OH feature, Compound Y is a ketone and Compound X was a secondary alcohol.

Mass spectrum sample answer

Bonds adjacent to the C=O bond often break leading to characteristic patterns for carboxylic acids and ketones. If the mass spectrum of Compound Y has peaks at m/z = parent ion – 17 (loss of OH) and m/z = parent ion − 45 (loss of COOH), then Compound Y is a carboxylic acid and Compound X was a primary alcohol.

If Compound Y is a ketone, the mass spectrum would show two prominent peaks separated by 30 (C+O). This would indicate that Compound X was a secondary alcohol.

Proton NMR sample answer

Carboxylic acids have a lone H atom separated from the influence of other H atoms because it is bound to an oxygen atom. This would produce a singlet with an integral of 1. If the proton NMR spectrum of Compound Y has this feature, Compound Y is a carboxylic acid and Compound X was a primary alcohol.

The splitting pattern of a ketone depends on the nature of the chains on either side of the C=O, but it would not contain a singlet peak if Compound Y was a simple ketone.

26.

Marking Criteria	Marks
• Assesses accuracy, including performing both calculations for the methods based on the results shown, and comparing the estimate to the theoretic concentration, and thereby making an assessment. • Assesses reliability of each set of results with reference to the specific data and making suggestions of how reliability could have been improved, with reasoning. • Assessed the validity of the methods making references to the specific aspects mentioned in the method of both investigation and acknowledges that any issue with accuracy and/or reliability does indicate potential issues with the validity of the method.	**7**
• As above with one significant error or omission.	**6**
• Assesses accuracy, including performing both calculations for the methods based on the results shown, and comparing the estimate to the theoretic concentration, and thereby making an assessment. AND EITHER: • Assesses reliability of each set of results with reference to the specific data and making suggestions of how reliability could have been improved, with reasoning. OR • Assessed the validity of the methods making references to the specific aspects mentioned in the method of both investigation and acknowledges that any issue with accuracy and/or reliability does indicate potential issues with the validity of the method.	**5**
• Assesses accuracy, including performing a calculation for ONE of the methods correctly based on the results shown, and comparing the estimate to the theoretic concentration, and thereby making an assessment. AND EITHER: • Describes issues with the reliability of each set of results with reference to the specific data OR • Describes issues with the validity of the methods making references to the specific aspects mentioned in the method	**4**
• Qualitatively describes how specific details of the results and method can be used to assess accuracy, reliability and validity, demonstrating a satisfactory understanding of these terms. OR • Carrying out the calculation of the estimate of $[H_2SO]$ for either set of results.	**3**
• Qualitatively describes how specific details of the results and method can be used to assess TWO of either the accuracy, reliability or validity, demonstrating a satisfactory understanding of these terms.	**2**
• Some relevant information	**1**

Sample answer

	A	B
Accuracy (include suitable calculations to support assessment)	Mean ($BaSO_4$) (exc 2.40) (3.75-1.26) +(3.33-1.26) /2 = 2.275g =2.275 / 233.33 = 0.00975 mol $n(SO_4^-)$ = 0.00975mol (1:1 ratio) (in 100mL) $c(SO_4^{2-})$ = 0.0975 $molL^{-1}$ Thus $c(H_2SO_4)$ analysed = 0.0975 $molL^{-1}$. Since accepted $c(H_2SO_4)$ = 0.155$molL^{-1}$ the result is quite inaccurate. (approx. 37% error).	Mean titre = 17.45 mL = 0.01745L $n(Na_2CO_3)=cV$ =0.01745 x0.20 =0.00349 mol $n(H_2SO_4)$ = 0.00349 mol $c(H_2SO_4) = n/V$ =0.00349/0.025 =0.140 $molL^{-1}$ Since result is also below the accepted value but the % error is much lower (9.7%) thus making it a much more accurate result compared to Method A. However, neither group achieved the aim, because their results were greater than 0.1 $molL^{-1}$ from the accepted value.
Reliability	The experiment produced relatively inconsistent results, with one result being considerably different from the other two. The reliability would therefore be assessed as quite low.	The last two titres are acceptably close, suggesting the reliability is better than those results for Method A. However, the first titre is significantly higher than the others. This may have been a 'rough' titre used to gauge the approximate end-point. A fourth titre would allow the reliability to be checked to see if this titre was close to the 2nd and 3rd titre.
Validity of method carried out in analysis	As the aim was to determine quantitatively the $[H_2SO_4]$, but limitations in the method including the way the fine $BaSO_4$ was filtered (some ppt would likely have passed through into the filtrate): measuring the initial volume analysed with a measuring cylinder and not volumetric flask, and difficulty judging when excess Ba^{2+} had been added, resulted in an estimate significantly lower than the accepted value, and also produced unreliable results, which suggest invalid aspects in the method.	As the aim was to determine quantitatively the $[H_2SO_4]$, using acid-base titration as a technique was a more valid method, resulting in a much higher level of accuracy, but still lower than the aim. The correct indicator was selected and rinsing techniques appropriate. Repeating with a second or third additional titre and not counting the first titre could have produced a more accurate estimate, further increasing the validity of the method.

27.

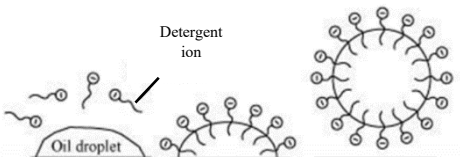
Marking Criteria	Marks
• Critically analyses both sources of information demonstrating an extensive knowledge and understanding of the main reactions/processes involved, including at least one balanced chemical equation and supporting diagram.	**7**
• Critically analyses both sources of information demonstrating a sound knowledge and understanding of all the main reactions/processes involved.	**6**
• Explains some merits and limitations made by each source, demonstrating a sound understanding of at least TWO of the relevant reactions/processes involved.	**5**
• Describes some merits and limitations made by at least one of the sources, demonstrating a sound understanding of at least TWO of the relevant reactions/processes involved.	**4**
• Describes some of the relevant chemical principles relating to the context provided, demonstrating satisfactory knowledge of some of the processes/reactions involved.	**3**
• Outlines at least one of the relevant chemical principles relating to the context provided, demonstrating limited knowledge of the processes/reactions involved.	**2**
• Some relevant information	**1**

The information provided by the vlogger in the YouTube video is correct in that the sodium bicarbonate and vinegar added to the sink would produce a salt solution and a gas, as per the equation:

$$NaHCO_3(s) + CH_3COOH\ (aq) \rightarrow NaCH_3COO\ (aq) + H_2O\ (l) + CO_2\ (g)$$

This reaction would cause fizzing, but the comment made by the viewer is likely to be correct-this fizzing alone would be very unlikely to remove the fatty deposit causing the blockage. The vlogger is incorrect when they state that the salty water produced ($NaCH_3COO$) would be able to dissolve the fat-as there is no surfactant that would be able to break down the fat and form an emulsion with water to remove it.

Fats/oils are non-polar and water is polar. These two chemicals will not interact without a surfactant such as a soap or detergent. These surfactants have non-polar hydrophobic 'tails' in their molecules which can bond to the largely non-polar fat/oil, and polar ends (hydrophilic) which can interact and bond to water. Thus when a surfactant is present, with agitation, the fat deposit could be broken down into small micelles, effectively forming an emulsion which would be able to flow through the pipes, unblocking the drain.



Therefore, overall the vlogger's suggested method to unblock the fat deposit is certainly flawed and the alternate method made by the viewer, to add caustic soda, has merit. This is because the addition of a very strong base (NaOH) to the fat/oil deposit will result in a saponification reaction occurring

The glycerol backbone of the fat /oil will be attacked by the NaOH, forming soap molecules (long chained sodium salts of fatty acids) and glycerol. :
fat + NaOH → soap + glycerol
Both of the products of this reaction are water soluble, and hence could flow out of the pipes when water was flushed down the sink some time after the caustic soda was added. While effective, the method does have a greater environmental impact and the caustic nature of NaOH(s) means safety precautions must be considered relating to its safe storage and use (eg stored away from children, used with gloves and in ventilated area).

28 (a)

Marking Criteria	Marks
• Relates peak to double bond in vinyl chloride • Relates polymerisation to loss of double bond	2
• Some relevant information about the peak or the process of polymerisation of vinyl chloride	1

Sample answer:

Peak A is between 1600 cm^{-1} and 1650 cm^{-1}. The bond in vinyl chloride that corresponds to this is C=C. When vinyl chloride polymerises, this bond "opens up" so that there are no C−C bonds. Therefore the IR spectrum of PVC does not show this feature.

28(b)

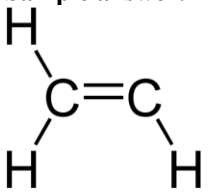
Marking Criteria	Marks
• Explains the presence of the peak as due to isotope effects. • Identifies the isotope responsible as ^{37}Cl	2
• Explains the presence of the peak as due to isotope effects.	1

Sample answer:
There is a prominent peak at two m/z units greater than the parent ion peak because some vinyl chloride contains the ^{37}Cl isotope of chlorine, which is about one-third as abundant as the ^{35}Cl isotope.

28(c)

Marking Criteria	Marks
Drawing has a mass equal to that of the base peak Structure is a fragment of vinyl chloride	2
Drawing has a mass equal to that of the base peak	1

Sample answer:



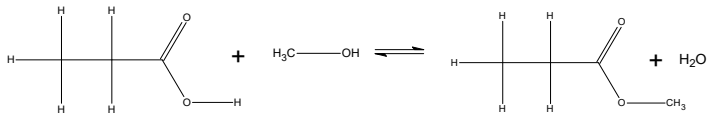
29 (a)

Marking Criteria	Marks
• Provides the correct IUPAC name of the product of the esterification reaction.	1

Methyl propanoate

29 (b)

Marking Criteria	Marks
• Calculates the value for K from the data provided.	4
• Calculates a value for K from the data provided with one error or omission	3
• Carries out two steps necessary towards solving the problem.	2
• Provides some relevant information	1



$[CH_3OH]_{eq}$ = 15% = 15 g /100 g = 3 g per 20 g = 3 /32.042 = 0.09363 mol/20 g

Initial moles	15/74.078 = 0.202 mol	4 /32.042= 0.1248mol	0	0
Change in moles	0.03177	0.03117	0.03117	0.03117
Moles at equilibrium	0.17023	0.09363	0.03117	0.03117
$[\ ]_{eq}$	8.5115	4.6815	1.5585	1.5585

$K_{eq} = [C_4H_8O_2]\,[H_2O] / [C_3H_6O_2]\,[CH_3OH] = 1.5585^2 / 8.5115 \times 4.6815 = 2.4289 / 39.8465 = 0.06$

29 (ci)

Marking Criteria	Marks
• Explains how the absence of sulfuric acid will effect the $[CH_3OH]$ analysed with sufficient justification of its role in the reaction	2
• Provided some relevant information.	1

The addition of the $[H_2SO_4]$ catalyses the reaction and acts as a dehydrating agent, effectively decreasing the concentration of free water on the right, shifting the equilibrium to the right. If this is not added, the reaction would be far slower and would have a lower % conversion of methanol, thus meaning the $[CH_3OH]$ analysed after 24 h would be expected to be much higher, in fact, possibly quite close to the its initial concentration.

29 (cii)

Marking Criteria	Marks
• Explains how the absence of sulfuric acid will effect the estimated value of 'K' for the reaction, with sufficient justification	2
• Provided some relevant information.	1

This would mean the value of the other species calculated from this are also different. The [products] calculated would be much lower, and [reactants] higher. The value of K would thus be estimated as much lower (and is in fact a value for Q, as the system analysed has not reached equilibrium).

30.

Marking Criteria	Marks
• Identifies a similarity and a difference in mass spectra. • Clearly explains similarity and difference by relating feature of spectrum to feature of molecule.	4
• Identifies a similarity and a difference in the mass spectra. • Explains either similarity or difference by relating feature of spectrum to feature of molecule.	3
• Identifies expected similarity or difference in mass spectra.	2
• Some relevant information.	1

Sample answer:

Both species produce a parent ion peak at m/z = 17 because:

- $^{13}CH_4$ is has a mass of $13 + 4\times1 = 17$, and
- $^{14}NH_3$ is has a mass of $14 + 3\times1 = 17$

The methane spectrum has peaks at m/z = 16, 15, 14, 13 corresponding to losing successive H atoms.
In the mass spectrum of ammonia, it is not possible to have a peak at m/z = 13, because there are only three H atoms to lose.

31a

Marking Criteria	Marks
• Justifies at least 4 features of the synthesis design process by applying the key ideas of the collision theory and / or LeChatelier's principle	5
• Justifies at least 3 features of the synthesis design process by applying the key ideas of the collision theory and / or LeChatelier's principle	4
• Provides some explanation for at least 2 features of the synthesis design process, referring to satisfactory knowledge of the collision theory and / or LeChatelier's principle	3
• Provides some explanation for one feature of the synthesis design process, referring to satisfactory knowledge of the collision theory and / or LeChatelier's principle	2
• Provides some relevant information.	1

Sample Answer

The first step in the synthesis of Z involves a non-reversible reaction between W and X. Their reaction is endothermic and requires energy from the environment to be absorbed by the system to overcome the activation energy. Employing high temperatures in the reaction chamber for this reaction will increase the average KE of the reactant particles and the frequency of collisions between W and X will increase. Moreso, more of the colliding molecules will possess the E_A -the activation energy required for a collision to be successful and result in formation of chemical Y, used in the next reactor.

The second reactor involves inputs of Y from Reactor 1, which should have gone to completion. To this reactor, more X is added, as it is an intermediate ie created in Step 1, used in Step 2. The reaction between Y and X is a reversible reaction, and LeChatelier's Principle can be applied to determine reaction conditions which would optimise the yield of useful product Z.

- As the forward reaction is exothermic, low temperatures would favour a higher % yield as low temperatures tend to favour exothermic processes which release heat into the surroundings, thereby countering the effect of the low temperature exerted on the system. However, low temperatures results in a low reaction rate, so if low temperatures are employed, the system will take considerable time to reach equilibrium, making it not economically viable. A compromise temperature (moderately elevated temperature of 400^{o}C will allow for a high enough % conversion to Z at a fast enough rate to make the process economically viable. Addition of a metal oxide catalyst further increases the reaction rate, which is only being carried out at moderate, but not extremely high temperatures which would optimise rate.
- The reaction is carried out at pressures double that of atmospheric pressure. Increased pressure will result in higher frequency of collisions, thus increasing rate, as well as favouring the forward reaction, which produces less moles of gas, thus minimising the effect of the increased pressure.

The separation chamber ensures any Y or X in the output mixture is separated from Z (eg by cooling and liquefication), thus recycling these gases, reducing the cost of the synthesis process and avoiding need to treat unused X and Y, which could have environmental impacts which would need to be addressed before they were released, adding further to the cost of the process.

31b

Marking Criteria	Marks
• Identifies TWO factors that would be considered when selecting a location for this plant with specific reference to the data provided and for each factor makes a judgement, based on some criteria, for its consideration.	**3**
• Identifies TWO factors that would be considered when selecting a location for this plant with specific reference to the data provided and for at least one of these factors, makes a judgement, based on some criteria, for its consideration.	**2**
• Provides some relevant information.	**1**

Sample answer:
One important factor that must be considered is how Raw Material W and gas X will be transported to the plant site. If the site can be build relatively close to where W is mined, this will reduce money and energy costs. If the site cannot be located close to the source of W, transport routes from its production site to the plant site must be adequate. Likewise, if a facility to produce gas X could be on site at the plant, this will be economically advantageous and reduce energy costs associated with transport, which also reduces environmental impact of the production.

A second factor is how close the site will be to market for useful product Z. Perhaps the site could be near a sea port so that Z can be transported to markets on boats and less transport costs and energy thus required to transport Z to the ships.

If any of the materials are hazardous or if the reaction conditions could result in hazards such as explosions or release of toxic/corrosive chemicals, the site should be build away from populous towns/cities and an exclusion zone build around the site to minimise damage / loss of life if an accident at the site were to occur.

32

Marking Criteria	Marks
• Outlines a logical sequence of suitable tests • Includes expected observations for all tests for each possible ion • Includes a balanced chemical equation	6
• Outlines a mostly correct sequence of suitable tests • Includes expected observations for all tests for each possible ion • Includes a balanced chemical equation	5
• Outlines a sequence of tests and most of the expected observations • Includes a mostly correct balanced chemical equation	4
• Provides tests that can identify ions • Includes some expected observations and/or a balanced chemical equation	3
• Provides one test that could identify a cation OR anion OR • Provides tests that can identify cations and anions OR • Provides a balanced chemical equation and one test that can identify a cation OR anion	2
• Some relevant information	1

Sample answer:

Anion test
Dip red litmus paper in unknown solution
If it turns blue, the anion is carbonate. Confirm by adding nitric acid. Bubbles of $CO_2(g)$ confirm carbonate. In the reaction, X is the cation with a valency of 2+.

$$2HNO_3(aq) + CO_3^{2-}(aq) \longrightarrow CO_2(g) + H_2O(l) + 2NO_3^-(aq)$$

Confirmation: The gas should turn limewater milky when it is bubbled through.

If the litmus remains red:
Add barium chloride
If a white precipitate forms, the anion is sulfate.

$$BaCl_2(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s) + 2Cl^-(aq)$$

- If no precipitate forms, the anion is chloride.

Cation test
Add sodium hydroxide.

- If blue precipitate forms (copper hydroxide), the anion is Cu^{2+}.

$$Cu^{2+}(aq) + 2NaOH(aq) \longrightarrow Cu(OH)_2 + 2Na^+(aq)$$

  Confirmation: blue-green colour in flame test.

- If a white precipitate forms, the cation could still be either zinc or calcium.

Add excess sodium hydroxide

- If the precipitate remains, the cation is calcium
  Confirmation: brick red colour in flame test

- If the precipitate dissolves and forms a colourless solution, the cation is zinc (which forms soluble complexes with OH^-).

33 (a)

Marking Criteria	Marks
• Shows, by calculation, the H_2SO_4 limits the reaction.	**2**
• Calculates the moles of either the H_2SO_4 or KOH	**1**

Sample Answer:

$n(H_2SO_4)$=cv = 0.5 x 0.08 = 0.04 mol
n(KOH) = 0.089 mol

Since 0.04 moles of H_2SO_4 requires 0.08 moles KOH (which is smaller than the moles of KOH added), H_2SO_4 limits reaction.

33 (b)

Marking Criteria	Marks
• Calculates the maximum theoretical temperature reached, stating at least 2 assumptions made.	**3**
• Calculates the maximum theoretical temperature reached OR • Calculates the maximum theoretical temperature reached with one error AND includes one assumption made.	**2**
• Provides some relevant information.	**1**

Sample answer:
Energy released by neutralisation:

$n(H_2O)$ produced = 2 x 0.04 = 0.08 mol

Energy released = 59.1 x 0.08 = 4.73 kJ
Energy released upon dissolving KOH:
n(KOH)=m/MM = 5 / 56.108 = 0.089 mol
Energy released = 56 x 0.089 = 5.126 kJ

Energy released due to neutralisation:

Total energy released = 5.126 + 4.728 = 9.854 kJ = 9854 J

$q=mc\Delta T$

$9854 = 80 \times 4.18 \times \Delta T$

$\Delta T = 29.47\ ^{o}C$

Final max temperature = 24.3 + 29.47 = 53.8°C

This calculation assumes:

- Calorimeter absorbs negligible heat
- C of solution = C of distilled water
- No volume increase occurs due to addition of KOH to the acid