Name: ________________

Class: ________________

Practice exam

Year 12 Chemistry exam

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write with a black pen
- Use pencil to draw diagrams
- For questions in Section II, all relevant workings and calculations are required.
- NESA approved calculators allowed

Questions/Marks

- Total marks: 100
- Section I – 20 marks
    - Attempt Questions 1–20
    - Allow approx. 35 minutes
- Section II – 80 marks
    - Attempt Questions 21–32
    - Allow aprrox. 2 hours and 25 minutes

Section I: Multiple choice (20 marks)

Section I consists of 20 questions, each worth one mark. Each question has only one correct answer. Circle the correct answer. Attempt all questions. Marks will not be deducted for incorrect answers. You are advised to spend no more than 35 minutes on this section.

1 Nitrogen dioxide is a brown gas while dinitrogen tetroxide is a colourless gas.

$$2NO_2\ (g) \leftrightharpoons N2O_4\ (g) \qquad \Delta H \text{ is negative}$$

The two gases are mixed in a closed vessel at room temperature to produce a pale-brown colour.

If the vessel is placed in an ice bath, the gas mixture will:

A become colourless.

B turn a darker brown.

C remain a pale brown colour.

D initially become colourless, then return to a pale brown colour.

2 Nitrogen reacts with oxygen to form nitrous oxide according to the following equation:

$$N_2\ (g) + O_2\ (g) \leftrightharpoons 2NO\ (g) \qquad \Delta H = +181 \text{ kJ mol}^{-1}$$

The equilibrium constant for this reaction is 4.1×10^{-31}.

When the volume of the reaction vessel is halved:

A the forward reaction is favoured.

B the equilibrium constant increases.

C the equilibrium constant decreases.

D there is no change to the equilibrium system.

3 A 500 mL solution containing both sodium chromate (yellow) and sodium dichromate (orange) reached equilibrium according to the following equation:

$$Cr_2O_7^{2-}\ (aq)\ +\ 3H_2O\ (l)\ \leftrightharpoons\ 2CrO_4^{2-}\ (aq)\ +\ 2H_3O^+\ (aq)$$

50 mL of 2 $molL^{-1}$ NaOH was added to the system.

Which of the following describes the system when equilibrium has been re-established?

A The concentration of the dichromate increases, and the solution becomes more yellow.

B The concentration of the dichromate decreases, and the solution becomes more yellow.

C The concentration of the dichromate increases, and the solution becomes more orange.

D The concentration of the dichromate decreases, and the solution becomes more orange.

Questions 4 and 5 refer to the following reaction.

4 Consider the equilibrium:

$$N_2\ (g)\ +\ 3H_2\ (g)\ \leftrightharpoons\ 2NH_3\ (g) \qquad \Delta H < 0$$

The expression for the equilibrium constant for this reaction is:

A $\dfrac{[N_2]\,[H_2]^3}{[NH_3]^2}$

B $\dfrac{2[NH_3]}{3[H_2]\,[N_2]}$

C $\dfrac{3[H_2]\,[N_2]}{2[NH_3]}$

D $\dfrac{[NH_3]^2}{[N_2]\,[H_2]^3}$

5 Under which of the following conditions, would only 15 % of ammonia be produced?

A K > 0 and high temperature

B K > 0 and low temperature

C K < 0 and high temperature

D K < 0 and low temperature

6 Identify the pair containing a strong base and a weak base.

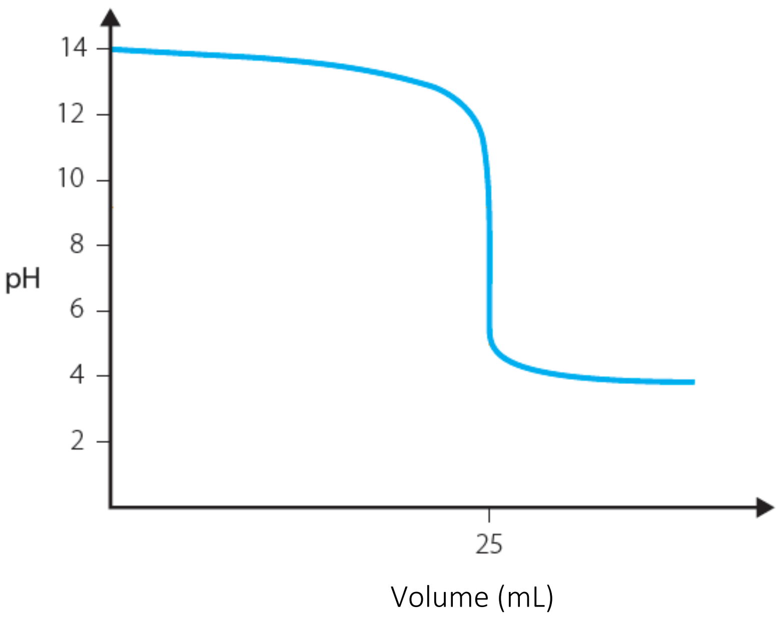
A HCl and CH_3COOH

B Na_2CO_3 and H_2SO_4

C $NaOH$ and NH_3

D KOH and $CH_3CH_2CH_2COOH$

7 A student performed a titration and graphed their results. Identify the chemical that was placed in the burette for this titration.



A 0.1 $molL^{-1}$ $Ba(OH)_2$

B 0.1 $molL^{-1}$ NH_3

C 0.1 $molL^{-1}$ CH_3COOH

D 0.1 $molL^{-1}$ HCl

8 Referring to the equation below, which of the following statements is correct?

$$CH_3COOH\ (aq) + H_2O\ (l) \leftrightharpoons CH_3COO^-\ (aq) + H3O^+\ (aq)$$

A CH_3COO^- is the conjugate base of CH_3COOH

B H_3O^+ is the conjugate base of H_2O

C H_3O^+ is the conjugate acid of CH_3COOH

D CH_3COO^- is the conjugate acid of CH_3COOH

9 A 25.0 mL sample of acetic acid has a pH of 1.30. It is mixed with 20.0 mL of 0.130 $molL^{-1}$ calcium hydroxide.

What is the pH of this mixture?

A 2.4

B 2.9

C 11.1

D 11.6

10 The pK_a of hydrofluoric acid, HF, at 25°C is 3.17.

The pH of a 0.05 $molL^{-1}$ solution of HF is closest to:

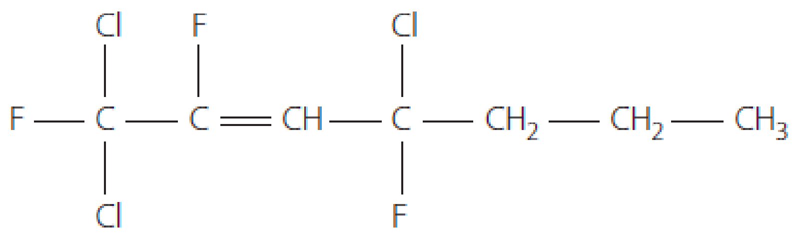
A 1

B 2

C 3

D 4

11 What is the correct IUPAC name for the following molecule?



A 1,1,4-trichloro-1,2,4-trifluoro-2-heptene

B 1,1,4-trichloro-1,2,3-trifluoro-2-hexene

C 1,1,4-trichloro-1,2,3-trifluoro-2-heptene

D 1,1,4-trichloro-1,2,4-trifluoro-2-octene

12 Which of the following will form methyl ethanoate during ester formation?

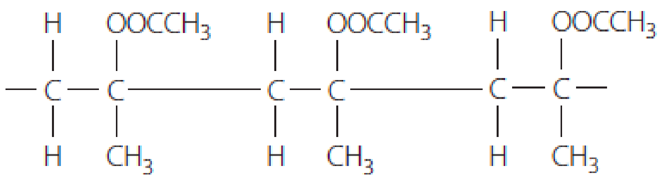
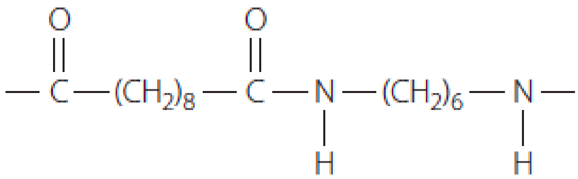
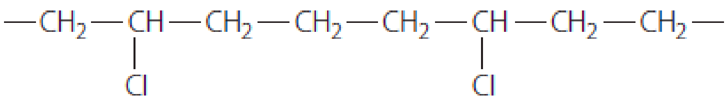
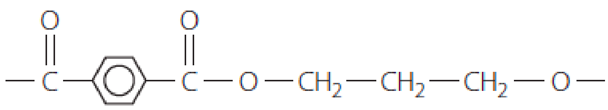
A ethanol and ethanoic acid

B ethanol and methanoic acid

C methanol and ethanoic acid

D methanol and methanoic acid

13 The table below shows some common polymers, the type of polymer they form and the number of monomers that form the polymer. Which of the following is correct?

	Polymer	Type of polymer	Number of monomers
a		condensation	2
b		condensation	1
c		addition	2
d		condensation	2

A **a**
B **b**
C **c**
D **d**

14 Ethane and ethene are molecules of similar size and mass but ethene is highly reactive, while ethane only reacts under extreme conditions. The difference in their reactivity is due to:

A their different molar masses.
B the extra hydrogen atoms in ethane.
C the different shapes of the molecules.
D the carbon–carbon double bond in ethene.

15 Which of the following is a correct statement about primary and tertiary alcohols?

A Primary alcohols can be oxidised to aldehydes while tertiary alcohols are oxidised to ketones.

B Primary alcohols can be oxidised to aldehydes while tertiary alcohols cannot be oxidised.

C Primary alcohols have one hydroxyl functional group while tertiary alcohols have three hydroxyl functional groups.

D Primary alcohols always have a hydroxyl functional group on the terminal carbon of the parent chain while tertiary alcohols have their functional group on the third carbon of the parent chain.

16 What does carbon-13 NMR use to analyse the structure of molecules?

A carbon nuclei

B hydrogen nuclei

C electronegativity of carbon

D electrons held by carbon atoms

17 What added information does infrared spectroscopy give over mass spectrometry?

A purity of substance

B size of alkyl groups

C presence or absence of functional groups

D the number of functional groups that are present

18 In an experiment, 25.00 g of a fertiliser containing ammonium sulfate was analysed by gravimetric analysis according to the following steps.

- Step 1: The sample was dissolved.
- Step 2: An excess of barium chloride was added forming a barium sulfate precipitate. Barium chloride was added until no further precipitate formed.
- Step 3: The barium sulfate precipitate formed was filtered, dried and weighed. A mass of 16.27 g was recorded.

What is the percentage of sulfate in the fertiliser?

A 6.70%

B 26.80%

C 32.54%

D 65.08%

19 The following tests were performed on unknown cation solutions P, Q and R.

- Test 1: Each of the solutions P, Q and R were added to a 0.10 mol L^{-1} solution of sodium sulfate. P and R formed a white precipitate. Q did not precipitate.
- Test 2: Each of the solutions P, Q and R were added to a 0.10 mol L^{-1} solution of sodium chloride. Q formed a white precipitate. P and R did not precipitate.
- Test 3: Each of the solutions P, Q and R were added to a 0.10 mol L^{-1} solution of sodium hydroxide. Q formed a brown precipitate, R formed a white precipitate. P did not precipitate.

Which of the following correctly identifies P, Q and R?

	P	Q	R
a	Ba^{2+}	Pb^{2+}	Cu^{2+}
b	Ba^{2+}	Ag^{+}	Ca^{2+}
c	Mg^{2+}	Ag^{+}	Ca^{2+}
d	Mg^{2+}	$Pb2^{+}$	Cu^{2+}

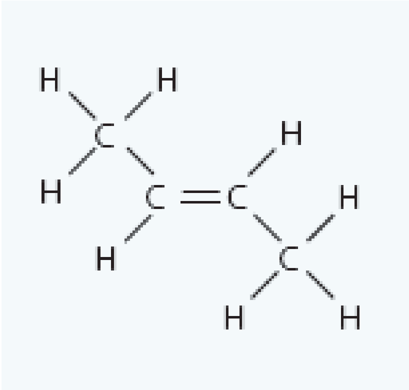
A **a**

B **b**

C **c**

D **d**

20 Carbon-13 NMR is used to analyse organic molecules like the one shown below.



Which of the following correctly identifies the number of carbon environments and the chemical shift in the molecule above?

	Carbon environments	Chemical Shift
a	2	5–40 and 90–150
b	2	20–50 and 90–150
c	3	5–40, 20-50 and 90–150
d	3	5–40 and 160–185

A **a**

B **b**

C **c**

D **d**

Section II: Answer booklet (80 Marks)

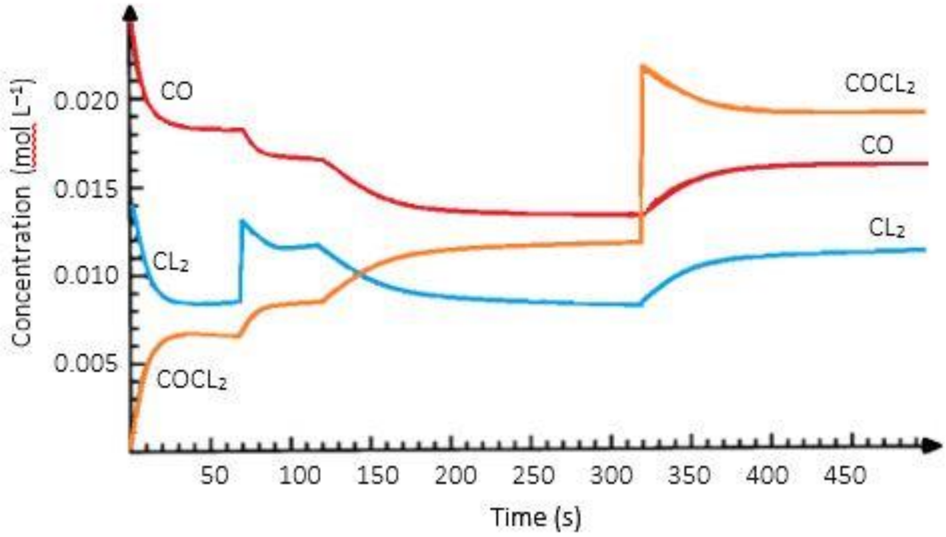
Section II consists of 11 questions. Answer the questions in the space provided. Ensure all workings and calculations are shown. You are advised to spend no more than 2 hours and 25 minutes on this section.

Question 21 (5 marks)

During this course, you modelled dynamic equilibrium. Evaluate the effectiveness of your model in consideration of the key features of equilibrium.

Question 22 (10 marks)

The decomposition of phosgene, $COCl_2$, is an endothermic reaction.



a Explain the changes that are affecting the system from 0 s to 500 s.

6

b Calculate the equilibrium constant for the reaction shown in the graph above at times 50 s and 250 s and justify the difference between these two values.

4

Question 23 (5 marks)

Compare, both qualitatively and quantitatively, how the solubility of silver phosphate, at 25°C, changes when placed in 0.100 mol L^{-1} silver nitrate compared to its solubility in water.

Question 24 (4 marks)

List the following 0.1 mol L^{-1} solutions in order of increasing pH.

$$CH_3COOH,\ NaOH,\ HCl,\ CH_3COONa,\ H_2SO_4$$

Justify your answer, including the use of chemical equations.

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

Question 25 (7 marks)

Understanding acids and bases helps to understand the human body, environmental issues and industrial processes.

a Define the term ‘buffer’.

1

b $H_2PO_4^-$ / HPO_4^{2-} is a buffer in living cells. Use this example to explain the importance of buffers. Include a chemical equation in your answer.

3

c Using two examples, describe the use of acids and / or bases in everyday life and / or industrial processes.

3

Question 26 (9 marks)

A student was asked to determine the concentration of acetic acid in white vinegar.

The student decided to use the following procedure.

- Weigh out 2.742 g of anhydrous sodium carbonate and make up to 250 mL in a volumetric flask.
- Titrate the sodium carbonate solution with 25.00 mL hydrochloric acid. The average titre used was 11.30 mL.
- Titrate the hydrochloric acid with sodium hydroxide. 25.00 mL of hydrochloric acid was used and the average titre of sodium hydroxide was 21.10 mL.
- The following day, the student diluted the white vinegar by pipetting 25.00 mL of white vinegar into a 250 mL volumetric flask and filling with distilled water.
- 25.00 mL of the standardised sodium hydroxide solution was titrated with the diluted white vinegar. The student recorded the following results:

Titre	Volume (mL)
#1	30.20
#2	30.15
#3	30.85
#4	30.25

Calculate the concentration of acetic acid in white vinegar and assess the validity of the student's result.

Question 27 (9 marks)

A student is given samples of three colourless organic liquids without labels. It is known that the liquids are propene, 2-propanol and propanoic acid.

Outline the experimental process that the student could use to identify **each** of the three liquids. Include a risk assessment, details of chemicals used, and any special conditions required. Justify, using equations, why each test would be performed.

Question 28 (6 marks)

The intermolecular bonding that forms in alkanes, alcohols and carboxylic acids determines physical properties of the substances.

a Identify the type of intermolecular bonds that form between alkane molecules. **1**

b Compare the strength of the intermolecular bonding between alkane and alcohol molecules. **2**

c Explain, using a diagram, why the boiling points of carboxylic acids and alcohols of similar size are different. **3**

Question 29 (5 marks)

Coral reefs have been significantly impacted by changes in water temperature and pH over the last 10–15 years. A decrease in pH causes coral bleaching and eventual coral death. The following equations show the interaction of carbon dioxide with water.

$$CO_2(g) \rightleftharpoons CO_2\,(aq)$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3\,(aq)$$

$$H_2CO_3\,(aq) + H_2O\,(l) \rightleftharpoons HCO_3^-\,(aq) + H_3O^+\,(aq)$$

Assess the impact of the combustion of fossil fuels on coral reefs.

Question 30 (7 marks)

Nitric acid is made industrially using the Ostwald process, which uses the sequence of chemical reactions shown below.

1 $4NH_3\,(g) + 5O_2\,(g) \rightarrow 4NO\,(g) + 6H_2O\,(g)$

2 $2NO\,(g) + O_2\,(g) \rightleftharpoons 2NO_2\,(g)$

3 $3NO_2\,(g) + H_2O\,(l) \rightarrow 2HNO_3\,(aq) + NO\,(g)$

a Calculate the yield of nitric acid (in kg) you would expect if the process started with 150 kg of ammonia and the process is only 65% efficient due to factors including the equilibrium reaction in step 2.

3

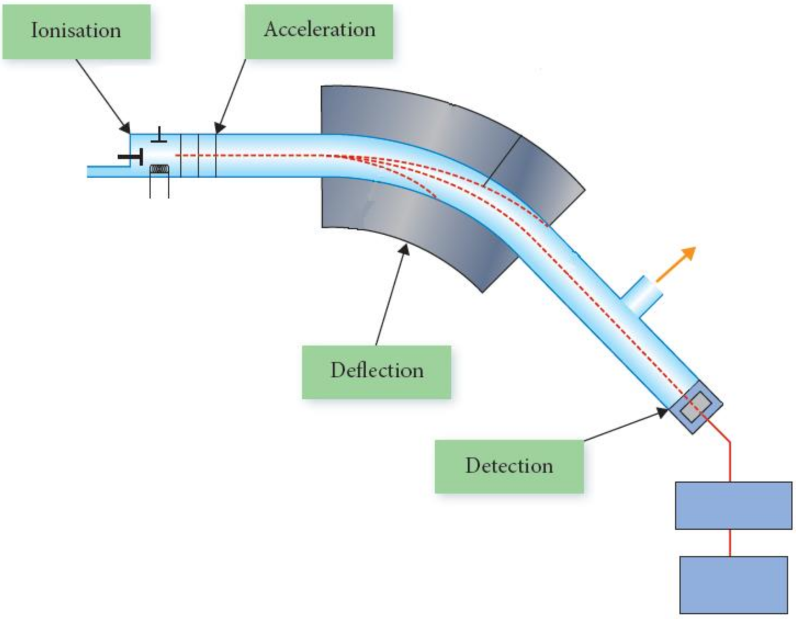
b The exothermic reaction shown in step 2 produces nitrogen dioxide.

Analyse the temperature and pressure conditions that would favour the production of nitrogen dioxide.

4

Question 31 (4 marks)

Explain, using the diagram below, how a mass spectrum could be produced to analyse a sample of ethanoic acid.



Question 32 (9 marks)

A sample of fish was analysed for the presence of mercury using atomic absorption spectroscopy. Samples of known mercury concentrations were measured. These results are shown below.

Mercury concentration (ppm)	Absorbance
2.0	0.25
4.0	0.40
6.0	0.56
8.0	0.71
10.0	0.84

a On the grid below, construct a calibration curve of this data.

3

b Assess the accuracy of the data collected.

3

c The fish sample was analysed using the same process as the known concentration samples; an absorbance reading of 0.64 was recorded.

Calculate the concentration of mercury in the fish in mol L^{-1}.

3

Year 12 Chemistry in Focus12 1st ed. exam answers

Section I: Multiple choice

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

Section II: Short answer 80 marks

Question 21 (5 marks)

Marking guidelines

Marking Criteria	Mark
• Describes a model for dynamic equilibrium • Evaluates all parts of the model for their effectiveness in modelling equilibrium	5
• Describes a model for dynamic equilibrium • Evaluates some parts of the model for their effectiveness in modelling equilibrium	4
• Describes a model for dynamic equilibrium	3
• Describes most aspects of a model for dynamic equilibrium	2
• Outlines a model for dynamic equilibrium	1

Sample answer

In an experiment, 100 mL of water was placed in measuring cylinder A (reactant), while measuring cylinder B began empty (product). One inverted pipette was placed in measuring cylinder A until no further water entered the pipette; a thumb was placed over the top of the pipette and the water was transferred to measuring cylinder B (forward reaction). The other inverted pipette was then placed into measuring cylinder B until no further water entered the pipette; a thumb was placed over the top of the pipette and the water was transferred to measuring cylinder A (reverse reaction). Volumes in each measuring cylinder were recorded. This represented one cycle of the model. The cycle was repeated until the volume of water in each measuring cylinder remained constant for five consecutive cycles, i.e. equilibrium was reached.

This model was very effective in modelling dynamic equilibrium since it showed that the rates of the forward and reverse reactions were not the same in the initial stages of the experiment, but had changed throughout the experiment until the rates became the same; hence, the volumes in each of the cylinders did not change. The experiment could be repeated starting with 70 ml in one cylinder and 30 mL in the other cylinder to show that regardless of the starting point, the rates adjusted until they reached the same end-point (volumes in each measuring cylinder were the same as the previous experiment). Two pipettes could be used for each of the forward and reverse reactions to show that the rate could be increased so the system reached equilibrium quicker but again, the same volumes were reached in each of the cylinders as in the first experiment.

Different pipettes could be used to represent different reactions; hence, different endpoints were reached. This model is effective in helping to visualise that:

- changing rates of reaction throughout the experiment until equilibrium is reached
- the rates of the forward and reverse reaction were the same when equilibrium is reached
- different reactions have different ratios of reactants and products at equilibrium.

Question 22 (10 marks)

Part a marking guidelines

Marking Criteria	Mark
• Includes an equation for the reaction • Provides specific information about the changes made and the times at which the changes were made. • Uses Le Chatelier's Principle to explain the three changes made to the system	5–6
• Includes an equation for the reaction • Provides some information about the changes made and the times at which the changes were made. • Uses Le Chatelier's Principle to explain two changes made to the system	3–4
• Identifies the three changes made to the system • OR • Describes one change to the system and its effect on the system	1–2

Sample answer

Initially, there was only [CO] = 0.025 $molL^{-1}$, [Cl_2] = 0.015 $molL^{-1}$. Since decomposition of $COCl_2$ is endothermic, the reaction represented by the diagram can be written as:

$$CO\ (g) + Cl_2\ (g) \leftrightharpoons COCl_2\ (g) \quad \Delta H < 0$$

The system reached equilibrium at 30 seconds and remained there for another 40 seconds. At 70 seconds, Cl_2 was added to the system and its concentration increased from 0.008 $molL^{-1}$ to 0.0135 $molL^{-1}$; hence, the system adjusted to minimise this sudden increase in Cl_2 by favouring the forward reaction to decrease the [Cl_2], and the [CO] also decreased while the [$COCl_2$] increased.

Equilibrium was re-established at 90 s. At 120 s, the [CO] and [Cl_2] decreased while the [$COCl_2$] increased, which indicated that the temperature of the system had been decreased since the forward reaction was favoured to minimise the change, favouring the reaction that produced more heat. Equilibrium was re-established at 210 s. At 320 s, there was a sudden increase in the [$COCl_2$] from 0.0115 $molL^{-1}$ to 0.022 $molL^{-1}$; hence, the system adjusted to minimise this sudden increase in $COCl_2$ by favouring the reverse reaction to decrease the [$COCl_2$], and the [Cl_2] and [CO] were both increased. Equilibrium was re-established again at 400 s. No further changes were made to the system.

Part b marking guidelines

Marking Criteria	Mark
• Provides equilibrium expression • Uses appropriate data for each calculation • Identifies that equilibrium constant at 250 s is greater than the equilibrium constant at 50 s. • Relates the greater equilibrium constant at 250 s to the greater proportion of products due to the lower temperature of the system.	4
• Provides equilibrium expression • Uses appropriate data for each calculation • Identifies that equilibrium constant at 250 s is greater than the equilibrium constant at 50 s.	3
• Provides equilibrium expression • Uses appropriate data for each calculation	2
• Provides equilibrium expression	1

Sample answer

At t = 50 s: [CO] = 0.018 molL^{-1}, [Cl_2] = 0.008 molL^{-1}, [$COCl_2$] = 0.007 molL^{-1}.

$$K = \frac{[COCl_2]}{[CO][Cl_2]} = \frac{0.007}{0.018 \times 0.008} = 49$$

At t = 250 s: [CO] = 0.0135 molL^{-1}, [Cl_2] = 0.0085 molL^{-1}, [$COCl_2$] = 0.0115 molL^{-1}.

$$K = \frac{[COCl_2]}{[CO][Cl_2]} = \frac{0.0115}{0.0135 \times 0.0085} = 100$$

The equilibrium constant at 250 s is greater than the equilibrium constant at 50 s. This occurred because the temperature decreased at 120 s, so the system minimised the change by favouring the forward reaction, which increased the concentration of the products, $COCl_2$, while decreasing the concentration of the reactants, CO and Cl_2; hence, the numerator in the equilibrium expression increased, while the denominator decreased, and the K value increased.

Question 23 (5 marks)

Marking guidelines

Marking Criteria	Mark
• Uses Le Chatelier's Principle to describe the effect on the solubility of Ag_3PO_4 in water and 0.100 $molL^{-1}$ silver nitrate • Provides equilibrium expression • Provides correct algebraic expression for K_{sp}, in terms of *s* • Calculates the solubility of Ag_3PO_4 in water • Calculates the solubility of in 0.100 $molL^{-1}$ silver nitrate • Describes quantitatively the effect on the solubility of Ag_3PO_4 in water and 0.100 $molL^{-1}$ silver nitrate	5
• Uses Le Chatelier's Principle to describe the effect on the solubility of Ag_3PO_4 in water and 0.100 $molL^{-1}$ silver nitrate • Provides equilibrium expression • Provides correct algebraic expression for K_{sp}, in terms of *s* • Calculates solubility of Ag_3PO_4 in water	4
• Uses Le Chatelier's Principle to describe the effect on the solubility of Ag_3PO_4 in water and 0.100 $molL^{-1}$ silver nitrate • Provides equilibrium expression • Provides correct algebraic expression for K_{sp}, in terms of *s*	3
• Uses Le Chatelier's Principle to describe the effect on the solubility of Ag_3PO_4 in water and 0.100 $molL^{-1}$ silver nitrate • Provides equilibrium expression	2
• Uses Le Chatelier's Principle to describe the effect on the solubility of Ag_3PO_4 in water and 0.100 $molL^{-1}$ silver nitrate OR Provides equilibrium expression	1

Sample answer

$Ag_3PO_4\ (s) \leftrightharpoons 3Ag^+\ (aq) + PO_4^{3-}\ (aq)$

When silver nitrate is added to the system, this causes the $[Ag^+]$ to increase. According to Le Chatelier's Principle, the system will adjust to minimise the change by favouring the reaction which decreases the $[Ag^+]$, hence the reverse reaction is favoured and the solubility of Ag_3PO_4 decreases.

In water: $K_{sp} = 8.89 \times 10^{-17}$ Let $[PO_4^{3-}] = s$, therefore $[Ag^+] = 3s$

$K_{sp} = [Ag^+]^3 \times [PO_4^{3-}]$

$8.89 \times 10^{-17} = [3s]^3 \times [s]$

$8.89 \times 10^{-17} = 27s^4$

$s^4 = \frac{8.89 \times 10^{-17}}{27} = 3.29 \times 10^{-18}\ molL^{-1}$

$s = \sqrt[4]{3.29 \times 10^{-18}} = 4.26 \times 10^{-5}\ molL^{-1}$

Hence, solubility of Ag_3PO_4 in water is 4.26×10^{-5} $molL^{-1}$.

In 0.100 $molL^{-1}$ silver nitrate:

$[PO_4^{3-}] = s\ molL^{-1}$, $[Ag^+] = 0.100 + 3s \approx 0.100\ molL^{-1}$, since $s << 0.100$

$K_{sp} = 8.89 \times 10^{-17} = [Ag^+]^3 \times [PO_4^{3-}] = 0.100^3 \times s$

$s = \frac{8.89 \times 10^{-17}}{0.100^3} = 8.89 \times 10^{-14}\ molL^{-1}$

Hence, solubility of Ag_3PO_4 in 0.100 $molL^{-1}$ silver nitrate is 8.89×10^{-14} $molL^{-1}$.

$\frac{4.26 \times 10^{-5}}{8.89 \times 10^{-14}} = 479 \times 10^6$

Therefore, the solubility of Ag_3PO_4 is about 479 million times less in 0.100 $molL^{-1}$ silver nitrate than it is in water.

Question 24 (4 marks)

Marking guidelines

Marking Criteria	Mark
• Lists the solutions in order of increasing pH • Justifies the order • Includes a relevant chemical equation for each solution	4
• Lists the solutions in order of increasing pH • Justifies the order • Includes some relevant chemical equations	3
• Lists the solutions in order of increasing pH OR • Lists some of the solutions in order of increasing pH AND • Includes at least one relevant chemical equation	2
• Lists the solutions in order of increasing pH OR • Includes a relevant chemical equation	1

Sample answer

Increasing pH means listing the solutions from most acidic to most basic: H_2SO_4, HCl, CH_3COOH, CH_3COONa, NaOH. All solutions have a concentration of 0.1 $molL^{-1}$; however, the $[H_3O^+]$ varies. pH is dependent on the $[H_3O^+]$, not the [solute].

Sulfuric acid is a strong acid and it is also diprotic.

$H_2SO_4\ (aq)\ +\ 2H_2O\ (l)\ \rightarrow\ SO_4^{2-}\ (aq)\ +\ 2H_3O^+\ (aq)$; therefore, it has the greatest $[H_3O^+]$ and hence the lowest pH.

Hydrochloric acid is a strong acid as well and hence it completely ionises; however, it is only monoprotic.

$HCl\ (aq)\ +\ H_2O\ (l)\ \rightarrow\ Cl^-\ (aq)\ +\ H_3O^+\ (aq)$; therefore, it also has a high $[H_3O^+]$, but not as high as for H_2SO_4, hence it has the second lowest pH.

Acetic acid is monoprotic like HCl, but it is a weak acid and it only partially ionises so the $[H_3O^+]$ is less for CH_3COOH than for HCl; therefore, it has a higher pH than HCl.

$$CH_3COOH\ (aq)\ +\ H_2O\ (l)\ \leftrightharpoons\ CH_3COO^-\ (aq)\ +\ H_3O^+\ (aq)$$

CH_3COONa is a salt. The acetate acts as a proton acceptor when in aqueous solution.

$CH_3COO^-\ (aq)\ +\ +\ H_2O\ (l)\ \leftrightharpoons\ CH_3COOH\ (aq)\ +\ OH^-\ (aq)$ Since OH^- are produced, this solution has a higher pH than the acids mentioned earlier. It is a basic salt.

Finally, NaOH is a strong base and completely ionises in solution to form OH^- and hence, it has the highest pH of all of the solutions.

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

Question 25 (7 marks)

Part a marking guidelines

Marking Criteria	Mark
• Defines the term 'buffer'	1

Sample answer

A buffer is a solution containing equal numbers of moles of a weak acid and its conjugate base that can resist a change in pH when an acid or base is added to it.

Part b marking guidelines

Marking Criteria	Mark
• Includes a relevant balanced chemical equation • Uses the equation to explain the effect of adding an acid to the system • Uses the equation to explain the effect of adding a base to the system	3
• Includes a relevant balanced chemical equation AND EITHER • Uses the equation to explain the effect of adding an acid to the system OR • Uses the equation to explain the effect of adding a base to the system	2
• Includes a relevant balanced chemical equation	1

Sample answer

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

When the pH of the system decreases, the system adjusts to minimise the change by favouring the reaction that increases the pH, i.e. decreases $[H_3O^+]$; hence, the reverse reaction is favoured.

When the pH of the system increases, the system adjusts to minimise the change by favouring the reaction that decreases the pH, i.e. increases $[H_3O^+]$, so the forward reaction is favoured.

Part c marking guidelines

Marking Criteria	Mark
• Describes the use of acids and / or bases in everyday life and / or industrial processes, using two examples	3
• Describes the use of acids and / or bases in everyday life and / or an industrial process, using one example OR • Outlines the use of acids and / or bases in everyday life and / or industrial processes, using two examples	2
• Outlines the use of acids and / or bases in everyday life and / or an industrial process, using one example OR • Identifies two examples of the use of acids and / or bases in everyday life and / or industrial processes	1

Sample answer

The human stomach contains hydrochloric acid which assists with the digestion of proteins in our food. However, as the food moves into the small intestine, a basic environment is needed for the enzymes in the small intestine to continue the digestion process. Hence, the food is neutralised by bile from our liver as it leaves the acid and enters the small intestine.

Fabric made from natural fibres contains natural oils and waxes which make it difficult to dye. To overcome this, the fabric is boiled in a basic solution, usually sodium hydroxide, for a couple of hours. The fabric is then rinsed in acetic acid to neutralise the sodium hydroxide before the dyeing process continues.

Question 26 (9 marks)

Marking guidelines

Marking Criteria	Mark
• Demonstrates a thorough understanding of the calculations and equations for all steps and calculates the concentration of acetic acid in white vinegar that is consistent with the data given • Reports the concentration of acetic acid in white vinegar to 4 significant figures • Makes a judgement regarding the validity of the student's result and supports it with evidence	8–9
• Demonstrates a thorough understanding of the calculations and equations for all steps and calculates the concentration of acetic acid in white vinegar that is consistent with the data given • Makes a judgement regarding the validity of the student's result and supports it with some evidence	6–7
• Demonstrates a sound understanding of the calculations required by including correct calculations for most steps • Provides at least two correct balanced equations	4–5
• Demonstrates a basic understanding of the calculations required by including some correct calculations OR • Demonstrates a limited understanding of the calculations required by including two correct calculations AND • Provides at least one correct balanced equation	2–3
• Calculates the volume of acetic acid by excluding the outlier OR • Calculates the number of moles of sodium carbonate in the standard solution OR • Provides one correct balanced equation	1

Sample answer

Standard solution of Na_2CO_3:

$$n_{Na_2CO_3} = \frac{m_{Na_2CO_3}}{MM_{Na_2CO_3}} = \frac{2.742}{105.99} = 0.02587 \text{ mol}$$

$$[Na_2CO_3] = \frac{n_{Na_2CO_3}}{V_{solution}} = \frac{0.02587}{0.2500} = 0.1035 \text{ molL}^{-1}$$

Titration between sodium carbonate and hydrochloric acid:

$Na_2CO_3\ (aq) + 2HCl\ (aq) \rightarrow 2NaCl\ (aq) + CO_2\ (g) + H_2O\ (l)$

$n_{Na_2CO_3} = [Na_2CO_3] \times V_{Na_2CO_3} = 0.1035 \times 0.01130 = 1.169 \times 10^{-3} \text{ molL}^{-1}$

$n_{HCl} = 2 \times n_{Na_2CO_3} = 2 \times 1.169 \times 10^{-3} = 2.339 \times 10^{-3} \text{mol}$

$$[HCl] = \frac{n_{HCl}}{V_{HCl}} = \frac{2.339 \times 10^{-3}}{0.02500} = 0.09355 \text{ molL}^{-1}$$

Titration between hydrochloric acid and sodium hydroxide:

$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$

$n_{HCl} = 2.339 \times 10^{-3}$ mol since same volume and concentration as that used in previous titration with Na_2CO_3.

$n_{NaOH} = n_{HCl} = 2.339 \times 10^{-3}$ mol

$$[NaOH] = \frac{n_{NaOH}}{V_{NaOH}} = \frac{2.339 \times 10^{-3}}{0.02110} = 0.1108 \text{ molL}^{-1}$$

Titration between acetic acid in diluted white vinegar and sodium hydroxide:
$NaOH\ (aq) + CH_3COOH\ (aq) \rightarrow CH_3COONa\ (aq) + H_2O\ (l)$
$n_{NaOH} = [NaOH] \times V_{NaOH} = 0.1108 \times 0.02500 = 2.771 \times 10^{-3}$ mol
$n_{CH_3COOH} = n_{NaOH} = 2.771 \times 10^{-3}\ mol$
$V_{CH_3COOH} = 0.03020\ L$ since 3rd titre is an outlier and is excluded from the calculation.

$$[CH_3COOH] = \frac{n_{CH_3COOH}}{V_{CH_3COOH}} = \frac{2.771 \times 10^{-3}}{0.03020} = 0.09175 \text{ molL}^{-1}$$

Undiluted white vinegar:
$[\mathrm{CH_3COOH}] = 10 \times [\mathrm{CH_3COOH}]$ in diluted white vinegar $= 10 \times 0.09175$
$= 0.9175 \text{ molL}^{-1}$

The student's procedure was valid on the first day. Excluding the outlier when determining the volume of acetic acid used on the second day was also valid. However, the [NaOH] would decrease overnight since some of the NaOH would react with CO_2 in the air and hence the [NaOH] on the second day would be less than that determined on the first day. Therefore, the value used for the titration on the second day is not valid and hence the value for the concentration of acetic acid in white vinegar is not valid. The actual $[CH_3COOH]$ in white vinegar would be less than the value determined by the student.

Question 27 (9 marks)

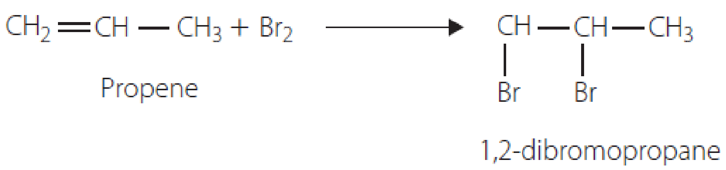
Marking guidelines

Criteria	Marks
Extensive description of THREE chemical tests including observations and/or description of expected results. Extensive chemical explanation of THREE tests performed, including a relevant equation for EACH.	8–9
Thorough description of THREE chemical tests including observations and/or description of expected results. Thorough chemical explanation of THREE tests performed, including a relevant equation for EACH.	6–7
Sound description of TWO chemical tests including observations and/or description of expected results. Sound chemical explanation of TWO tests performed, including two equations. OR Some description of THREE chemical tests included with key components not included/incorrect. Some attempt made at justification for THREE chemical tests, including at least one equation	4–5
Sound description of at least one chemical test including observations and/or description of expected results. Sound chemical explanation of at least one test performed, including two equations. OR Some description and justification of at least two tests, with key components missing/incorrect.	2–3
Some correct points made about at least one test performed.	1

Sample answer

Risk: Organic chemicals are highly flammable, keep away from heat sources to avoid ignition. Potassium dichromate and bromine are toxic and should be handled with gloves, in a fume cupboard if available (especially to combat bromine fumes). All waste should be disposed of in a waste container, not washed down the sink.

<u>TEST 1: To identify propene</u>
Test: 10 drops of each colourless liquid is added to separate, labelled test tubes. 2–3 drops of bromine are added to each test tube and shaken.
Result: The test tube containing propene will show a colour change from orange-brown to colourless. The other two test tubes will show no colour change and remain orange-brown.
Justification: when added to a molecule with a carbon–carbon double bond, the orange-brown bromine will add across the double bond to form a colourless final molecule: 1,2-dibromopropane. The other molecules do not contain a carbon-carbon double bond so do not react with bromine.

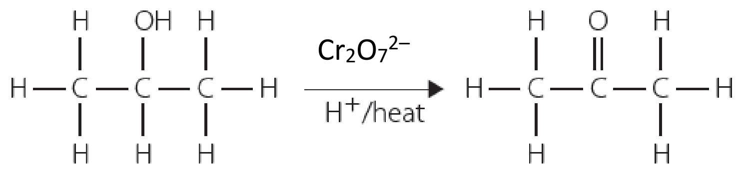


TEST 2: To identify 2-propanol

Test: 10 drops of each colourless liquid is added to separate, labelled test tubes. 3–4 drops of acidified potassium dichromate solution are added to each test tube and they are warmed in a water bath for 2–3 minutes or until a colour change is observed.

Result: The test tube containing 2-propanol shows a colour change from orange to green. The other two test tubes will show no colour change and remain orange.

Justification: The orange dichromate ions will change colour from orange to green as they undergo a reduction reaction with an organic molecule that is oxidising. 2-propanol will oxidise to propanone, so a colour change occurs. See reaction equation below. The other two molecules will not oxidise with dichromate ion solution, so no colour change is seen.



TEST 3: To identify propanoic acid

Test: 10 drops of each colourless liquid is added to separate, labelled test tubes. 5 drops of sodium carbonate or sodium hydrogencarbonate is added to each test tube.

Result: The test tube containing the propanoic acid

Justification: Propanoic acid reacts with the base carbonate ions/hydrogencarbonate ions to form carbon dioxide that is observed through the formation of bubbles when the chemicals are added. As the other two substances are not acids, they will not react in this way and no bubbles will be observed.

$$CH_3CH_2COOH(aq) + CO_3^{2-}(aq) \rightarrow CH_3CH_2COO^-(aq) + H_2O(l) + CO_2(g)$$

Question 28 (6 marks)

Part a marking guidelines

Criteria	Marks
Correct type of intermolecular bonding identified.	1

Sample answer

Dispersion forces

Part b

Criteria	Marks
Intermolecular bonds identified and compared on strength	2
Intermolecular bonds identified but not compared.	1

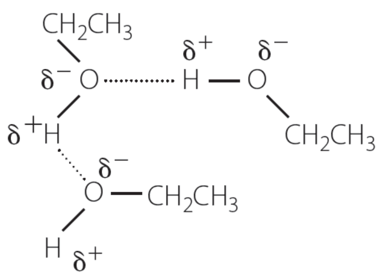
Sample answer

Alkanes have dispersion forces between molecules that are much weaker than the hydrogen bonds that form between alcohol molecules.

Part c

Criteria	Marks
Types of intermolecular bonds identified and explained. Comparison of intermolecular bonds thoroughly explained. Link to boiling point clearly explained. Diagram used effectively	3
Sound explanation of bonding and link to boiling point with diagram OR Good explanation of bonding and comparison but no link to boiling point, or no diagram used	2
At least one substantial and correct point made.	1

Alcohol molecules can form hydrogen bonds between molecules due to the presence of the highly polar O—H bond, allowing the positive H on one molecule to form a strong attraction to the negative O on a different molecule – the hydrogen bond, as seen in the diagram below.



Carboxylic acids have two parts to their functional group, the highly polar O—H that behaves the same as for alcohols, but they also have a polar C=O carbonyl functional group that can form dipole–dipole bonds. Hence, the carboxylic acid molecule can form two types of intermolecular forces, one of which is the same as for alcohols.

Hence, carboxylic acids form stronger overall intermolecular forces between molecules than alcohols do, which requires more heat energy to break, so carboxylic acids will have higher boiling points than alcohols of similar size.

Question 27 (5 marks)

Marking guidelines

Criteria	Marks
An extensive description of the chemistry of fossil fuel combustion and analysis of the consequences of this combustion in terms of the equilibrium reactions given. An appropriate judgement is made regarding the impact.	5
A thorough description of the chemistry of combustion is made, and a sound analysis of the consequences in terms of equilibrium is included. An appropriate judgement is made.	3–4
A basic description of the chemistry and consequences referring to equilibrium is made, with a judgement included	2
Some description of either the chemistry and/or consequence is included.	1

Sample answer (note: Assess = make a judgement)

When fossil fuels are combusted they produce carbon dioxide, as shown in the example of coal combustion below:

$$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$$

This carbon dioxide is emitted into the atmosphere where it can be absorbed by the oceans.

- Equation 1: if the levels of carbon dioxide in the atmosphere – CO_2 (g) – are increased, the equilibrium reaction will be driven to the right by Le Chatelier's principle. The system will adjust to decrease the concentration of CO_2 (g). So, the concentration of carbon dioxide in ocean water – CO_2 (aq) – will be increased.
- Equation 2: as the levels of CO_2 (aq) are increased, the second reaction is also driven to the right to adjust the system to decrease the concentration. Hence, more carbonic acid – H_2CO_3 (aq) – will be produced.
- Equation 3: as the levels of H_2CO_3 (aq) are increased the reaction is driven to the right, increasing the ionisation of carbonic acid, thus increasing the concentration of H_3O^+ and increasing the acidity of the ocean water.

As the pH levels fall and acidity increases the corals are negatively impacted and will bleach and die.

Hence, the combustion of fossil fuels and production of carbon dioxide that then increases acidity through a series of equilibrium reactions has a significant effect on coral reefs.

Question 8 (7 marks)

Part a marking guidelines

Criteria	Marks
Final mass of nitric acid calculated showing full working. Correct significant figures used.	3
Mass of nitric acid calculated with a minor mistake, or some working not shown	2
Some correct steps performed in the calculation of nitric acid	1

Sample answer

Using the equations $n(NH_3)$: $n(HNO_3)$ = 4:8/3

$$n(\mathrm{NH_3}) = \frac{m}{MM} = \frac{150 \times 10^3}{14.01 + (3 \times 1.008)} = 8805.9 \text{ mol}$$

$$\text{mole ratio } \frac{n(\mathrm{HNO_3})}{n(\mathrm{NH_3})} = \frac{8/3}{4}$$
$$n(\mathrm{HNO_3}) = 5870.6 \text{ mol}$$

$$MM(\mathrm{HNO_3}) = 1.008 + 14.01 + (3 \times 16.00) = 63.018 \text{ g mol}^{-1}$$
$$m(\mathrm{HNO_3}) = n \times MM = 5870.6 \times 63.018 = 369953 \text{ g}$$
$$369953 \times 0.65 = 240470 \text{ g} = 240 \text{ kg (3sf)}$$

Part b

Criteria	Marks
Extensive explanation of the temperature and pressure conditions required, referring to equilibrium theory.	4
Thorough explanation of the temperature and pressure conditions required with minor omissions or inconsistencies in the explanation	3
Sound and substantially correct explanation of both temperature and pressure conditions with some information missing or incorrect OR Thorough explanation of ONE of the conditions required.	2
Some correct points made regarding at least one of the required conditions	1

Sample answer

Pressure – As there are three molecules of gas on the left-hand side of the equation, and only two molecules on the right-hand side, the pressure should be high to drive the reaction in the forward direction. High pressure will cause the system to try to decrease the pressure by Le Chatelier's principle. To do this, the system will favour the direction that reduces the number of molecules in a given volume. If the reaction goes in the forward direction then three gas molecules become two gas molecules, decreasing the overall pressure of the system.

Temperature – as the reaction is exothermic, low temperatures would drive the reaction in the forwards direction to produce heat that will re-establish equilibrium. Low temperatures can be a problem as this will also decrease the reaction rate. Hence, the temperature used should be a balance between the low temperature required for equilibrium and higher temperatures required for a substantial reaction rate.

Question 8 (4 marks)

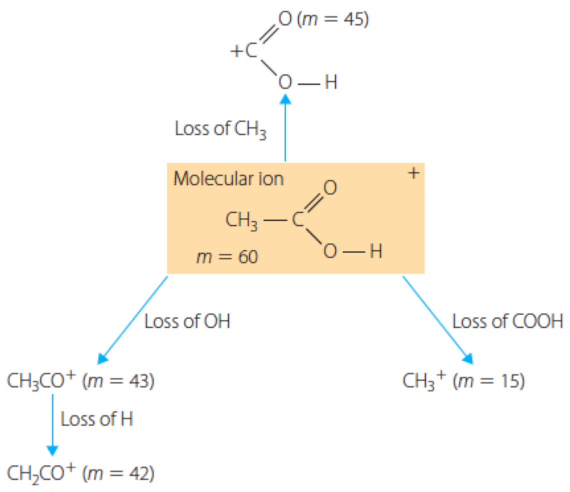
Marking guidelines

Criteria	Marks
Thorough explanation of each section of the diagram, with specific reference to ethanoic acid and possible ways it will fragment.	4
Thorough explanation of each section of the diagram with no specific reference to ethanoic acid OR Sound explanation of the process with some small omissions and reference made to ethanoic acid fragmentation	3
Sound explanation of most sections of the diagram with no reference to ethanoic acid OR Basic explanation of most sections of the diagram with some key omissions and some reference to ethanoic acid made	2
Some correct points made about at least one stage of the process.	1

Sample answer

Ionisation

A vapourised sample of the ethanoic acid is injected into the ionisation chamber where it is bombarded with high-energy electrons that cause electrons to be removed from a molecule. The resulting molecular ion is shown in the diagram below.



Also, as seen in the diagram, the molecular ion can fragment into smaller cations, free radicals (neutral, uncharged but highly reactive atoms/molecules) or hydrogen ions (H^+). Any of the charged ions/atoms/molecules can be analysed by the mass spectrometer.

Acceleration

Positive particles are accelerated along the path by an electrical field.

Deflection

A magnetic field is used to deflect ions based on mass (m) and charge (z). Small, highly charged particles are deflected by a greater amount. The magnetic field is varied to ensure separation of all particles occurs.

Detection

Particles hit a detector and their intensity is measured and used as a measure of abundance.

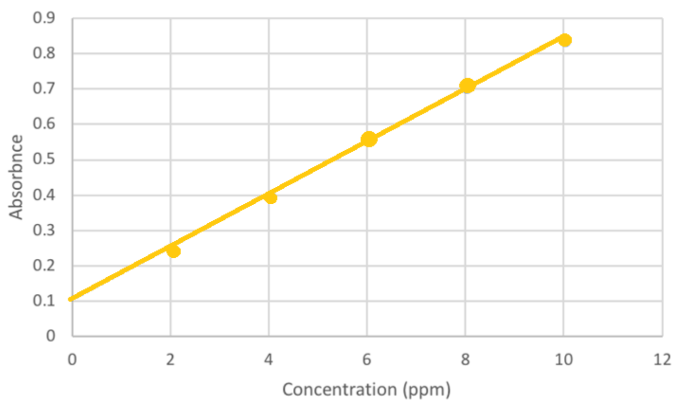
The results are presented as a mass spectrum with mass/charge ratio (m/z) on the horizontal axis and abundance on the vertical axis. This is then analysed to determine the structure of the original molecule.

Question 9 (9 marks)

Part a marking guidelines

Criteria	Marks
Calibration graph correctly constructed with appropriate labels and units on both axes and a line of best fit constructed.	3
Calibration graph constructed mostly correctly with some minor errors	2
One aspect of the graph completed correctly	1

Sample answer



Part b

Criteria	Marks
Provides a thorough analysis of accuracy of result data, referring to the graph and providing a correct justification/conclusion.	3
Provides a sound analysis of accuracy of result data, referring to the graph and/or providing an appropriate justification/conclusion	2
Provides a basic analysis of accuracy and/or some attempt at an appropriate justification/conclusion	1

Sample answer

The data provides the ability to draw a linear line of best fit. It is expected that the absorbance is proportional to the concentration of mercury in the solution; hence a linear trend is expected and would show an accurate trend.

It is also expected that a zero concentration of mercury would give an absorbance of zero. In this data, the extrapolation of the line of best fit to the vertical axis shows an absorbance of 0.1 for a zero mercury concentration. As this is clearly not possible, this data is not accurate. The most likely explanation for this is an incorrectly calibrated spectrophotometer.

Overall, the trend is accurate due to the linear trend; however, the individual data points are not due to the absorbance that exists at zero concentration.

Part c

Criteria	Marks
Concentration extracted from the graph showing a construction/marked on graph. Calculation of conversion to concentration in mol L^{-1} completed with full working and to correct significant figures	3
Concentration extracted from graph with justification and calculation complete with minor errors or significant figures incorrect OR Concentration calculation fully correct but justification for ppm concentration not shown on graph	2
Some part of the calculation completed correctly	1

Using the graph (should show construction on the graph) the concentration in ppm for an absorbance of 0.64 is approximately 7.5 ppm.

$$7.5\ \text{ppm} = 7.5\ \text{g}\ \text{L}^{-1} = 7.5 \times 10^{-3}\ \text{g}\ \text{L}^{-1}$$

$$n(\text{Hg}) = \frac{\text{m}}{\text{MM}} = \frac{7.5 \times 10^{-3}}{200.6} = 3.74 \times 10^{-5}\ \text{mol}$$

$$c(\text{Hg}) = 3.7 \times 10^{-5}\ \text{mol}\ \text{L}^{-1}\ (2\text{sf})$$