SHORE

Exam Number: ☐☐☐

Year 12

Chemistry

Trial Examination

2019

General instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Board approved calculators may be used
- A data sheet and a Periodic Table are provided at the back of this paper
- Write your Student Exam Number where required
- **Note:** Any time you have remaining should be spent revising your answers

Total marks – 100

Section 1

20 marks

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

Section 2

80 marks

- Attempt Questions 21 - 38
- Allow about 2 hours and 25 minutes for this section

DO NOT REMOVE THIS PAPER FROM THE EXAMINATION ROOM

Section 1 – 20 marks
Attempt Questions 1–20
Allow about 35 minutes for this part

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

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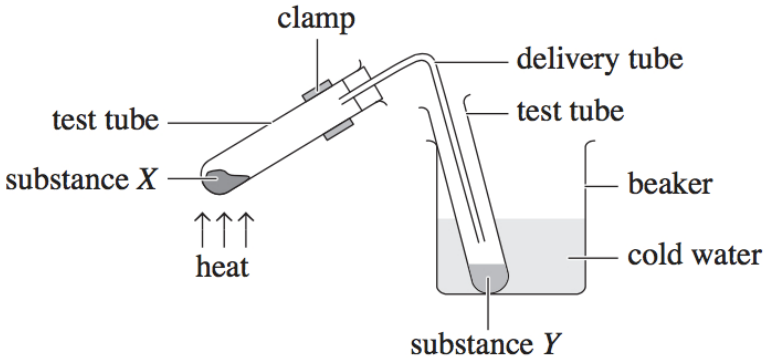
1. Which of the following statements about systems is correct?

(A) An open system can transfer matter but not energy with its surroundings.
(B) An open system can transfer energy but not matter with its surroundings.
(C) A closed system can transfer energy but not matter with its surroundings.
(D) A closed system can transfer neither energy nor matter with its surroundings.

2. The diagram shows hydrated cobalt(II) chloride after it has been heated and all signs of a reaction have ceased.



Which row of the table correctly shows the most likely identities of the substances *X* and *Y*?

	Substance X	*Substance Y*
(A)	water	dehydrated cobalt(II) chloride
(B)	dehydrated cobalt(II) chloride	water
(C)	dehydrated cobalt(II) chloride	chlorine
(D)	cobalt(II) oxide	water

3. Consider the equilibrium process

$$CH_2CH_2(g) + H_2(g) \rightleftharpoons CH_3CH_3(g) \qquad \triangle H = -136 \text{ kJmol}^{-1}$$

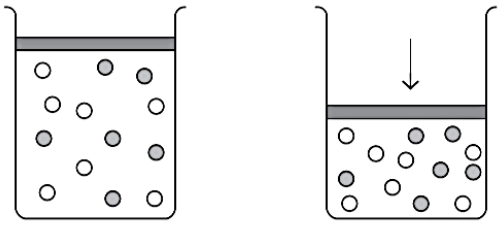
Which of the following changes would cause the magnitude of the equilibrium constant for this reaction to increase?

(A) The temperature is decreased.
(B) The pressure is decreased.
(C) The concentration of H_2 in the equilibrium mixture is increased.
(D) The concentration of CH_3CH_3 in the equilibrium mixture is increased.

4. Which of the following aqueous solutions of ionic compounds would form a precipitate when mixed?

(A) potassium chloride and sodium hydroxide
(B) magnesium sulfate and sodium chloride
(C) sodium iodide and ammonium nitrate
(D) sodium sulfate and barium nitrate

5. The diagram shows a mixture of gases in a sealed container where the volume is decreased.



Which of the following statements most accurately describes this system?

(A) As volume increases, the gas molecules move faster.
(B) As volume decreases, the gas molecules move further before colliding.
(C) As volume decreases, the gas molecules can have more collisions.
(D) Changing the volume has no effect on the movement of molecules.

6. The pH of an alkaline solution is 8.

Which of the following expressions could represent this solution?

(A) $[OH^-] = 10^{-8}$
(B) $-\log_{10}[H^+] = 8$
(C) $\log_{10}[OH^-] = 8$
(D) $\log_{10}[H^+] = 8$

7. Magnesium reacts with dilute hydrochloric acid to liberate hydrogen.

What is the volume of hydrogen produced at 298.15 K and 100 kPa when 1.22 g of magnesium is reacted with excess dilute acid?

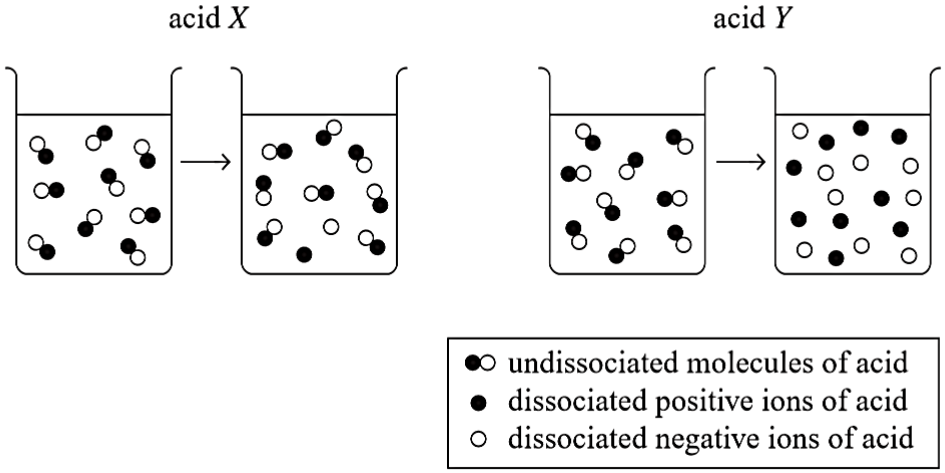
(A) 1140 mL
(B) 1240 mL
(C) 2270 mL
(D) 2450 mL

8. Nitric acid completely dissociates in aqueous solutions. 1.0 mL of 10 mol L^{-1} solution was diluted to 1 L with distilled water. 100 mL of this resulting solution was then further diluted to 1 L using distilled water.

What pH is the final solution closest to?

(A) 1
(B) 2
(C) 3
(D) 4

9. The diagram shows the behaviour of two different acids when they are dissolved in distilled water.



Which row of the table correctly describes the two acids?

	Acid X	*Acid Y*
(A)	concentrated	dilute
(B)	dilute	concentrated
(C)	strong	weak
(D)	weak	strong

10. Consider the system

$$HF(aq) + H_2O(l) \rightleftharpoons F^-(aq) + H_3O^+(aq).$$

Which of the following represents a conjugate acid–base pair present in this system?

(A) $HF(aq)/F^-(aq)$
(B) $HF(aq)/H_3O^+(aq)$
(C) $HF(aq)/H_2O(l)$
(D) $F^-(aq)/H_3O^+(aq)$

11. In an experiment, 4-hydroxybutanoic acid [$HO(CH_2)_3COOH$] forms a polymer containing 1000 monomer units.

Which of the following is closest to the approximate molar mass (in g mol^{-1}) of this polymer?

(A) 2.0×10^2
(B) 1.4×10^4
(C) 8.6×10^4
(D) 1.1×10^5

12. How many hydrogen atoms are there in one molecule of 2,2-dimethylbutan-1-ol?

(A) 8
(B) 10
(C) 12
(D) 14

13. Which of the following solutions, upon mixing will produce the solution with the highest temperature change?

(A) 50mL of 0.05M HNO_3 + 100mL of 0.4M NaOH
(B) 200mL of 0.05M CH_3COOH + 100mL of 0.01M NaOH
(C) 100mL of 0.1M H_2SO_4 + 50mL of 0.4M KOH
(D) 50mL of 0.2M HCl + 100mL of 0.025 $Ba(OH)_2$

14. What type of reaction is represented by the conversion of hexan-3-ol to hexan-3-one?

(A) addition
(B) substitution
(C) combustion
(D) oxidation

15. The infrared spectrum of a pure compound showed a broad band between 2500 and 3000 cm^{-1}; a series of moderate bands at 2900, 2990 and 3200 cm^{-1}; an intense band at 1720 cm^{-1}; and numerous bands between 1640 and 750 cm^{-1}.

Which of the following compounds matches these absorbances?

(A) ethene
(B) ethanol
(C) ethyl ethanoate
(D) ethanoic acid

16. Which type of bonding forms between the monomers that react together to form nylon polymers?

(A) amide bonds
(B) ester bonds
(C) ionic bonds
(D) hydrogen bonds

17. Which of the following pairs of compounds are NOT isomers?

(A) hexan-2-ol and 2,2-dimethylbutan-1-ol
(B) methyl ethanoate and propanoic acid
(C) butane and cyclobutane
(D) butan-2-one and 2-methylpropanal

18. How many peaks would appear in the ^{13}C NMR spectra of pentan-3-one?

(A) 2
(B) 3
(C) 4
(D) 5

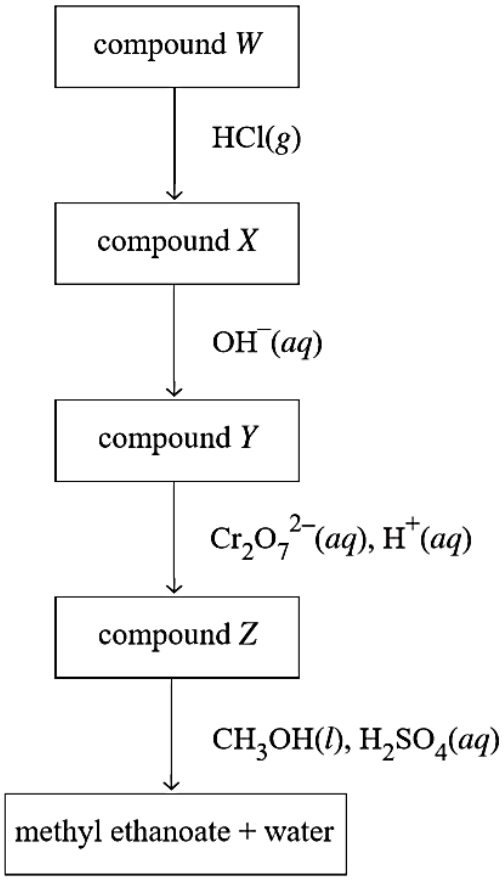
19. A solution was prepared by dissolving a pure compound in water. The solution was subjected to a series of tests. The results are shown in the table.

Test	*Reaction*
flame test	The flame turns lilac/pink.
adding $BaCl_2(aq)$	A precipitate forms.
adding $HCl(aq)$	Bubbles of gas form.

Which of the following compounds was dissolved into the water?

(A) calcium carbonate
(B) potassium carbonate
(C) sodium sulfate
(D) potassium sulfate

20. The flow chart shows a sequence of reactions that result in the formation of methyl ethanoate.



Which row of the table correctly identifies the compounds labelled *W, X, Y* and *Z*?

	Compound W	*Compound X*	*Compound Y*	*Compound Z*
(A)	ethane	chloroethane	ethanol	methanoic acid
(B)	methane	chloromethane	methanol	methanoic acid
(C)	ethane	chloroethane	ethanol	ethanoic acid
(D)	ethene	chloroethane	ethanol	ethanoic acid

END OF SECTION 1

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Exam Number: ☐ ☐ ☐

2019 Chemistry Trial Examination

Section 2 – 80 marks
Attempt Questions 21–38
Allow about 2 hours and 25 minutes for this section

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 question you are answering.

Question 21 (3 marks)

Sulfur trioxide, SO_3, is made by the reaction of sulfur dioxide, SO_2, and oxygen, O_2, in the presence of a catalyst.

In a closed system in the presence of a catalyst, the reaction quickly reaches equilibrium at 1000 K.

A mixture of 2.00 mol of $SO_2(g)$ and 2.00 mol of $O_2(g)$ was placed in a 4.00 L evacuated, sealed vessel and kept at 100 K until equilibrium was achieved. At equilibrium, the vessel was found to contain 1.66 mol of $SO_3(g)$.

Calculate the equilibrium constant, K_{eq} for the above equilibrium at 1000 K.
Show all relevant working. **3**

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Question 22 (6 marks)

In order to demonstrate some solution chemistry, a science teacher prepares a number of practical tasks.

In the first task she mixes 25 mL of 0.1 M $BaCl_2$ with 25 mL of 0.1 M $CuSO_4$.

(a) Write a complete balanced chemical equation to represent this reaction, including states. **1**

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(b) Write the net ionic equation for this reaction. **1**

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In another demonstration the teacher makes a saturated solution.

She adds 1.52 g of $Cu(OH)_2$ (s) to 100.0 mL of water, and tells her students that the K_{sp} of $Cu(OH)_2$ is 2.2×10^{-20}.

(c) Write the dissociation equation of $Cu(OH)_2$ (s). **1**

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(d) Use the K_{sp} value to calculate the concentration of OH^- ions in this saturated solution of $Cu(OH)_2$. **3**

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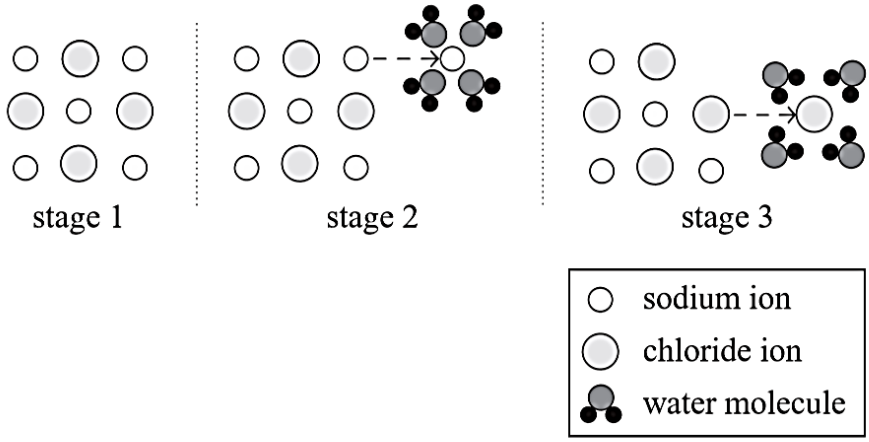
Question 23 (5 marks)

The diagram shows sodium chloride (common salt) dissolving in water.



(a) A saturated solution of sodium chloride in water was found to have a concentration of 359 g L^{-1}. **3**

With reference to the diagram, describe the dissociation of sodium chloride.

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(b) Calculate the value of K_{sp} for this system. **2**

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Question 24 (4 marks)

Consider the reaction

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57.20 \text{ kJ mol}^{-1}.$$

(a) Using the reaction, outline how activation energy (E_a) varies for the forward and the reverse reactions in equilibrium reactions. **2**

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(b) How would increasing the temperature affect this reaction? Explain your answer. **2**

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Question 25 (4 marks)

Carbonic acid is formed when carbon dioxide dissolves in water. Carbonic acid plays a major part in the buffering of human blood, which has a typical pH of 7.40. One way to show the ionisation of carbonic acid is

$$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq).$$

(a) Write an expression for the equilibrium constant (K_{eq}) for this reaction. **1**

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(b) Buffers play a role in many natural systems. **2**

Using human blood, or another relevant example, explain why buffers are important.

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(c) What is the typical hydrogen ion concentration in human blood? Show your working. **1**

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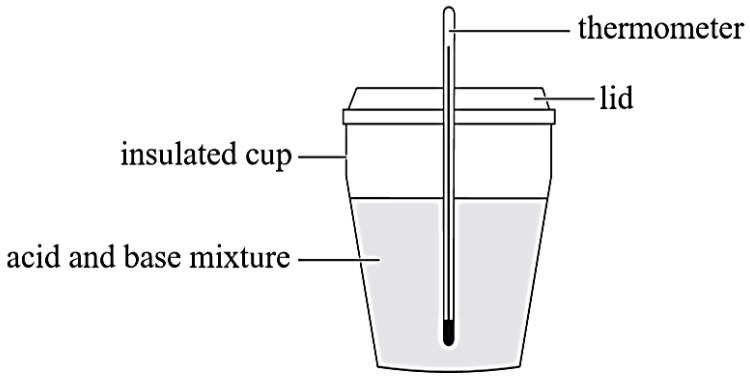
Question 26 (8 marks)

The diagram shows a coffee cup calorimeter used by a student to measure the enthalpy of neutralisation of an acid–base reaction.



120.0 mL of 0.500 mol L^{-1} sodium hydroxide was added to 60.0 mL of 0.500 mol L^{-1} sulfuric acid. Both solutions were at a temperature of 24.2 °C. After mixing, the final temperature was 26.3 °C.

(a) Calculate the enthalpy change per mole of water formed in this reaction. **3**

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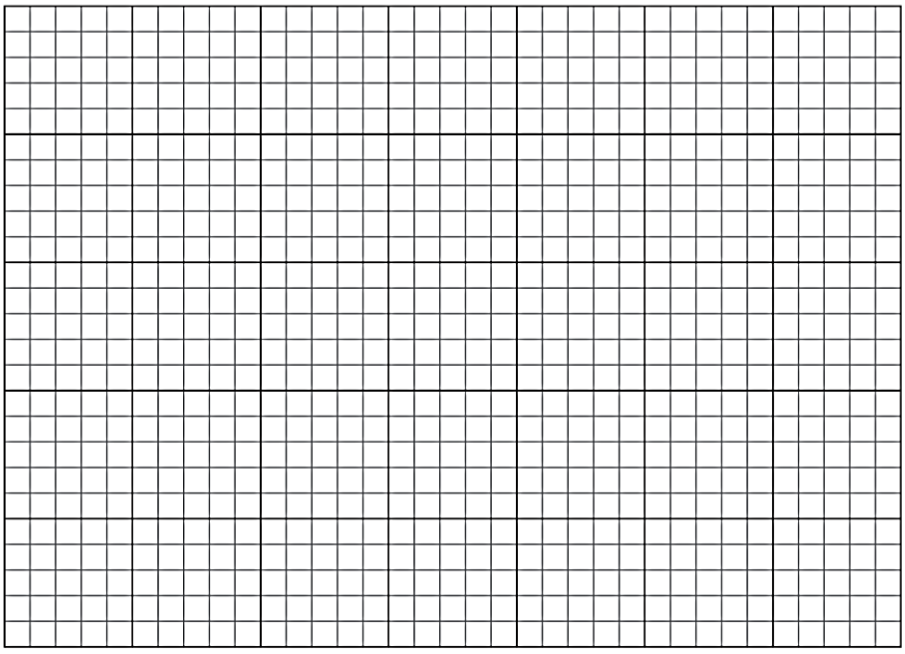
Question 26 continues on page 15

(b) The heat of combustion of a number of alcohols was measured. The results are shown in the table. **3**

Alcohol	*Enthalpy of combustion (kJ mol^{-1})*
methanol	–726
propan-1-ol	–2021
butan-1-ol	–2676
pentan-1-ol	–3331
hexan-1-ol	–3984

Using the data provided, construct a graph that shows the relationship between chain length (number of carbon atoms) and enthalpy of combustion for these alcohols.



(c) Using construction lines on the graph above, predict the value of the enthalpy of combustion of ethanol in kJ per gram of ethanol. **2**

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End of Question 26

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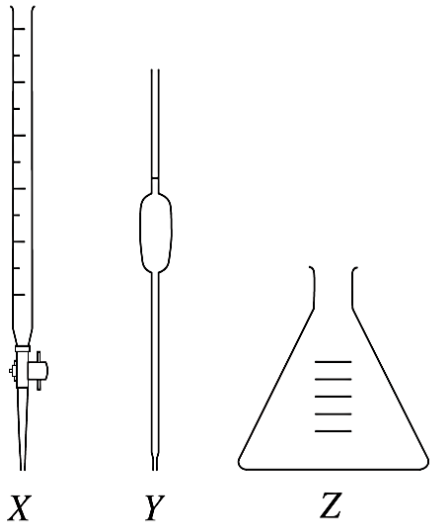
Question 27 (3 marks)

The diagram shows three pieces of glassware (*X*, *Y* and *Z*) used in conventional acid–base titrations (indicator colour change). **3**



Identify each piece of equipment and outline its role in a titration.

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Question 28 (4 marks)

Various models of acids and bases have been used over time. **4**

Compare the theories of Arrhenius and Brønsted–Lowry.

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Question 29 (4 marks)

Polyvinyl alcohol is a water-soluble addition polymer used in adhesives and paints. The monomer used has the following structure:

$$CH_2 = CHOH$$

(a) Draw the structural formula for a 3-unit segment of the polymer. **1**

Question 29 continues on page 19

Question 29 continued

(b) Explain how bromine water can be used to distinguish between a solution of the monomer and a solution of the polymer. **2**

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(c) State the systematic name for the monomer used in forming polyvinylchloride. **1**

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Question 30 (4 marks)

In a beaker, enough sodium hydroxide of concentration 0.0288 M is added to10.5 mL of 0.0355 M of sulfuric acid to make a total volume of 50.0 mL.

(a) Write a chemical equation for the reaction **1**

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(b) Calculate the pH of the remaining mixture **3**

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Question 31 (5 marks)

Describe and justify the process used to prepare an ester in the school laboratory.
Include a diagram and a specific safety precaution in your answer. **5**

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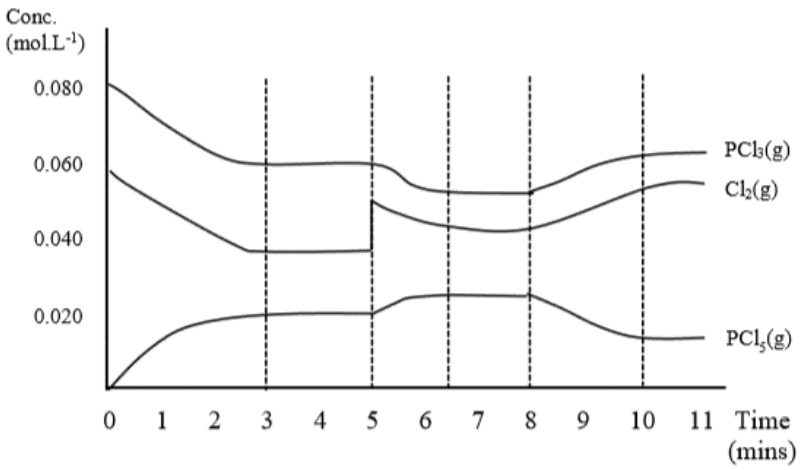
Question 32 (4 marks)

Consider the graph below, which shows the concentration of each species in the equilibrium system:

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \quad \Delta H = -92 \text{ kJ/mol}$$

This is measured over 11 minutes, during which time various changes are imposed on the system



(a) When does the system first reach equilibrium? Justify your answer. **1**

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(b) What change was imposed at t = 5 minutes? Explain what would happen to the rates of the forward and reverse reactions immediately after this change. **3**

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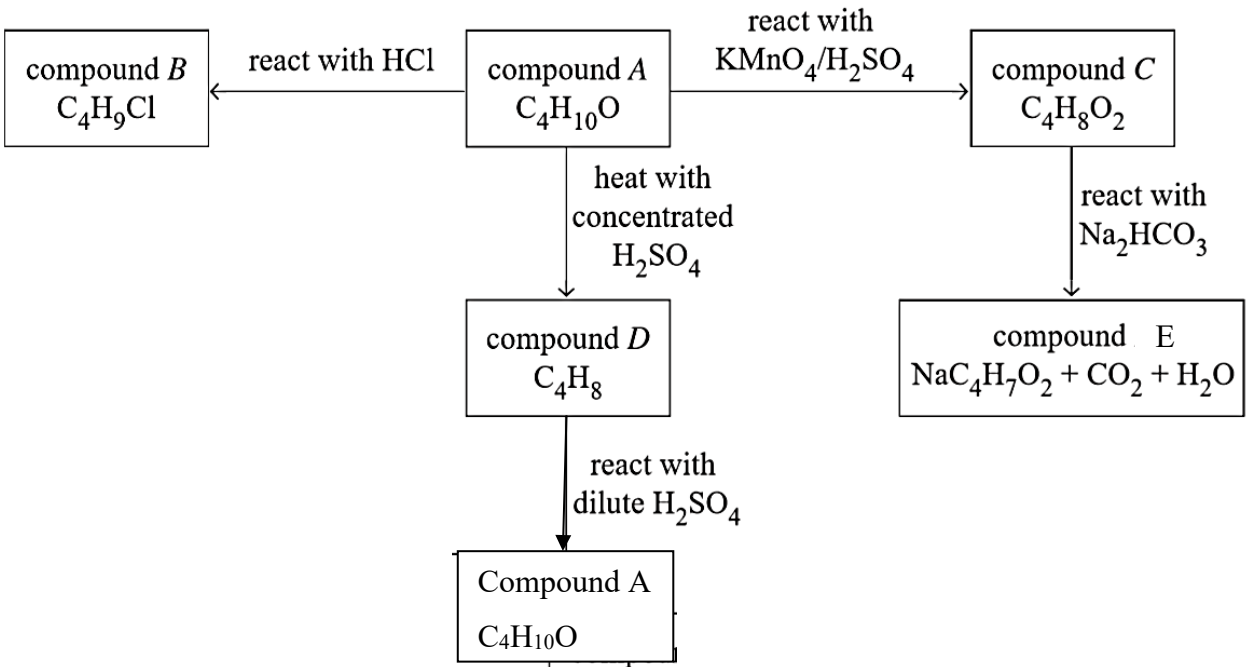
Exam Number: ☐ ☐ ☐

Question 33 (5 marks)

The flow chart shows the reactions of five different organic compounds **5**



Complete the table by drawing the structural formulae for the compounds and justifying your answers with reference to the information provided.

Compound	*Structural formula*	*Justification*
Compound *A* $C_4H_{10}O$		
Compound *B* C_4H_9Cl		

Question 33 continues on page 24

Question 33 continued

Compound	*Structural formula*	*Justification*
Compound *C* $C_4H_8O_2$		
Compound *D* C_4H_8		
Compound *E* $NaC_4H_7O_2$		

End of Question 33

Question 34 (3 marks)

Many people wash their dirty dishes with soapy water.

(a) Describe how soapy water is able to clean dishes covered with grease or fat while fresh water is not. **2**

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(b) Draw a diagram to show how soaps form micelles in a mixture of oil and water. **1**

Question 35 (7 marks)

A student was asked to determine the mass of $CaCO_3$ present in a 2.25 g sample of chalk. The chalk reacted with 100.0 mL of a 1.00 M HCl solution. After the bubbling stopped, excess HCl remained. The excess HCl was titrated with 1.00 M NaOH. The average titre was 17.15 mL.

(a) Calculate the number of moles of sodium hydroxide which reacted with the excess HCl. **1**

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(b) Determine the number of moles of HCl added to the chalk sample and use this to calculate the actual number of moles of calcium carbonate present in the sample. **4**

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(c) Calculate the percentage of calcium carbonate by mass present in the 2.25 g chalk sample. **2**

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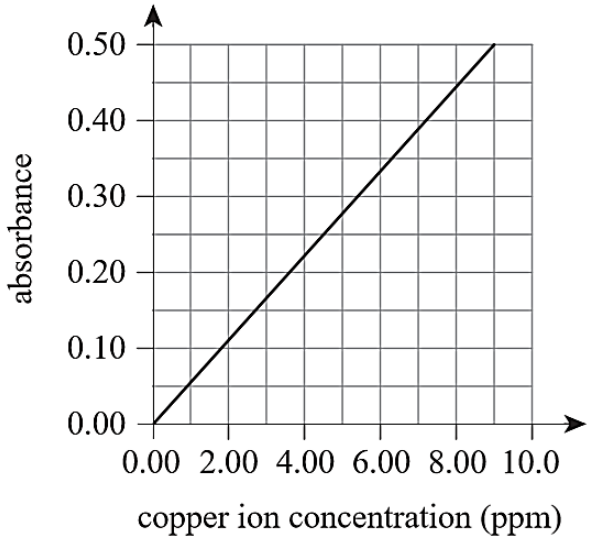
Question 36 (3 marks)

A copper mine was monitoring copper concentration in a stream. Five samples were collected from the stream and the absorbance of each sample was measured. The results are shown in the table. **3**

Sample	*Absorbance*
1	0.37
2	0.39
3	0.40
4	0.13
5	0.44

The absorbance of a series of standard $Cu(NO_3)_2$ solutions was then prepared. The measurements were graphed to obtained the standard curve shown.



Using the absorbance data and standard curve provided, determine a reliable value for the concentration of copper in the stream.

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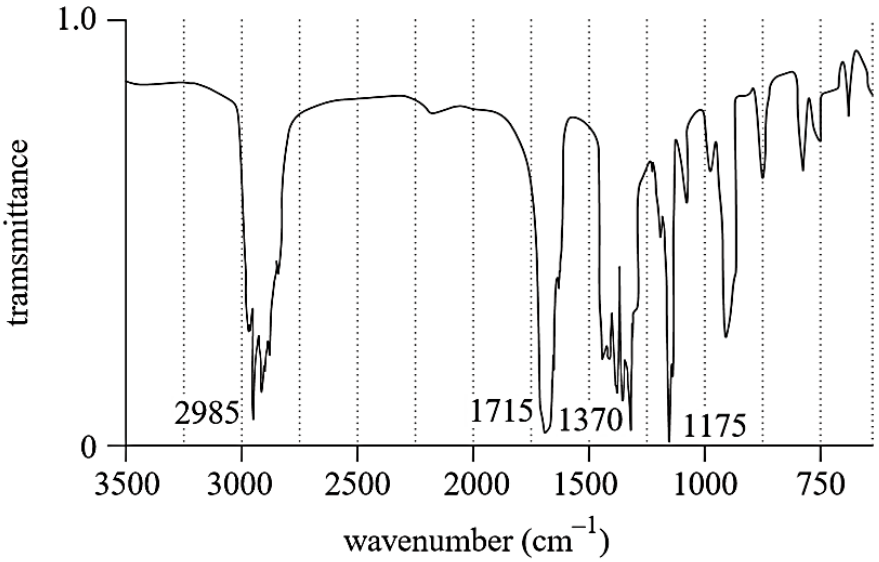
Question 37 (3 marks)

Draw a flow chart for a procedure using chemical tests to distinguish between solutions of silver nitrate, lead nitrate and sodium carbonate. **3**

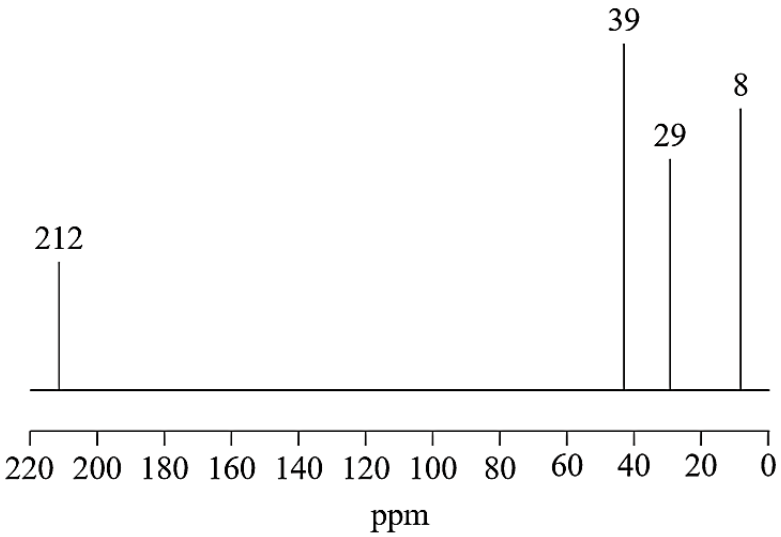
Question 38 (5 marks)

A student investigating the identity of compound *X* examined the following spectroscopic data. **5**

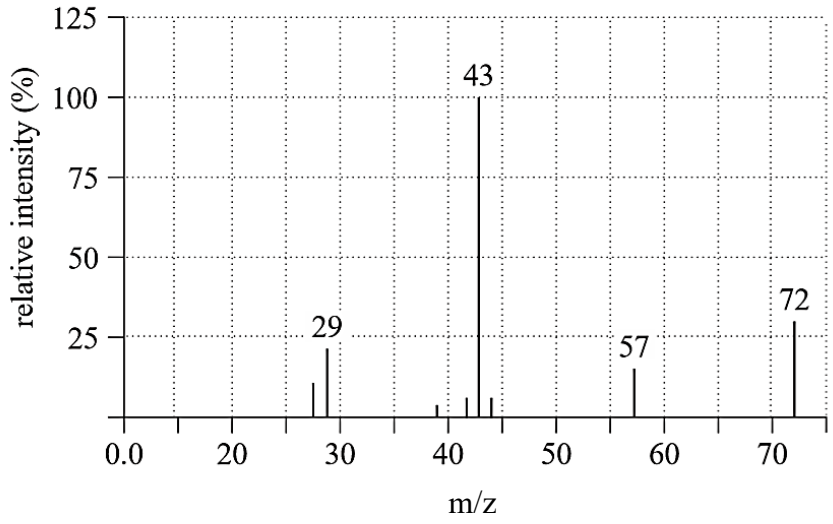
Infrared spectrum of compound *X*



^{13}C NMR spectra of compound *X*



Mass spectrum of compound *X*



Question 38 continues on page 30

Question 38 continued

After narrowing down the identity of compound *X* to one of two possibilities, the student conducted a final chemical test to identify the compound. The student tested the reaction of compound *X* with acidified potassium permanganate and no colour change was observed.

Identify compound *X*. Support your answer with an analysis of the evidence provided.

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Section 2 – Extra writing space

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If you use this space, clearly indicate which question you are answering.

SHORE

Exam Number: ☐☐☐

Year 12

Chemistry

Trial Examination – Suggested Answers and Marking Guidelines

2019

General instructions

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- Working time – 3 hours
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Total marks – 100

Section 1

20 marks

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

Section 2

80 marks

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- Allow about 2 hour and 25 minutes for this section

DO NOT REMOVE THIS PAPER FROM THE EXAMINATION ROOM

Section 1 – 20 marks
Attempt Questions 1–20
Allow about 35 minutes for this part

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

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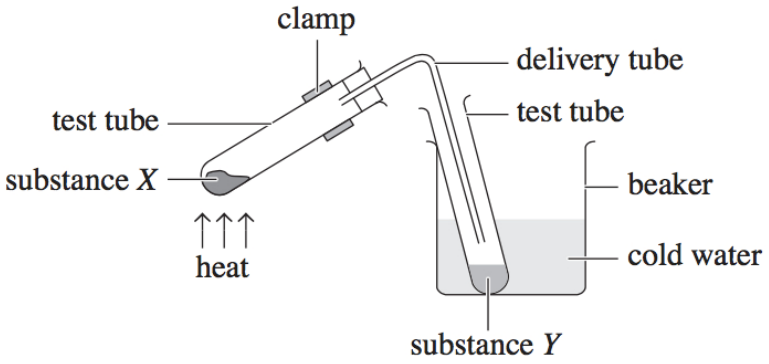
(B) An open system can transfer energy but not matter with its surroundings.
(C) A closed system can transfer energy but not matter with its surroundings.
(D) A closed system can transfer neither energy nor matter with its surroundings.

Question 1 **C**	Mod 5 Static and Dynamic Equilibrium CH12–5 Band 2
A closed system can transfer energy but not matter with its surroundings. An open system can transfer both energy and matter with its surroundings.	

2. The diagram shows hydrated cobalt(II) chloride after it has been heated and all signs of a reaction have ceased.



Which row of the table correctly shows the most likely identities of the substances *X* and *Y*?

	Substance X	*Substance Y*
(A)	water	dehydrated cobalt(II) chloride
(B)	dehydrated cobalt(II) chloride	water
(C)	dehydrated cobalt(II) chloride	chlorine
(D)	cobalt(II) oxide	water

Question 2 **B**	Mod 5 Static and Dynamic Equilibrium CH12–5 Bands 3–4
Heating hydrated cobalt(II) chloride gives dehydrated cobalt(II) chloride, *X*, and water, *Y*.	

3. Consider the equilibrium process

$$CH_2CH_2(g) + H_2(g) \rightleftharpoons CH_3CH_3(g) \qquad \triangle H = -136 \text{ kJmol}^{-1}$$

Which of the following changes would cause the magnitude of the equilibrium constant for this reaction to increase?

(A) The temperature is decreased.
(B) The pressure is decreased.
(C) The concentration of H_2 in the equilibrium mixture is increased.
(D) The concentration of CH_3CH_3 in the equilibrium mixture is increased.

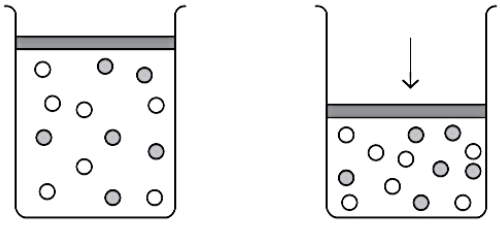
Question 3 **A**	Mod 5 Factors that Affect Equilibrium
Equilibrium constants are constant if the temperature is constant. Changing the temperature changes the equilibrium constant. Changing other variables does not change the value of the equilibrium constant.	CH12–5, CH12–12 Bands 3

4. Which of the following aqueous solutions of ionic compounds would form a precipitate when mixed?

(A) potassium chloride and sodium hydroxide
(B) magnesium sulfate and sodium chloride
(C) sodium iodide and ammonium nitrate
(D) sodium sulfate and barium nitrate

Question 4 **D**	Mod 5 Solution Equilibria
Precipitation reactions occur when (positive) cations and (negative) anions in aqueous solution combine to form an insoluble ionic solid called a precipitate. These insoluble solids will have a low solubility product (K_{sp}). Examining the solubility constants on the data sheet, the only substance with a very low solubility constant is barium sulfate ($K_{sp} = 1.08 \times 10^{-10}$), so this solution will precipitate.	CH12–6 Bands 3–4

5. The diagram shows a mixture of gases in a sealed container where the volume is decreased.



Which of the following statements most accurately describes this system?

(A) As volume increases, the gas molecules move faster.
(B) As volume decreases, the gas molecules move further before colliding.
(C) As volume decreases, the gas molecules can have more collisions.
(D) Changing the volume has no effect on the movement of molecules.

Question 5 **C**

Volume has no effect on the speed of particles. When volume is decreased the particles travel shorter distances before a collision takes place, so more collisions take place in a given time.

Mod 5 Static and Dynamic Equilibrium
CH12–6 Bands 3–4

6. The pH of an alkaline solution is 8.

Which of the following expressions could represent this solution?

(A) $[OH^-] = 10^{-8}$

(B) $-\log_{10}[H^+] = 8$

(C) $\log_{10}[OH^-] = 8$

(D) $\log_{10}[H^+] = 8$

7. Magnesium reacts with dilute hydrochloric acid to liberate hydrogen.

What is the volume of hydrogen produced at 298.15 K and 100 kPa when 1.22 g of magnesium is reacted with excess dilute acid?

(A) 1140 mL
(B) 1240 mL
(C) 2270 mL
(D) 2450 mL

Question 6 **B**

B is the only expression that corresponds to the definition $pH = -\log_{10}[H^+]$.

Mod 6 Using Brønsted–Lowry Theory
CH12–6, CH12–13 Bands 3–4

Question 7 **B**

$Mg(s) + 2HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$

$$n(\text{Mg}) = \frac{\text{mass (Mg)}}{\text{atomic mass (Mg)}} = \frac{1.22}{24.31} = 0.05019 \text{ mol}$$

$$n(H_2) = n(\text{Mg}) = 0.05019 = \frac{\text{volume } H_2}{\text{molar volume}}$$

$V(H_2) = 0.05019 \times 24.79 = 1.24 \text{ L} = 1240 \text{ mL}$

Mod 6 Properties of Acids and Bases
CH12–6, CH12–13 Band 4

8. Nitric acid completely dissociates in aqueous solutions. 1.0 mL of 10 mol L^{-1} solution was diluted to 1 L with distilled water. 100 mL of this resulting solution was then further diluted to 1 L using distilled water.

What pH is the final solution closest to?

(A) 1
(B) 2
(C) 3
(D) 4

Question 8 **C**

first dilution: 1 mL $\rightarrow$ 1000 mL ($\times$ 1000)

second dilution: 100 mL $\rightarrow$ 1000 mL ($\times$ 10)

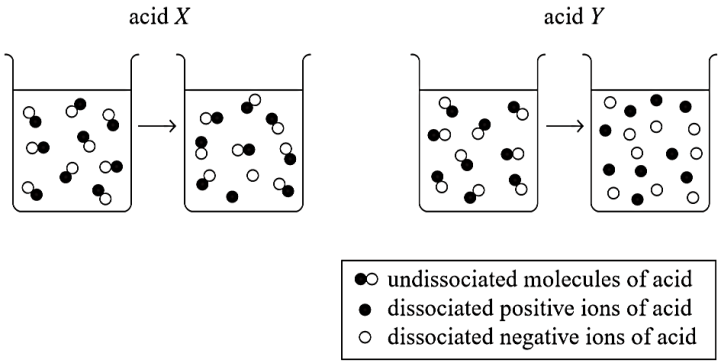
total dilutions: $1000 \times 10 = 10\,000$

$\therefore$ final $[H^+] = \frac{10}{10\,000} = 10^{-3}$ mol

$\therefore$ $pH = -\log_{10}[H^+] = -\log_{10}[10^{-3}] = 3.00$

Mod 6 Using Brønsted–Lowry Theory
CH12–6, CH12–13 Bands 4–5

9. The diagram shows the behaviour of two different acids when they are dissolved in distilled water.



Which row of the table correctly describes the two acids?

	Acid X	*Acid Y*
(A)	concentrated	dilute
(B)	dilute	concentrated
(C)	strong	weak
(D)	weak	strong

Question 9 **D**

The diagrams for both acids show nine molecules in the same volume, hence both acid solutions have the same initial concentration.

Only one of the nine molecules of acid *X* dissociates, so *X* is a weak acid. All nine molecules of acid *Y* dissociate (dissociates completely), so *Y* is a strong acid.

Note: The terms 'concentrated' and 'dilute' describe the amount of acid in the solution, NOT the degree of dissociation of the acids themselves.

Mod 6 Using Brønsted–Lowry Theory
CH12–6, CH12–13 Band 3

10. Consider the system

$$HF(aq) + H_2O(l) \rightleftharpoons F^-(aq) + H_3O^+(aq).$$

Which of the following represents a conjugate acid–base pair present in this system?

(A) $HF(aq)/F^-(aq)$
(B) $HF(aq)/H_3O^+(aq)$
(C) $HF(aq)/H_2O(l)$
(D) $F^-(aq)/H_3O^+(aq)$

Question 10 **A**

Conjugate acid–base pairs only differ by a proton (H^+).

Only the pair $HF(aq)/F^-(aq)$ meets this criterion.

Mod 6 Using Brønsted–Lowry Theory
CH12–6, CH12–13 Band 3

11. In an experiment, 4-hydroxybutanoic acid [$HO(CH_2)_3COOH$] forms a polymer containing 1000 monomer units.

Which of the following is closest to the approximate molar mass (in g mol^{-1}) of this polymer?

(A) 2.0×10^2
(B) 1.4×10^4
(C) 8.6×10^4
(D) 1.1×10^5

Question 11 **C**

The molar mass of 4-hydroxybutanoic acid, $HO(CH_2)_3COOH$, is 104.11 amu. It will form a condensation polymer according to the reaction

$$(n + 2)HO(CH_2)_3COOH \rightarrow HO(CH_2)_3CO(O(CH_2)_3CO)nO(CH_2)_3COOH + nH_2O.$$

molar mass of polymer = $(1000 \times 104.11) - (998 \times 18.106)$
= 85 986 amu

The closest approximate molar mass is 8.6×10^4 g mol^{-1}.

Mod 7 Polymers
CH12–6, CH12–13 Band 3

12. How many hydrogen atoms are there in one molecule of 2,2-dimethylbutan-1-ol?

(A) 8
(B) 10
(C) 12
(D) 14

Question 12 **D**

2,2-dimethylbutan-1-ol has the condensed structural formula of $(CH_3)_3CH_2CH_2OH$, giving a total of 14 hydrogen in each molecule.

Mod 7 Nomenclature
CH12–6, CH12–14 Bands 4–5

13. Which of the following solutions, upon mixing will produce the solution with the highest temperature change?

(A) 50mL of 0.05M HNO_3 + 100mL of 0.4M NaOH

(B) 200mL of 0.05M CH_3COOH + 100mL of 0.01M NaOH

(C) 100mL of 0.1M H_2SO_4 + 50mL of 0.4M KOH

(D) 50mL of 0.2M HCl + 100mL of 0.025 $Ba(OH)_2$

	$n(H^+)$	$n(OH^-)$
(A)	0.0025	0.04
(B)	0.01	0.001
(C)	0.02	0.02
(D)	0.01	0.005

14. What type of reaction is represented by the conversion of hexan-3-ol to hexan-3-one?

(A) addition
(B) substitution
(C) combustion
(D) oxidation

Question 14 **D**	Mod 7 Alcohols
The CHOH of hexan-3-ol is oxidised to C=O in hexan-3-one.	CH12–4, CH12–14 Band 3

15. The infrared spectrum of a pure compound showed a broad band between 3200 and 3500 cm^{-1}; a series of moderate bands at 2900, 2990 and 3200 cm^{-1}; an intense band at 1725 cm^{-1}; and numerous bands between 1640 and 750 cm^{-1}.

Which of the following compounds matches these absorbances?

(A) ethene
(B) ethanol
(C) ethyl ethanoate
(D) ethanoic acid

Question 15 **D**	Mod 8 Analysis of Organic Substances
The presence of a broad band between 3000 and 3500 cm^{-1} indicates the presence of an OH group. The strong absorbance at 1725 cm^{-1} indicates the presence of a carbonyl group (C=O). Ethanoic acid is the only option that would produce these absorbance bands.	CH12–14 Band 3

16. Which type of bonding forms between the monomers that react together to form nylon polymers?

(A) amide bonds
(B) ester bonds
(C) ionic bonds
(D) hydrogen bonds

Question 16 **A**	Mod 7 Polymers
Nylon is a polyamide and is held together by amide bonds.	CH12–14 Band 2

17. Which of the following pairs of compounds are NOT isomers?

(A) hexan-2-ol and 2,2-dimethylbutan-1-ol
(B) methyl ethanoate and propanoic acid
(C) butane and cyclobutane
(D) butan-2-one and 2-methylpropanal

Question 17 **C**	Mod 7 Nomenclature
Isomers have different structural formulae but the same molecular formula. Cyclobutane has a molecular formula of C_4H_8 while butane has a molecular formula of C_4H_{10}. Therefore these two compounds are not isomeric.	CH12–13, CH12–14 Band 2

18. How many peaks would appear in the ^{13}C NMR spectra of pentan-3-one?

(A) 2
(B) 3
(C) 4
(D) 5

Question 18 **B**	Mod 7 Analysis of Organic Substances
Pentan-3-one can be represented by the condensed formula $(CH_3CH_2)_2C{=}O$. There are only three different chemical environments in pentan-3-one, so three peaks will appear in its mass spectrum.	CH12–14 Band 3

19. A solution was prepared by dissolving a pure compound in water. The solution was subjected to a series of tests. The results are shown in the table.

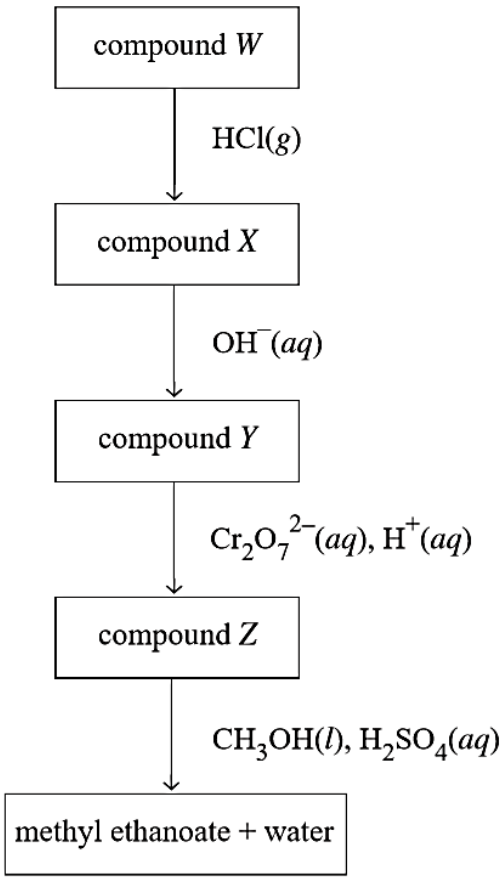
Test	*Reaction*
flame test	The flame turns lilac/pink.
adding $BaCl_2(aq)$	A precipitate forms.
adding $HCl(aq)$	Bubbles of gas form.

Which of the following compounds was dissolved into the water?

(A) calcium carbonate
(B) potassium carbonate
(C) sodium sulfate
(D) potassium sulfate

Question 19 **B**	Mod 7 Analysis of Inorganic Substances CH12–15 Bands 4–5
The lilac/pink flame test eliminates sodium compounds because they have a yellow flame test. A number of anions precipitate with barium ions. The formation of a gas with acid indicates the presence of a carbonate. Calcium carbonate is not soluble; since this compound dissolves in water, it is not calcium carbonate. This leaves potassium carbonate as the only possible answer.	

20. The flow chart shows a sequence of reactions that result in the formation of methyl ethanoate.



Which row of the table correctly identifies the compounds labelled *W*, *X*, *Y* and *Z*?

	Compound W	*Compound X*	*Compound Y*	*Compound Z*
(A)	ethane	chloroethane	ethanol	methanoic acid
(B)	methane	chloromethane	methanol	methanoic acid
(C)	ethane	chloroethane	ethanol	ethanoic acid
(D)	ethene	chloroethane	ethanol	ethanoic acid

Question 20 **D**

Methyl ethanoate results when ethanoic acid reacts with methanol, so *Z* must be ethanoic acid. This is produced by the oxidation of ethanol, so *Y* must be ethanol. Ethanol was produced by a substitution reaction involving chloroethane, so *X* must be chloroethane. Chloroethane was produced by the addition of HCl to ethene, so *W* must be ethene.

Mod 7 Analysis of Organic Substances
CH12–14, CH12–15 Bands 4–6

END OF SECTION 1

2019 Chemistry Trial Examination

Exam Number:

Section 2 – 80 marks
Attempt Questions 21–38
Allow about 2 hours and 25 minutes for this section

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 question you are answering.

Question 21 (3 marks)

Sulfur trioxide, SO_3, is made by the reaction of sulfur dioxide, SO_2, and oxygen, O_2, in the presence of a catalyst.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \quad \Delta H < 0$$

In a closed system in the presence of a catalyst, the reaction quickly reaches equilibrium at 1000 K.

A mixture of 2.00 mol of $SO_2(g)$ and 2.00 mol of $O_2(g)$ was placed in a 4.00 L evacuated, sealed vessel and kept at 100 K until equilibrium was achieved. At equilibrium, the vessel was found to contain 1.66 mol of $SO_3(g)$.

Calculate the equilibrium constant, K_{eq} for the above equilibrium at 1000 K.
Show all relevant working. **3**

21 (3 marks)
Outcomes Assessed: CH12–6, CH12–12
Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly calculates the value of the equilibrium constant (and unit)	3
• Uses correct equilibrium constant expression AND • Correctly calculates the concentrations of $SO_2(g)$ and $O_2(g)$ at equilibrium	2
• Writes the correct equilibrium constant expression	1

Sample answer
$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$

If 1.66 mol SO_3 forms, then 1.66 mol SO_2 must have reacted with 0.83 mol O_2.

Concentrations	$[SO_2]$ mol/L	$[O_2]$ mol/L	$[SO_3]$ mol/L
Initial	2.00/4 = 0.500	2.00/4 = 0.500	0
Change	–1.66/4 = – 0.415	–0.83/4 = – 0.207	+1.66/4 = 0.415
At equilibrium	0.500 – 0.415 = 0.085	0.500 – 0.207 = 0.293	0.415

$$K_{eq} = \frac{[SO_3(g)]^2}{[SO_2(g)]^2\,[O_2(g)]} = \frac{(0.415)^2}{(0.085)^2\,(0.293)} = 81.4\ M^{-1}$$

Question 22 (6 marks)

In order to demonstrate some solution chemistry, a science teacher prepares a number of practical tasks.

In the first task she mixes 25 mL of 0.1 M $BaCl_2$ with 25 mL of 0.1 M $CuSO_4$.

(a) Write a balanced chemical equation to represent this reaction, including states. **1**

22.a.

Marking Criteria	Marks
• Writes the correct balanced chemical equation including states.	**1**

$BaCl_2(aq) + CuSO_4(aq) \rightarrow BaSO_4(s) + CuCl_2(aq)$

(b) Write the net ionic equation for this reaction. **1**

22.b.

Marking Criteria	Marks
• Writes the correct net ionic equation.	**1**

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

In another demonstration the teacher makes a saturated solution.

She adds 1.52 g of $Cu(OH)_2$ (s) to 100.0 mL of water, and tells her students that the K_{sp} of $Cu(OH)_2$ is 2.2×10^{-20}.

(c) Write the dissociation equation of $Cu(OH)_2$ (s). **1**

22.c.

Marking Criteria	Marks
• Writes the correct balanced chemical equation including states.	**1**

$Cu(OH)_2(s) \leftrightarrow Cu^{2+}(aq) + 2OH^-(aq)$

(d) Use the K_{sp} value to calculate the concentration of OH^- ions in this saturated solution of $Cu(OH)_2$. **3**

22d.

Marking Criteria	Marks
• Correctly calculates $[OH^-]$.	**3**
• Response contains one error.	**2**
• Response contains one correct step.	**1**

$Cu(OH)_2(s) \leftrightarrow Cu^{2+}(aq) + 2OH^-(aq)$.

If $[Cu^{2+}] = x$ then $[OH^-] = 2x$.

$K_{sp} = [OH^-]^2[Cu^{2+}] = (2x)^2.x = 4x^3$

$2.2 \times 10^{-20} = 4x^3$

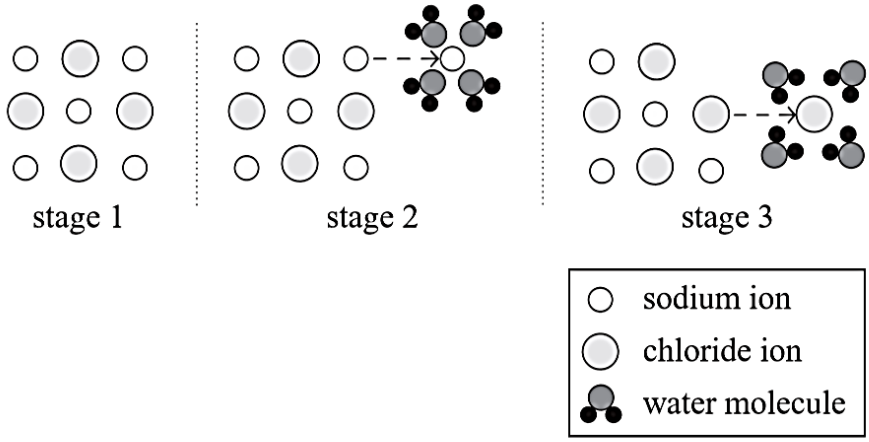
$x^3 = 5.5 \times 10^{-21}$ M

$x = 1.77 \times 10^{-7}$

Therefore $[OH^-] = 2 \times 1.77 \times 10^{-7} = 3.53 \times 10^{-7}$ M.

Question 23 (5 marks)

The diagram shows sodium chloride (common salt) dissolving in water.



(a) A saturated solution of sodium chloride in water was found to have a concentration of 359 g L^{-1}. **3**

With reference to the diagram, describe the dissociation of sodium chloride.

Question 23	
(a) The sodium chloride crystal lattice is composed of alternating positive (Na^+) and negative (Cl^-) ions. Water is polar and has both a relatively positive (δ^+) and a relatively negative (δ^-) end. Water molecules are in continuous motion and collide with the crystal lattice. The positively charged sodium ions in the crystal attract the relatively negative (δ^-) ends of the water molecules. The negatively charged chloride ions in the crystal attract the relatively positive (δ^+) ends of the water molecules. The action of the polar water molecules takes the crystal lattice apart, forming individual (solvated) sodium ions and chloride ions that are surrounded by water molecules. The opposite of this is association, where the solvated ions return to the lattice. When the rate of dissociation equals the rate of association, an equilibrium state occurs: $NaCl(s) \rightleftharpoons Na^+(aq) + Cl^-(aq)$	Mod 5 Solution Equilibria CH12–7 Bands 2–5 • Describes the dissociation. AND • Refers to the diagram. AND • Makes at least THREE additional relevant points. . . . . 3 • Describes the dissociation. AND • Refers to the diagram. AND • Makes at least TWO additional relevant points. . . . . 2 • Describes the dissociation. 1

(b) Calculate the value of K_{sp} for this system

(b) The formula is NaCl. The formula mass is 22.99 + 35.45 = 58.44 g mol^{-1}. moles of NaCl = $\frac{359}{58.44}$ = 6.14 $NaCl(s) \rightleftharpoons Na^+(aq) + Cl^-(aq)$ $K_{sp} = [Na^+][Cl^-] = [6.14][6.14] = 37.7$ (to three significant figures)	Mod 5 Solution Equilibria CH12–12 Bands 3–4 • Derives correct expression for solubility constant. AND • Calculates value accurately. . . . . 2 • Derives correct expression for solubility constant. 1

Question 24 (4 marks)

Consider the reaction

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57.20 \text{ kJ mol}^{-1}.$$

(a) Using the reaction, outline how activation energy (E_a) varies for the forward and the reverse reactions in equilibrium reactions. **2**

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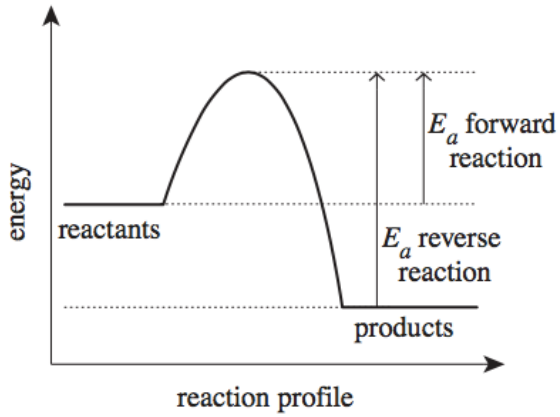
Question 24

(a) For an exothermic reaction, the activation energy of the forward reaction must be less than the activation energy of the reverse reaction. This is an exothermic reaction; hence the E_a for the forward reaction (forming dinitrogen tetroxide) is less than the E_a for the reverse reaction (forming nitrogen dioxide).



Note: A diagram is not required for full marks. It has been included for clarification.

Mod 5 Static and Dynamic Equilibrium
CH12–6, CH12–12 Bands 4–6

- Outlines forward reaction.

AND

- Outlines reverse reaction 2

- Outlines forward reaction.

OR

- Outlines reverse reaction 1

(b) How would increasing the temperature affect this reaction? Explain your answer. **2**

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(b) Increasing the temperature would drive the position of equilibrium to the left (formation of nitrogen dioxide). Le Châtelier's principle states that the addition of heat to a reaction will favour the endothermic direction of a reaction as this minimises the increase in heat content of the system when the temperature is increased.

Mod 5 Static and Dynamic Equilibrium
CH12–6, CH12–12 Bands 3–4

- Describes how increasing the temperature would affect the reaction.

AND

- Provides correct explanation 2

- Describes how increasing the temperature would affect the reaction.

OR

- Provides correct explanation 1

Question 25 (4 marks)

Carbonic acid is formed when carbon dioxide dissolves in water. Carbonic acid plays a major part in the buffering of human blood, which has a typical pH of 7.40. One way to show the ionisation of carbonic acid is

$$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq).$$

(a) Write an expression for the equilibrium constant (K_{eq}) for this reaction. **1**

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. . . . . .

(a)	$K_{eq} = \dfrac{[HCO_3^-][H^+]}{[H_2CO_3]}$	Mod 6 Qualitative Analysis CH12–5, CH12–12 Band 2 • Writes a correct expression 1

(b) Buffers play a role in many natural systems. **2**

Using human blood, or another relevant example, explain why buffers are important.

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(b)	A buffer is usually a mixture of a weak acid and its salt. Buffering resists changes in the pH of blood (or other natural systems) when acids or bases are added. It does this because added H^+ ion reacts with the weak base (and hence is removed by reaction) and added OH^- reacts with the weak acid (and hence is removed by reaction). Therefore the change in concentration of H^+ is minimised by the buffer and pH change is also minimised. Many processes of natural systems will only take place within a narrow pH range. If the pH deviates too far from the optimum, then the system will not work as well as it should. In the case of human blood, illness will occur.	Mod 6 Qualitative Analysis CH12–7, CH12–12 Bands 3–4 • Defines buffering. AND • Relates buffering to blood or other relevant natural system. AND • Makes at least ONE additional relevant point . . . . . 3 • Defines buffering. AND • Relates buffering to blood . . . . . 2 • Defines buffering. OR • Relates buffering to blood 1

(c) What is the typical hydrogen ion concentration in human blood? Show your working. **1**

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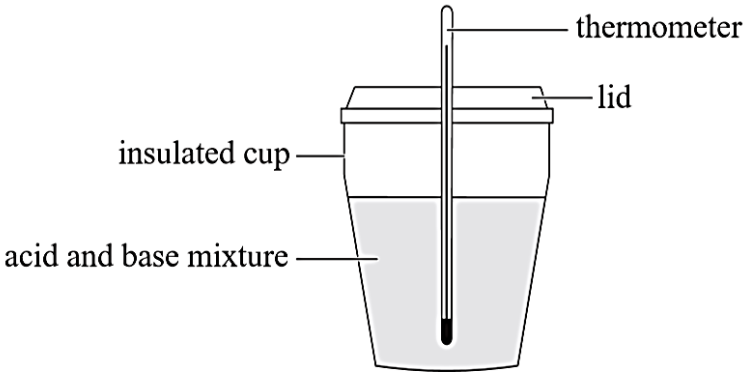
(c) $pH = -\log_{10}[H^+] \therefore [H^+] = 10^{-pH}$

$pH = 7.4 \therefore [H^+] = 10^{-7.4} = 3.98 \times 10^{-8}$ mol L^{-1}

Mod 6 Qualitative Analysis,
Mod 6 Calculating the Equilibrium Constant
CH12–6, CH12–12 Bands 3–4
- Calculates correct value AND shows working 1

Question 26 (8 marks)

The diagram shows a coffee cup calorimeter used by a student to measure the enthalpy of neutralisation of an acid–base reaction.



120.0 mL of 0.500 mol L^{-1} sodium hydroxide was added to 60.0 mL of 0.500 mol L^{-1} sulfuric acid. Both solutions were at a temperature of 24.2 °C. After mixing, the final temperature was 26.3 °C.

(a) Calculate the enthalpy change per mole of water formed in this reaction **3**

(a) $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

1 mole of sulfuric acid (a diprotic acid) reacts with 2 moles of alkali to form 2 moles of water.

$2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$

moles of water formed = moles of sodium hydroxide

$$= \frac{120}{1000} \times 0.500$$

$$= 0.0600 \text{ mol}$$

heat change $(q) = mc\Delta T$

$$= \frac{(120 + 60)}{1000} \times 4.18 \times 10^3 \times (26.3 - 24.2)$$

$$= \mathbf{0.18 \times 4.18 \times 10^3 \times 2.1 = 1.58 \text{ kJ}}$$

$$\therefore \Delta H = \frac{-q}{n(\text{water})} = \frac{-1.58 \text{ kJ}}{0.06 \text{ mol}} = -26.3 \text{ kJ mol}^{-1} \text{ (exothermic)}$$

Mod 6 Qualitative Analysis,
Mod 7 Alcohols
CH12–5, CH12–12 Band 2
- Gives balanced equation.

AND
- Performs the calculation.

AND
- Gives the correct answer. 3

- Gives balanced equation.

AND
- Performs the calculation OR gives the correct answer. 2

- Shows some understanding of the calculation. 1

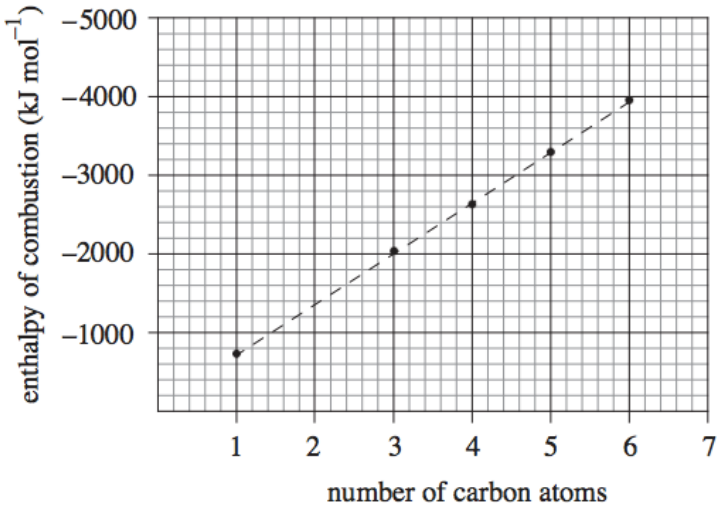
Question 26 continues on page 15

(b) The heat of combustion of a number of alcohols was measured. The results are shown in the table. **3**

Alcohol	*Enthalpy of combustion (kJ mol^{-1})*
methanol	–726
propan-1-ol	–2021
butan-1-ol	–2676
pentan-1-ol	–3331
hexan-1-ol	–3984

Using the data provided, construct a graph that shows the relationship between chain length (number of carbon atoms) and enthalpy of combustion for these alcohols.

(b)



Mod 6 Qualitative Analysis,
Mod 7 Alcohols
CH12–3, CH12–5, CH12–7 Bands 3–4

- Labels axes.

AND

- Accurately plots points.

AND

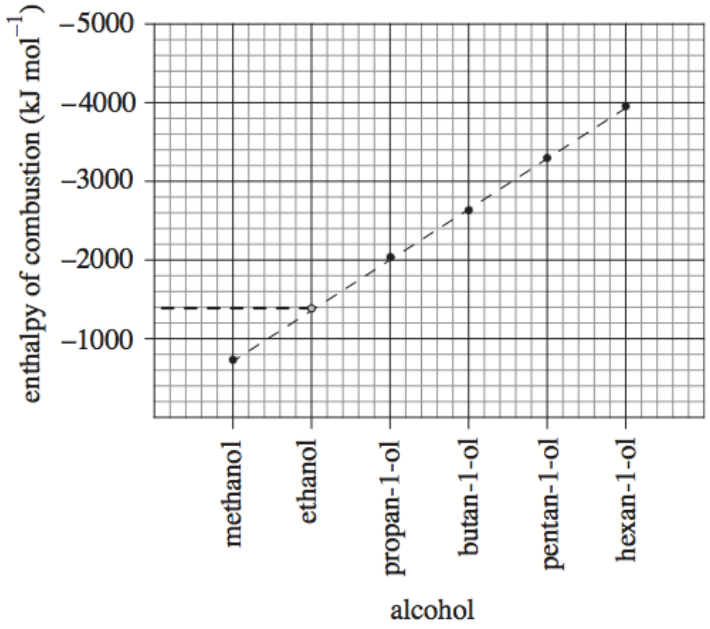
- Draws a line of best fit 3

- Any TWO of the above points 2

- Any ONE of the above points. 1

(c) Using construction lines on the graph above, predict the value of the enthalpy of combustion of ethanol in kJ per gram of ethanol. **2**

(c) The interpolated value for ethanol is shown on the graph below.



The enthalpy of combustion of ethanol is approximately -1400 kJ mol^{-1}. The molar mass of ethanol (CH_3CH_2OH) is 46.068 g mol^{-1}. The enthalpy of combustion of ethanol will equal approximately $-\frac{1400}{46.068} = -30.4$ kJ g^{-1}.

Mod 6 Quantitative Analysis
Mod 7 Alcohols
CH12–1, 2, 6, 7, 12 Bands 3–4

- Interpolates a value of between 1300 and 1400 kJ mol^{-1} as the correct molar enthalpy change from the graph.

AND

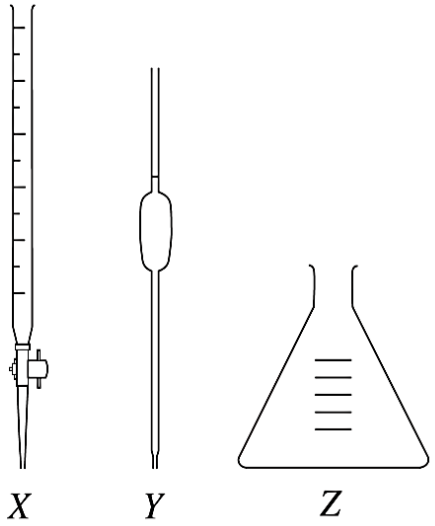
- Converts kJ mol^{-1} to kJ g^{-1} 2

- Any ONE of the above points 1

End of Question 26

Question 27 (3 marks)

The diagram shows three pieces of glassware (*X*, *Y* and *Z*) used in conventional acid–base titrations (indicator colour change). **3**



Identify each piece of equipment and outline its role in a titration.

X is a burette, *Y* is a pipette and *Z* is a conical flask. The burette's role in a titration is to deliver a variable volume of a liquid. The pipette's role in a titration is to deliver a fixed volume of a liquid. The conical flask's role in a titration is to contain the indicator and the liquids from the pipette and burette.	Mod 6 Qualitative Analysis CH12–13 Bands 2–4 • Identifies all THREE pieces of equipment. AND • Outlines the role of each . . . . . 3 • Identifies TWO pieces of equipment. AND • Outlines the role of each . . . . . 2 • Identifies ONE piece of equipment AND outlines its role. OR • Identifies TWO or more pieces of equipment 1

Question 28 (4 marks)

Various models of acids and bases have been used over time. **4**

Compare the theories of Arrhenius and Brønsted–Lowry.

In 1887, Arrhenius suggested that all aqueous solutions of acids contained an excess of hydrogen (H^+) ions and all aqueous solutions of bases (alkalis) contained an excess of hydroxide (OH^- ions). His proposal was that H^+ and OH^- ions are formed when the acid or base ionises as it dissolves in water. In 1923, Brønsted and Lowry independently proposed that an acid is a proton donor and a base is a proton acceptor. Water need not be present using their definition and a base does not have to contain a hydroxide. All Arrhenius acids will also be Brønsted–Lowry acids. Not all Brönsted–Lowry acids will be Arrhenius acids.	Mod 6 Using Brønsted–Lowry Theory CH12–7, CH12–13 Bands 2–5 • Gives details of the Arrhenius model. AND • Gives details of the Brønsted–Lowry model. AND • Makes a comparison . . . . . 3–4 • Gives details of the Arrhenius model. AND • Gives details of the Brønsted–Lowry model . . . . . 2 • Gives details of the Arrhenius model. OR • Gives details of the Brønsted–Lowry model 1

Question 29 (4 marks)

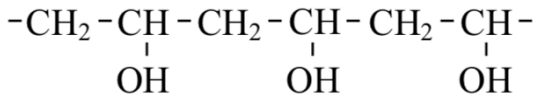
Polyvinyl alcohol is a water-soluble addition polymer used in adhesives and paints. The monomer used has the following structure:

$$CH_2 = CHOH$$

(a) Draw the structural formula for a 3-unit segment of the polymer. **1**

Marking Guidelines	Marks
• Correct structural formula	1

Sample answer



(b) Explain how bromine water can be used to distinguish between a solution of the monomer and a solution of the polymer. **2**

Marking Guidelines	Marks
• Explains how to distinguish between saturated an unsaturated hydrocarbons	2
• Fails to mention that Bromine water reacts with double bond	1

Sample answer

Bromine water is decolourised instantly by the monomer reacting with the double bond. The polymer has single bonds only and reacts very slowly or not at all.

(c) State the systematic name for the monomer used in forming polyvinylchloride. **1**

Marking Guidelines	Marks
• Correctly identifies it as chloroethene	1

Question 30 (4 marks)

In a beaker, enough sodium hydroxide of concentration 0.0288M is added to10.5mL of 0.0355M of sulfuric acid to make a total volume of 50.0mL.

(a) Write a chemical equation for the reaction **1**

$$2NaOH\ (aq) + H_2SO_4\ (aq) \rightarrow Na_2SO_4\ (aq) + 2H_2O$$

(b) Calculate the pH of the remaining mixture **3**

Marking Criteria	Marks
• Calculates the pH of the final mixture.	**3**
• Calculates the pH of the final mixture but makes one error.	**2**
• Completes one step in the calculation correctly.	**1**

$2NaOH\ (aq) + H_2SO_4\ (aq) \rightarrow Na_2SO_4\ (aq) + 2H_2O$

$n(NaOH) = cV = 0.0288 \times 0.0395 = 0.0011376$ mol
$n(H_2SO_4) = cV = 0.0355 \times 0.0105 = 0.00037275$ mol

LR: NaOH: $0.0011376/2 = 0.0005688$
H_2SO_4: $0.0037275 /1 = 0.00037275$

NaOH is in excess

$NaOH_{\text{reacting}} = 0.00037275 \times 2 = 0.0007455$ mol
$n(NaOH)_{\text{remaining}} = 0.0011376 - 0.0007455 = 0.0003921$ mol

$[OH^-]_{\text{final}} = n/V = 0.0003921/0.05 = 0.007842$ mol L^{-1}
$pOH = -\log 0.007842 = 2.106$

$pH = 11.9$

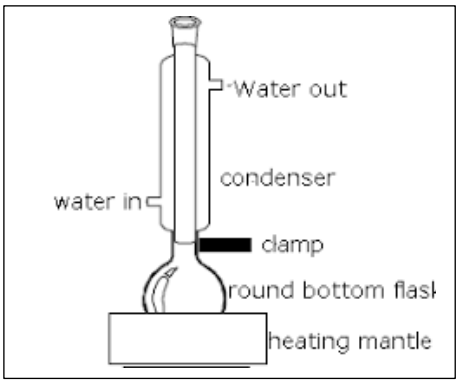
Question 31 (5 marks)

Describe and justify the process used to prepare an ester in the school laboratory.
Include a diagram and a specific safety precaution in your answer. **5**

31 (5 marks)
Outcomes Assessed: CH12–7, CH12–14
Targeted Performance Bands: 2-5

Criteria	Marks
• Describes and justifies the process used to prepare an ester thoroughly including a scientific diagram and a safety precaution	5
• Describes the reflux thoroughly and gives some justification for using the process including a scientific diagram and a safety precaution	4
• Describes some correct information about the reflux process	3
• Identifies some correct information about the reflux process	1- 2

Sample answer
Methanol, ethanoic acid and the catalyst, concentrated sulfuric acid, are placed in a flask attached to a reflux condenser. A heating mantle should be used to heat the flask (no naked flame but can reach temperatures > 100°C).



The mixture is heated for an hour, with the temperature of the heating mantle and the water flow rate through the condenser controlled to ensure that no gases escape into the laboratory. Boiling chips in the flask ensure even boiling.

Concentrated sulfuric acid acts as a catalyst. Its presence, in small quantity, provides a new pathway for the reaction. This new pathway has a lower activation energy than a non-catalysed pathway. As a result, the reaction occurs at a faster rate when the catalyst is present.

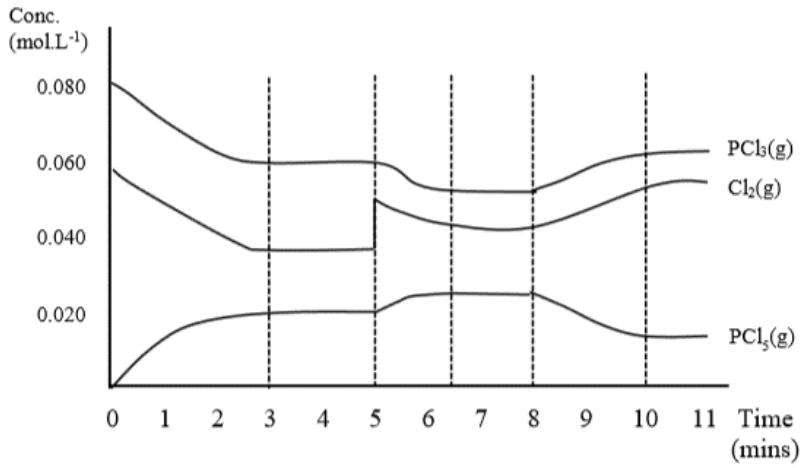
Sulfuric acid is also a dehydrating reagent. It is strongly attracted to water, which is a product of the esterification reaction. By Le Chatelier's Principle, the presence of sulfuric acid drives the reaction to the right (as esterification is an equilibrium reaction) as water is removed. Sulfuric acid can therefore increase the yield in the equilibrium reaction.
Diagram

Question 32 (4 marks)

Consider the graph below, which shows the concentration of each species in the equilibrium system:

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \quad \Delta H = -92 \text{ kJ/mol}$$

This is measured over 11 minutes, during which time various changes are imposed on the system



(a) When does the system first reach equilibrium? Justify your answer. **1**

Marking Criteria	Marks
• Identifies t = 3 minutes with a correct justification.	**1**

The system first reaches equilibrium at t = 3 minutes. This is clear from the graph because it is when the concentrations of each species in the system start to remain constant.

(b) What change was imposed at t = 5 minutes? Explain what would happen to the rates of the forward and reverse reactions immediately after this change. **3**

Marking Criteria	Marks
• Identifies that the concentration of Cl_2 was increased and explains subsequent changes in rates of both the forward and reverse reactions	**3**
• Identifies that concentration of Cl_2 was increased AND describes changes in the rate of the forward reaction OR the reverse reaction.	**2**
• Identifies that concentration of Cl_2 was increased OR describes changes in the rate of the forward reaction OR the reverse reaction.	**1**

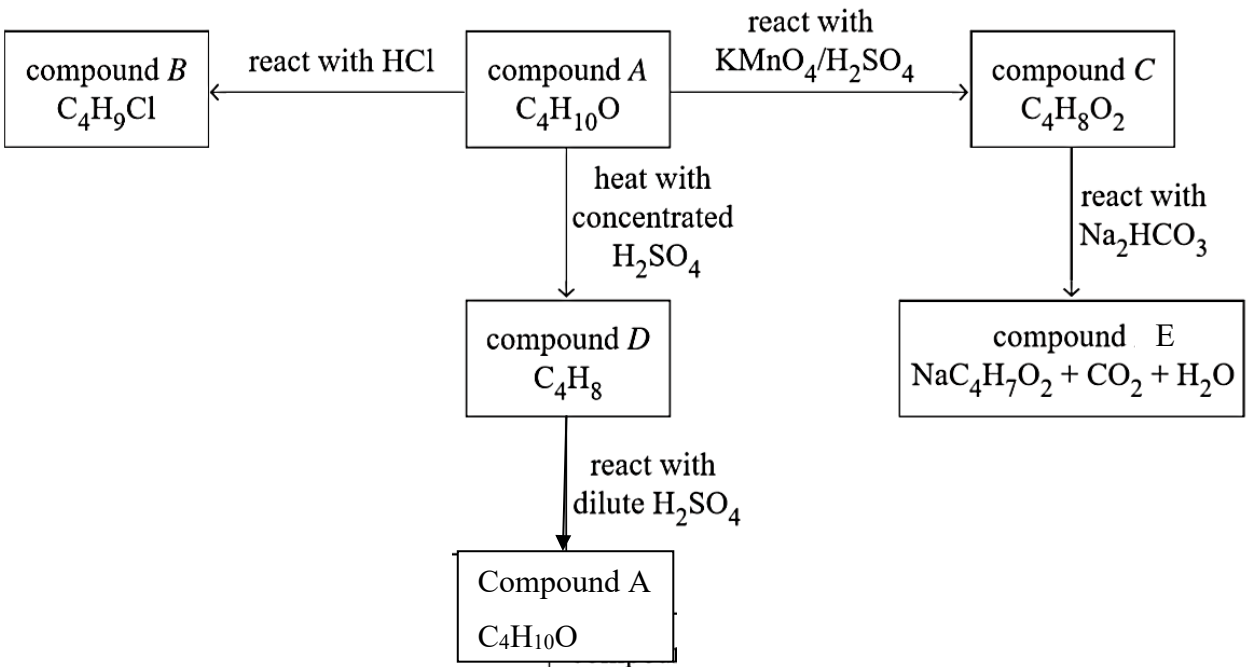
The concentration of Cl_2 gas was increased, and more collisions between the reactants will immediately increase the rate of the forward reaction (we 'see' this as a shift to the right, which is why the $[Cl_2]$ falls after the initial spike.

Since the forward reaction is favoured, reactant particles then fall, reducing the rate of the forward reaction, while the rate of the reverse speeds up, due to more collisions in products made from the initial shift. The rates equalise at 6.5 min and remain equal until 7min (i.e. system at equilibrium).

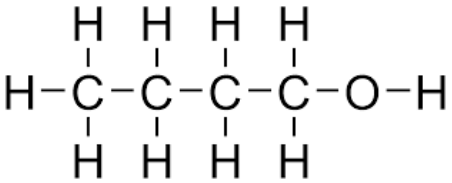
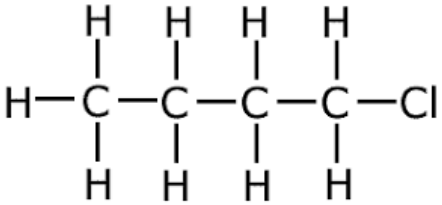
Or combined: As the rate of the forward reaction increases the reverse rate of reaction decreases.

Question 33 (5 marks)

The flow chart shows the reactions of five different organic compounds **5**

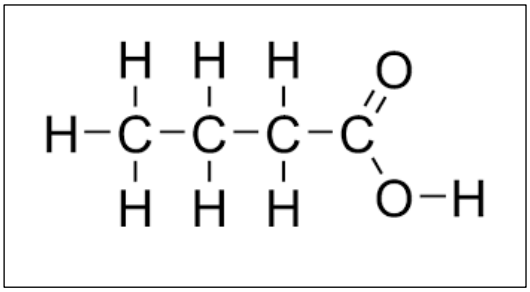
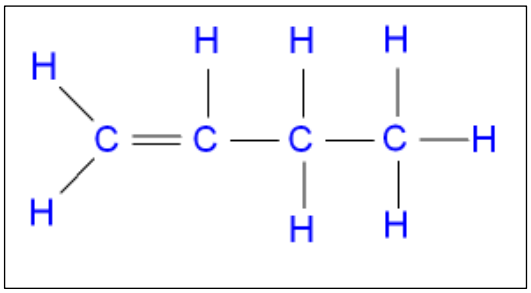
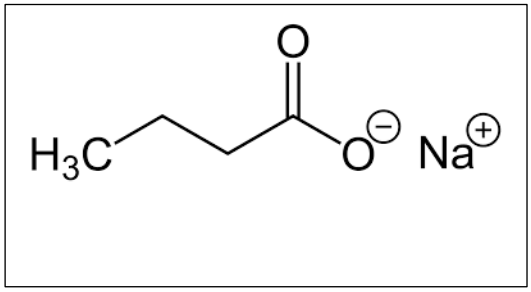


Complete the table by drawing the structural formulae for the compounds and justifying your answers with reference to the information provided.

Compound	*Structural formula*	*Justification*
Compound *A* $C_4H_{10}O$		Compound A is a primary alcohol as oxidation of compound A produces an acid, compound C.
Compound *B* C_4H_9Cl		Compound B is a chloroalkane formed by the replacement of OH with Cl in compound A

Question 33 continues on page 25

Question 33 continued

Compound	*Structural formula*	*Justification*
Compound *C* $C_4H_8O_2$		Compound C is the acid produced by the oxidation of compound A. This is confirmed by the production of CO_2 when reacted with carbonate ion.
Compound *D* C_4H_8		Compound D is the alkene produced from compound A through the dehydration reaction, which removes to OH and another H atom to form a double bond
Compound E $NaC_4H_7O_2$		Compound E is the sodium salt of the acid (compound C)

Criteria	Marks
Correctly draws structures of 5 compounds AND Provides justifications for all compounds	**5**
Correctly draws structures of 4 compounds AND Provides justifications for 4 compounds	**4**
Correctly draws structures of 3 compounds AND Provides justifications for 3 compounds	**3**
Correctly draws structures of 2 compounds AND Provides justifications for 1 compounds	**2**
Provides some relevant information	**1**

End of Question 33

Question 34 (3 marks)

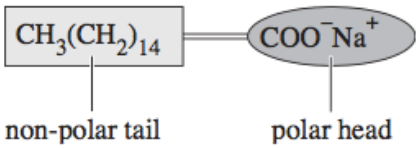
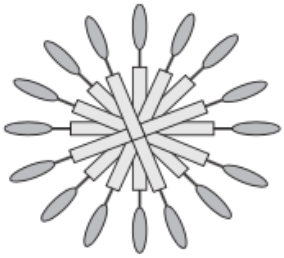
Many people wash their dirty dishes with soapy water.

(a) Describe how soapy water is able to clean dishes covered with grease or fat while fresh water is not. **2**

(a)	Water can only dissolve polar compounds like alcohols and some ionic compounds like sodium chloride. The addition of soap allows the resulting mixture to dissolve many non-polar substances. Soaps are the sodium or potassium salts of long-chain alkanoic acids. The carbon chain forms a non-polar tail and the carboxylate salt forms a polar head. Soaps form micelles in water with polar heads on the outside and non-polar tails on the inside. A micelle forms with the polar head groups on the outside of the micelle and the non-polar groups on the inside of the micelle. Fat and grease can dissolve into the non-polar interior of the micelle and form colloidal suspensions because of the polar head groups on the outside of the micelle.	Mod 7 Reactions of Organic Acids and Bases CH12–7, CH12–14 Bands 4–5 • Describes the structure of soap. AND • Explains how micelles dissolve greasy substances in water . . . . . 2 • Any ONE of the above points 1

NB: for 2 marks must include that the soap works as an emulsifier/ allows the water and oil to mix.

(b) Draw a diagram to show how soaps form micelles in a mixture of oil and water. **1**

(b)	For example, sodium stearate:  Micelle formed with polar heads on the outside: 	Mod 7 Reactions of Organic Acids and Bases CH12–7, CH12–14 Bands 4–5 • Draws a diagram to represent a micelle 1

Question 35 (7 marks)

A student was asked to determine the mass of $CaCO_3$ present in a 2.25 gram sample of chalk. The chalk reacted with 100 mL of a 1.00 M HCl solution. After the bubbling stopped, excess HCl remained. The excess HCl was titrated with 1.00 M NaOH. The average titre was 17.15 mL.

(a) Calculate the number of moles of sodium hydroxide which reacted with the excess HCl. **1**

Criteria	Marks
• Calculates the moles of sodium hydroxide which reacted with the excess HCl	1

Sample answer:

Moles of NaOH which react with excess HCl
n=C x V
n= 1.0 x 0.01715
n= 0.01715 moles of NaOH

(b) Determine the number of moles of HCl added to the chalk sample and use this to calculate the actual number of moles of calcium carbonate present in the sample. **4**

Criteria	Marks
• Calculates the moles of HCl added to the chalk sample • Determines the actual number of moles of HCl which reacted with the $CaCO_3$ • Uses a balanced equation to determine the molar ratio for each reaction • Calculates the number of moles of $CaCO_3$ in the chalk sample	4
• Three of the above correct	3
• Two of the above correct	2
• One of the above correct	1

Sample answer:

Moles of HCl added to the chalk
n= C x V
n= 1.00 x 0.100
n= 0.10
Since NaOH reacts with HCl in a 1: 1 molar ratio number of moles of excess HCl = 0.01715
Therefore number of moles of HCl which reacted with $CaCO_3$ = 0.10 - 0.01715 = 0.08285

$CaCO_{3(aq)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

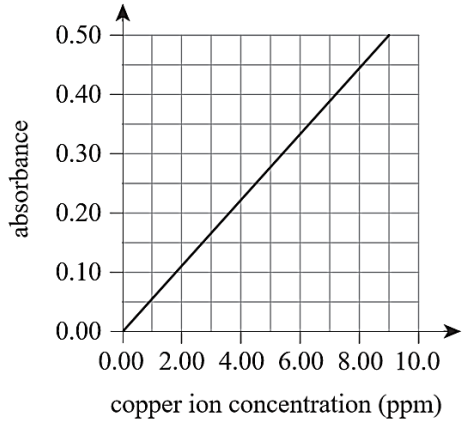
Since $CaCO_3$ reacts with HCl in a 1: 2 molar ratio
number of moles of $CaCO_3$ in chalk sample is 0.08285/2 = 0.041425

Question 36 (3 marks)

A copper mine was monitoring copper concentration in a stream. Five samples were collected from the stream and the absorbance of each sample was measured. The results are shown in the table. **3**

Sample	*Absorbance*
1	0.37
2	0.39
3	0.40
4	0.13
5	0.44

The absorbance of a series of standard $Cu(NO_3)_2$ solutions was then prepared. The measurements were graphed to obtained the standard curve shown.



Use the absorbance data and standard curve provided, determine a reliable value for the concentration of copper in the stream

Criteria	Marks
Excludes the outlier and calculates the correct average absorbance as 0.40 **AND** **Interpolates a value from the graph (showing construction lines)** **AND** **Correct final answer with units 7.00-7.40ppm**	**3**
2 of the above	**2**
1 of the above	**1**

Question 37 (3 marks)

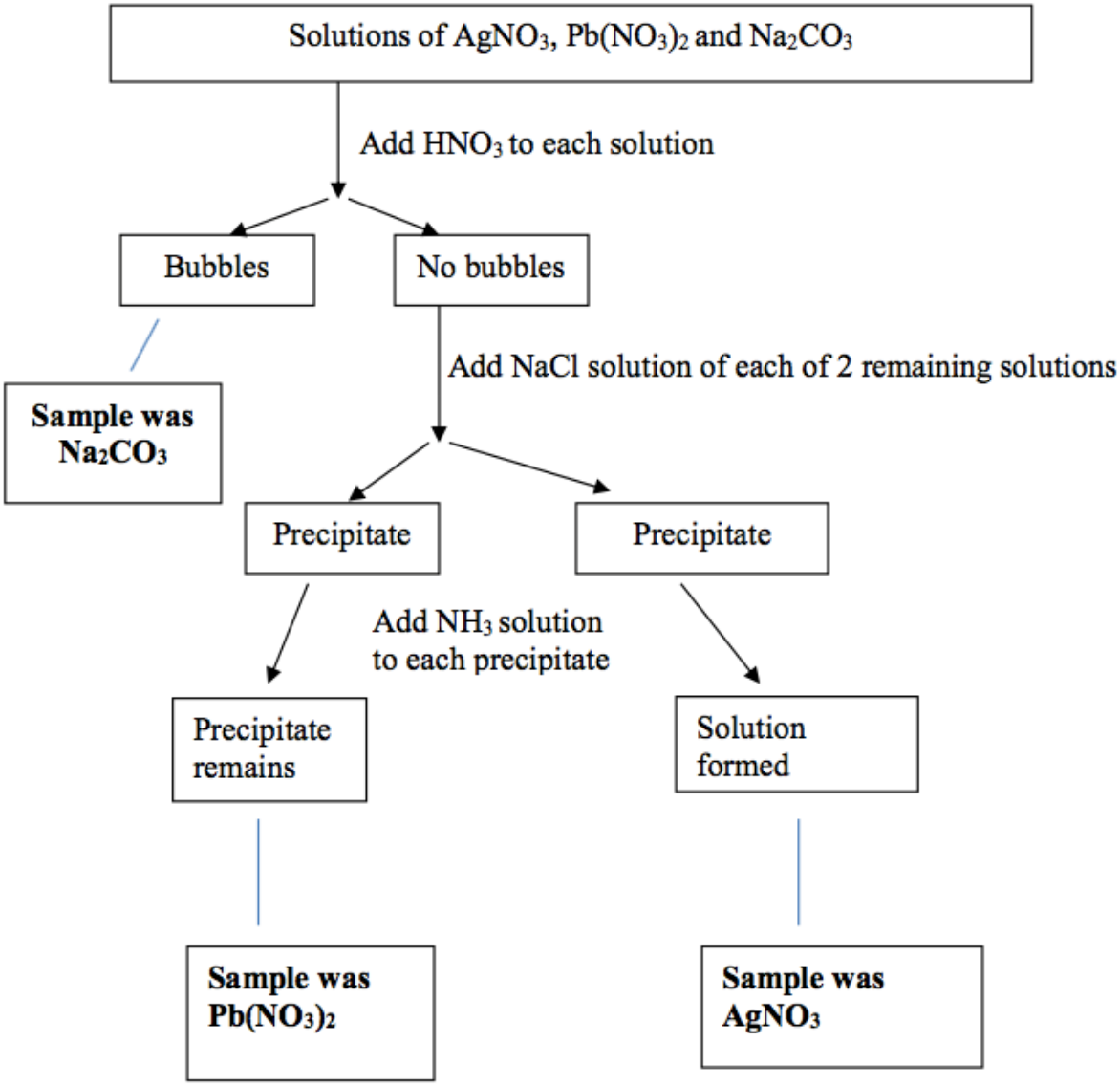
Draw a flow chart for a procedure using chemical tests to distinguish between solutions of silver nitrate, lead nitrate and sodium carbonate. **3**

37 (3 marks)
Outcomes Assessed: CH12–7, CH12–15
Targeted Performance Bands: 2-5

Criteria	Marks
• Draws a flow chart to show a correct method of identification of ALL THREE solutions	3
• Draws a flow chart to show a correct method of identification of TWO solutions	2
• Draws a flow chart to show a correct method of identification of ONE solution	1

NB a flow chart must be sequential ie use arrows

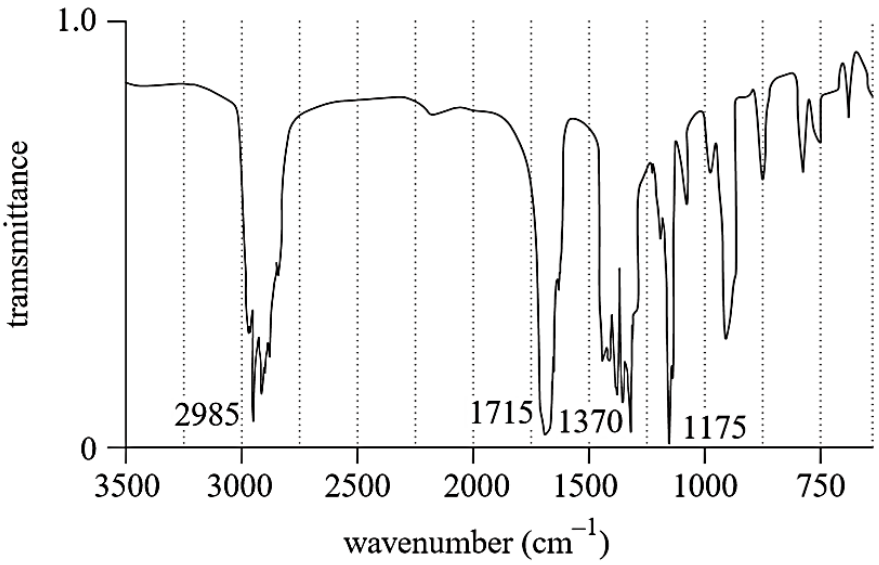
Sample answer



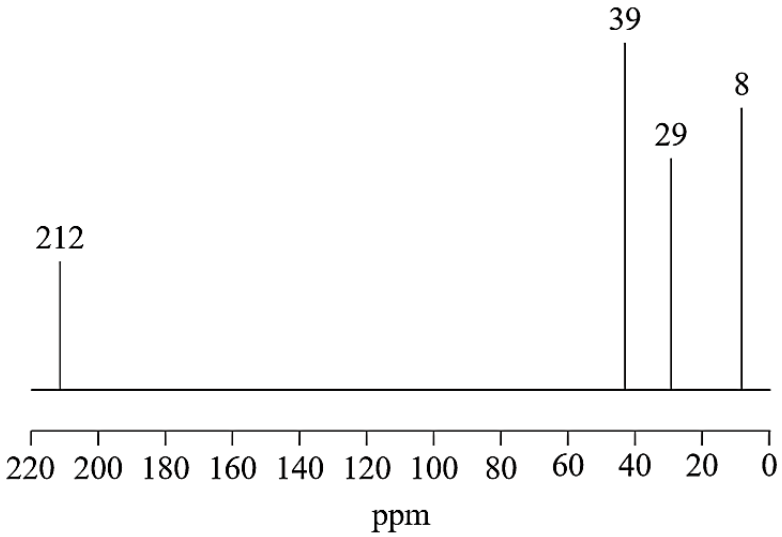
Question 38 (5 marks)

A student investigating the identity of compound *X* examined the following spectroscopic data. **5**

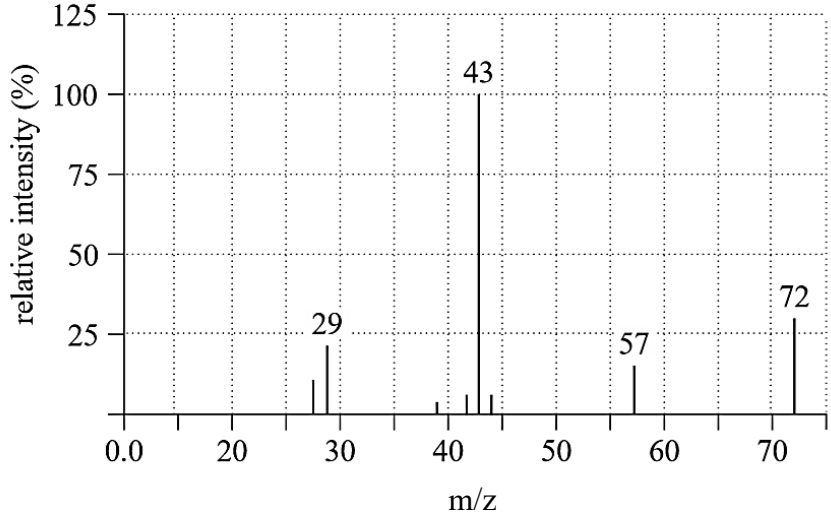
Infrared spectrum of compound *X*



^{13}C NMR spectra of compound *X*



Mass spectrum of compound *X*



Question 38 continues on next page

Question 38 continued

After narrowing down the identity of compound *X* to one of two possibilities, the student conducted a final chemical test to identify the compound. The student tested the reaction of compound *X* with acidified potassium permanganate and no colour change was observed.

Identify compound *X*. Support your answer with an analysis of the evidence provided.

The ^{13}C NMR indicates four different types of carbon. The 212 ppm peak is indicative of one carbonyl carbon, with the carbonyl being either an aldehyde or ketone. The peaks at 29 and 39 ppm are associated with carbons next to a carbonyl. The peak at 8 ppm is associated with a carbon adjacent to another unfunctionalised carbon. From this information, the compound is most likely either butanal or butanone. The highest peak in the mass spectrum occurs at an m/e of 72. If the compound contains only one oxygen, then 72 – 16 = 56 amu remains to be accounted for by carbons and hydrogens. The maximum number of CH_2 units can be determined by dividing through by 14 $\rightarrow \frac{56}{14} = 4$. From this information, the compound could be either butanone (a ketone) or butanal (an aldehyde). The peak at 57 represents a loss of 15 amu from the molecular ion and is due to a CH_3 group being cleaved from the molecular ion. The peak at 29 is almost certainly due to C_2H_5 (an ethyl group) and the peak at 57 is due to a $[CH_3CH_2CO]$ fragmentation pattern. This strongly suggests that the compound is butanone. The infrared spectrum supports that the compound is a ketone or aldehyde, as the absorbtion at 1715 cm^{-1} in the infrared spectrum is also associated with a carbonyl group. The absence of any broad band between 2500 to 3000 cm^{-1} eliminates the possibility of NH or OH-containing compounds. The peak at 2985 cm^{-1} is expected for any compound containing C–H bonds. The peaks below 1500 cm^{-1} are in the fingerprint region of the infrared and provide less information about the functional group, or groups, in the molecule. Butanal would be easily oxidised by acidified permanganate. As no colour change was observed in the final chemical test, the compound is not butanal. The identity of compound *X* is therefore butanone.	Mod 8 Analysis of Inorganic Substances CH12–4, 5, 6, 15 Bands 4–6 • Analyses all the spectra to produce evidence regarding the identity of compound *X*. AND • Determines the importance of the results of the chemical test. AND • Correctly identifies compound *X* as butanone. . . . . 5 • Analyses some spectra to produce evidence regarding the identity of compound *X*. AND • Determines the importance of the results of the chemical test. AND • Correctly identifies compound *X* as butanone . . . . . 3–4 • Correctly identifies compound *X* as butanone . . . . . 2 • Provides some relevant information 1