NSW Education Standards Authority

Chemistry

Additional sample examination questions

Effective from	2019 HSC Examination
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Contents

Sample Questions

Introduction

The first HSC examination for the new Chemistry Stage 6 syllabus will be held in 2019.

The syllabus and related assessment materials are available on the syllabus page of the NESA website.

The *Assessment and Reporting in Chemistry Stage 6* document provides the Chemistry HSC examination specifications. The *Chemistry – Sample examination materials* document indicates the layout and format of the HSC examination and provides examples of questions that may be found in HSC examinations, with annotations.

This document, *Chemistry – Additional sample examination questions*, provides additional examples of questions that may be found in HSC examinations for Chemistry. The document comprises new questions, as well as questions that have been published in the sample examination materials and some questions that have been drawn from previous HSC examinations.

The document has been developed to assist teachers to:

- create sample HSC examination papers
- prepare revision exercises
- model question design
- consolidate understanding of the syllabus.

The sample questions are arranged by module. Examples of both objective-response questions and short-answer questions for each of the modules, Equilibrium and Acid Reactions, Acid/base Reactions, Organic Chemistry and Applying Chemical Ideas, are provided.

Each sample question has been mapped to show how the question relates to content, syllabus outcomes and bands. Questions may require candidates to integrate knowledge, understanding and skills from different content areas. Each question is mapped to the main content area(s) being assessed but may be relevant to one or more content areas. When a question has been mapped to multiple content areas, it has been placed under the topic deemed to be most relevant.

Answers for the objective-response questions and marking guidelines for the short-answer questions are also provided. The sample questions, sample answers and marking guidelines provide teachers and students with guidance as to the types of questions that may be included in the examination and how they may be marked. They are not meant to be prescriptive.

Note:

- In this set of sample questions, some stimulus material is used in more than one question. This illustrates how the same content area can be examined in different ways.
- The new Chemistry Stage 6 syllabus includes content areas that were also part of previous syllabuses. Where this occurs, teachers and students may still refer to past HSC examination papers for examples of other types of questions that are relevant.
- In this document, ‘Bands’ means the performance bands targeted by the question.

- Preferred IUPAC nomenclature is the most current and widely recognised system of chemistry nomenclature, particularly for naming organic molecules.

  In a small number of cases, especially for commonly used substances, the IUPAC rules prefer use of trivial names (eg, formic acid, acetic acid) over the equivalent, more systematic names (eg, methanoic acid, ethanoic acid).

  IUPAC also recognises other, alternative systematic nomenclature. It does so only in cases where the name remains unambiguous. For example: 1-butanol, 1-butene, ammonia and acetylene.

  It is important that compounds are given names that are unambiguous, that is, names that lead to only one structure.

Question List

* denotes a multiple-choice question

Module 5 Equilibrium and Acid Reactions

Question	Marks	Content	Syllabus Outcomes	Bands
Mod 5 – 1*	1	Mod 5 Static and Dynamic Equilibrium	CH12−5, CH12−12	3−4
Mod 5 – 2*	1	Mod 5 Static and Dynamic Equilibrium	CH12−6, CH12−12	3−4
Mod 5 – 3*	1	Mod 5 Factors that Affect Equilibrium	CH12−5, CH12−12	4–5
Mod 5 – 4*	1	Mod 5 Factors that Affect Equilibrium	CH12−5, CH12−12	5−6
Mod 5 – 5*	1	Mod 5 Calculating the Equilibrium Constant (K_{eq})	CH12−4, CH12−12	3−4
Mod 5 – 6*	1	Mod 5 Calculating the Equilibrium Constant (K_{eq})	CH12−4, CH12−12	3−4
Mod 5 – 7*	1	Mod 5 Calculating the Equilibrium Constant (K_{eq})	CH12−6, CH12−12	4−5
Mod 5 – 8*	1	Mod 5 Calculating the Equilibrium Constant (K_{eq})	CH12−4, CH12−12	4−5
Mod 5 – 9*	1	Mod 5 Solution Equilibria	CH12−6, CH12−12	4−5
Mod 5 – 10	4	Mod 5 Static and Dynamic Equilibrium Mod 5 Solution Equilibria	CH12−7, CH12−12	3−6
Mod 5 – 11	3	Mod 5 Static and Dynamic Equilibrium Mod 5 Solution Equilibria	CH12−4, CH12−12	2−4
Mod 5 – 12	5	Mod 5 Factors that Affect Equilibrium	CH12−5, CH12−6, CH12−12	2−6
Mod 5 – 13	3	Mod 5 Calculating the Equilibrium Constant (K_{eq}) Mod 6 Quantitative Analysis	CH12−4, CH12−6, CH12−12	3–5
Mod 5 – 14	3	Mod 5 Calculating the Equilibrium Constant (K_{eq}) Mod 5 Solution Equilibria	CH12−5, CH12−6 CH12−12	3–5
Mod 5 – 15	3	Mod 5 Solution Equilibria Mod 8 Analysis of Inorganic Substances	CH12−2, CH12−12, CH12–15	3–5
Mod 5 – 16 (a)	3	Mod 5 Solution Equilibria	CH12−4, CH12−6, CH12−12	3−5
Mod 5 – 16 (b)	1	Mod 5 Solution Equilibria	CH12−6, CH12−12	4−5
Mod 5 – 17	6	Mod 5 Solution Equilibria	CH12–4, CH12–5, CH12–12	2–6

Module 6 Acid/base Reactions

Question	Marks	Content	Syllabus Outcomes	Bands
Mod 6 – 1*	1	Mod 6 Properties of Acids and Bases Mod 8 Analysis of Organic Substances	CH12−13, CH12−15	2−3
Mod 6 – 2*	1	Mod 6 Properties of Acids and Bases	CH12−6, CH12−13	3−4
Mod 6 – 3*	1	Mod 6 Using Brønsted−Lowry Theory	CH12−4, CH12−13	3−4
Mod 6 – 4*	1	Mod 6 Using Brønsted–Lowry Theory	CH12−6, CH12−13	4−5
Mod 6 – 5*	1	Mod 6 Quantitative Analysis	CH12−6, CH12−13	4−5
Mod 6 – 6*	1	Mod 6 Quantitative Analysis	CH12−4, CH12−5, CH12−13	4–5
Mod 6 – 7*	1	Mod 6 Quantitative Analysis Mod 6 Using Brønsted−Lowry Theory	CH12−5, CH12−6, CH12−13	4–5
Mod 6 – 8*	1	Mod 6 Quantitative Analysis Mod 6 Using Brønsted−Lowry Theory	CH12−5, CH12−6, CH12−13	5−6
Mod 6 – 9*	1	Mod 6 Quantitative Analysis	CH12−4, CH12−13	5−6
Mod 6 – 10 (a)	2	Mod 6 Quantitative Analysis Mod 6 Properties of Acids and Bases	CH12−2, CH12−6, CH12−13	3−4
Mod 6 – 10 (b)	4	Mod 6 Quantitative Analysis	CH12−4, CH12−6, CH12−13	2−5
Mod 6 – 10 (c)	3	Mod 6 Quantitative Analysis	CH12−4 CH12−6, CH12−13	3−5
Mod 6 – 11	3	Mod 6 Quantitative Analysis Mod 6 Using Brønsted−Lowry Theory	CH12−5, CH12−6, CH12−13	4−6
Mod 6 – 12 (a)	3	Mod 6 Quantitative Analysis	CH12−6, CH12−13	4−6
Mod 6 – 12 (b)	3	Mod 5 Factors that Affect Equilibrium Mod 6 Using Brønsted−Lowry Theory	CH12−6, CH12−12, CH12−13	2−5
Mod 6 – 13 (a)	3	Mod 6 Quantitative Analysis	CH12−6, CH12−13	4−6
Mod 6 – 13 (b)	2	Mod 6 Quantitative Analysis	CH12−6, CH12−13	4−5
Mod 6 – 14	8	Mod 6 Quantitative Analysis	CH12–2, CH12–3, CH12–4, CH12–6, CH12–13	2–6

Module 7 Organic Chemistry

Question	Marks	Content	Syllabus Outcomes	Bands
Mod 7 – 1*	1	Mod 7 Nomenclature	CH12−7, CH12−14	2−3
Mod 7 – 2*	1	Mod 7 Nomenclature	CH12−14	3−4
Mod 7 – 3*	1	Mod 7 Nomenclature	CH12−6, CH12−14	3−4
Mod 7 – 4*	1	Mod 7 Nomenclature Mod 7 Hydrocarbons	CH12−6, CH12−14	4−5
Mod 7 – 5*	1	Mod 7 Hydrocarbons	CH12−14	2−3
Mod 7 – 6*	1	Mod 7 Reactions of Organic Acids and Bases	CH12−7, CH12−14	2−3

Mod 7 – 7*	1	Mod 7 Reactions of Organic Acids and Bases	CH12−3, CH12−14	3–4
Mod 7 – 8 (a)	3	Mod 7 Hydrocarbons Mod 7 Nomenclature	CH12−4, CH12−14	3–5
Mod 7 – 8 (b)	4	Mod 7 Hydrocarbons Mod 7 Alcohols	CH12−4, CH12−7, CH12−14	2–5
Mod 7 – 9	7	Mod 7 Products of Reactions Involving Hydrocarbons	CH12−5, CH12–6, CH12−14	2–6
Mod 7 – 10	3	Mod 7 Alcohols	CH12−5, CH12−6, CH12−14	3–5
Mod 7 – 11 (a)	4	Mod 7 Reactions of Organic Acids and Bases	CH12−2, CH12−14	2–5
Mod 7 – 11 (b)	2	Mod 7 Reactions of Organic Acids and Bases	CH12−2, CH12−14	3–4
Mod 7 – 12	8	Mod 7 Reactions of Organic Acids and Bases	CH12−2, CH12−7, CH12−14	2–6
Mod 7 – 13	3	Mod 7 Reactions of Organic Acids and Bases	CH12−4, CH12−7, CH12−14	2–4
Mod 7 – 14	7	Mod 7 Polymers	CH12–7, CH12–14	2–6

Module 8 Applying Chemical Ideas

Question	Marks	Content	Syllabus Outcomes	Bands
Mod 8 – 1*	1	Mod 8 Analysis of Inorganic Substances	CH12−2, CH12−15	2–3
Mod 8 – 2*	1	Mod 8 Analysis of Inorganic Substances	CH12−5, CH12−15	3–4
Mod 8 – 3*	1	Mod 8 Analysis of Inorganic Substances	CH12−4, CH12−15	3–4
Mod 8 – 4*	1	Mod 8 Analysis of Inorganic Substances	CH12−5, CH12−15	5–6
Mod 8 – 5*	1	Mod 8 Analysis of Inorganic Substances	CH12−6, CH12−15	5–6
Mod 8 – 6*	1	Mod 8 Analysis of Organic Substances	CH12−4, CH12−7, CH12−15	3–4
Mod 8 – 7*	1	Mod 8 Analysis of Organic Substances	CH12−5, CH12−7, CH12−15	4–5
Mod 8 – 8*	1	Mod 8 Chemical Synthesis and Design Mod 5 Factors that Affect Equilibrium	CH12−5, CH12−6, CH12−15	4–5
Mod 8 – 9*	1	Mod 8 Chemical Synthesis and Design Mod 5 Factors that Affect Equilibrium	CH12−5, CH12−6, CH12−15	5–6
Mod 8 – 10	4	Mod 8 Chemical Synthesis and Design Mod 8 Analysis of Inorganic Substances Mod 6 Quantitative Analysis	CH12−4, CH12−6, CH12−13, CH12−15	2–5
Mod 8 – 11	9	Mod 8 Analysis of Inorganic Substances Mod 5 Factors that Affect Equilibrium	CH12−2, CH12–6, CH12–7, CH12−15	2–6
Mod 8 – 12	3	Mod 8 Analysis of Inorganic Substances	CH12−5, CH12−7, CH12−15	3–5
Mod 8 – 13 (a)	3	Mod 8 Analysis of Inorganic Substances	CH12−4, CH12−15	2–5
Mod 8 – 13 (b)	3	Mod 8 Analysis of Inorganic Substances	CH12−5, CH12−6, CH12−15	4–6

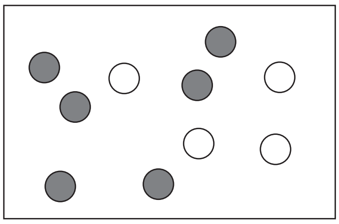
Mod 8 – 14	4	Mod 8 Analysis of Inorganic Substances	CH12–2, CH12–4, CH12–15	2–5
Mod 8 – 15	3	Mod 8 Analysis of Organic Substances	CH12−6, CH12−15	2–4
Mod 8 – 16	4	Mod 8 Analysis of Organic Substances	CH12−4, CH12−7, CH12−15	2–5
Mod 8 – 17 (a)	2	Mod 8 Analysis of Organic Substances	CH12−15	2–3
Mod 8 – 17 (b)	3	Mod 8 Analysis of Organic Substances	CH12−15	2–4
Mod 8 – 18	3	Mod 8 Analysis of Organic Substances	CH12−15	2–4

Module 5 Equilibrium and Acid Reactions

Mod 5 – Question 1

Particle ● reacts with particle ○ to form the molecule ●○. The system comes to an equilibrium.

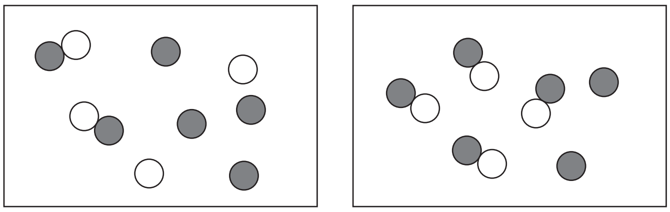
The diagram shows the initial reactants.



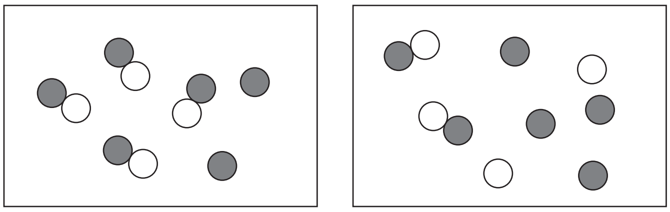
Which combination of diagrams best represents the molecule in a dynamic equilibrium and a static equilibrium?

Dynamic Static

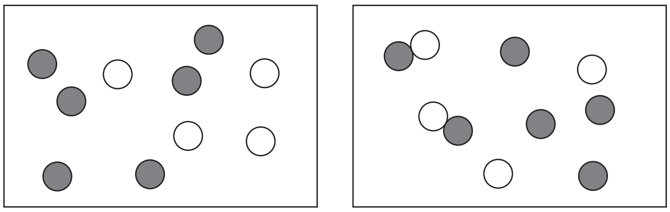
A.



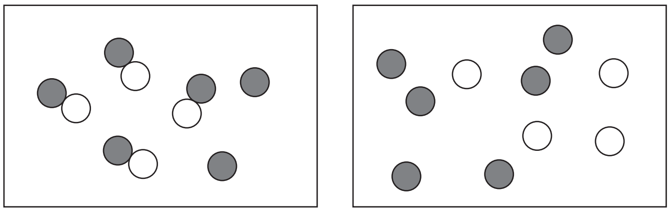
B.



C.



D.



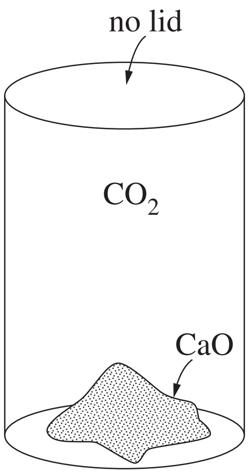
Content	Syllabus outcomes	Bands	Key
Mod 5 Static and Dynamic Equilibrium	CH12–5, CH12–12	3–4	A

Mod 5 – Question 2

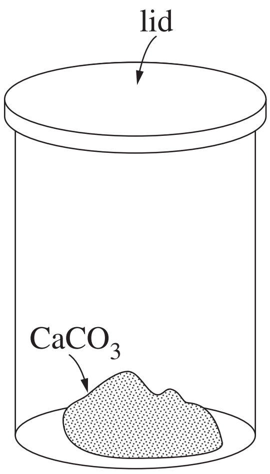
The conversion of calcium carbonate to calcium oxide and carbon dioxide is a reversible reaction and will reach equilibrium under certain conditions.

In which diagram is the system most likely to have reached equilibrium?

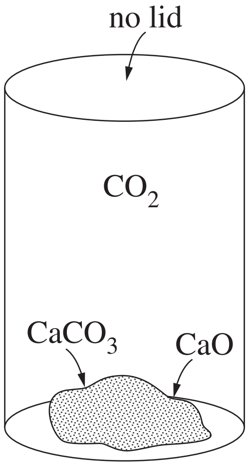
A.



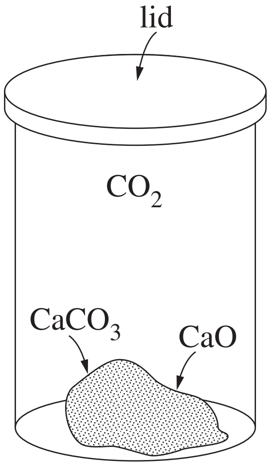
B.



C.



D.



Content	Syllabus outcomes	Bands	Key
Mod 5 Static and Dynamic Equilibrium	CH12–6, CH12–12	3–4	D

Mod 5 – Question 3

Nitrogen dioxide (a brown gas) and dinitrogen tetroxide (a colourless gas) are both forms of oxides of nitrogen. They are in equilibrium according to the equation

$$2NO_2(g) \rightleftharpoons N_2O_4(g).$$

An equilibrium mixture of the two gases at room temperature is light brown but at higher temperatures the colour becomes a much deeper brown.

What conclusion can be drawn from this observation?

A. The reverse reaction in the equation is endothermic.

B. The forward reaction in the equation is endothermic.

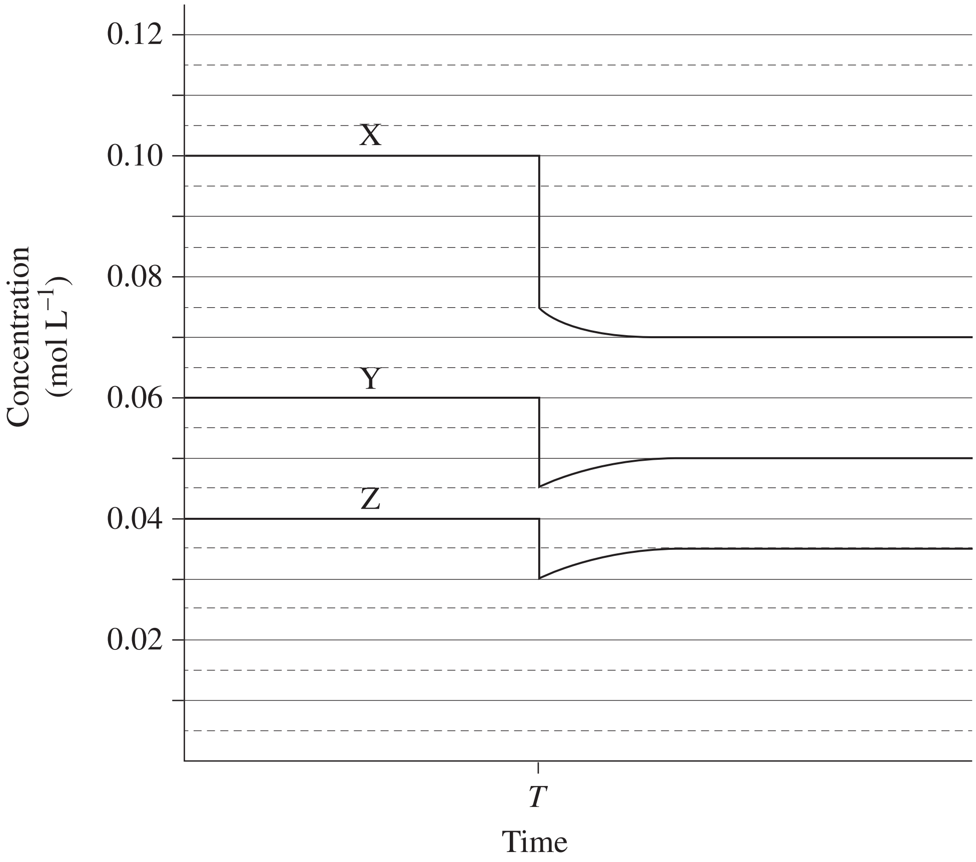
C. The brown colour is due to the strong nitrogen–oxygen bonds in NO_2.

D. The equilibrium concentration of N_2O_4 is not dependent on temperature.

Content	Syllabus outcomes	Bands	Key
Mod 5 Factors that Affect Equilibrium	CH12–5, CH12–12	4–5	A

Mod 5 – Question 4

Three gases X, Y and Z were mixed in a closed container and allowed to reach equilibrium. A change was imposed at time *T* and the equilibrium was re-established. The concentration of each gas is plotted against time.



Which reaction does the graph represent?

A. $X(g) + Y(g) \rightleftharpoons 2Z(g)$

B. $2X(g) \rightleftharpoons Y(g) + Z(g)$

C. $2X(g) \rightleftharpoons Y(g) + 3Z(g)$

D. $X(g) \rightleftharpoons Y(g) + Z(g)$

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 5 Factors that Affect Equilibrium	CH12–5, CH12–12	5–6	D

Mod 5 – Question 5

Consider the following reaction.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

What is the equilibrium expression for this reaction?

A. $\dfrac{2[NO][Cl_2]}{2[NOCl]}$

B. $\dfrac{[NO]^2[Cl_2]}{[NOCl]^2}$

C. $\dfrac{2[NOCl]}{2[NO][Cl_2]}$

D. $\dfrac{[NOCl]^2}{2[NO]^2[Cl_2]}$

Content	Syllabus outcomes	Bands	Key
Mod 5 Calculating the Equilibrium Constant (K_{eq})	CH12–4, CH12−12	3–4	B

Mod 5 – Question 6

Hydrogen gas reacts with iodine gas to form hydrogen iodide according to the following equation.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad \text{at 700 k}$$

At equilibrium, the concentrations for H_2, I_2 and HI are as follows: 0.214 mol L^{-1}, 0.214 mol L^{-1} and 1.57 mol L^{-1} respectively.

What is the value of the equilibrium constant for this reaction?

A. 0.018

B. 0.029

C. 34.3

D. 53.8

Content	Syllabus outcomes	Bands	Key
Mod 5 Calculating the Equilibrium Constant (K_{eq})	CH12–4, CH12−12	3–4	D

Mod 5 – Question 7

At a certain temperature, the K_{eq} for the following reaction is 75.

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

0.3 mol of O_3 and 1.5 mol of O_2 were introduced to a 5 L reaction vessel.

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

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

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 5 Calculating the Equilibrium Constant (K_{eq})	CH12–6, CH12–12	4–5	D

Mod 5 – Question 8

0.20 moles of phosphorus pentachloride were heated to 200°C in a 2 L container in the presence of a vanadium catalyst according to the following reaction.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

At equilibrium, the mixture was found to contain 0.16 moles of chlorine.

Which of the following is the equilibrium constant for this reaction at this temperature?

A. 0.32

B. 0.64

C. 1.56

D. 3.13

Content	Syllabus outcomes	Bands	Key
Mod 5 Calculating the Equilibrium Constant (K_{eq})	CH12–4, CH12−12	4–5	A

Mod 5 – Question 9

What will happen when sulfuric acid is added to a saturated solution of sparingly soluble calcium sulfate?

A. The concentration of calcium and sulfate ions will increase over time due to the presence of H^+ ions.

B. The concentration of calcium and sulfate ions will decrease over time due to the presence of H^+ ions.

C. The concentration of calcium and sulfate ions will increase over time due to the presence of SO_4^{2-} ions.

D. The concentration of calcium and sulfate ions will decrease over time due to the presence of SO_4^{2-} ions.

Content	Syllabus outcomes	Bands	Key
Mod 5 Solution Equilibria	CH12–6, CH12−12	4–5	D

Mod 5 – Question 10 (4 marks)

Describe the changes that occur in both bonding and entropy when potassium chloride is dissolved in water. Support your answer with a labelled diagram. **4**

Mapping grid:

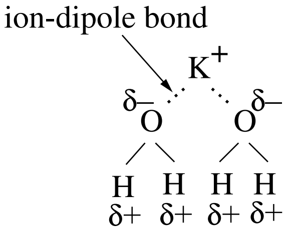
Content	**Syllabus outcomes**	**Bands**
Mod 5 Static and Dynamic Equilibrium Mod 5 Solution Equilibria	CH12–7, CH12–12	3–6

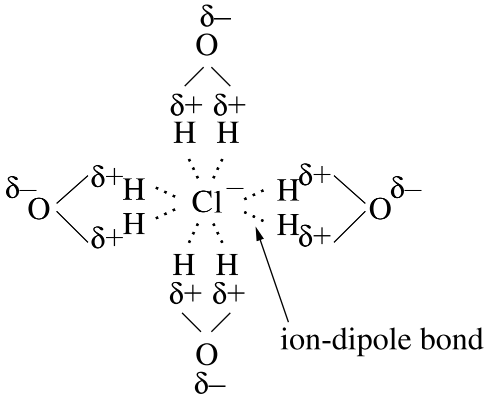
Marking guidelines:

Criteria	**Marks**
• Provides a description of the changes in both bonding and entropy • Supports answer with a labelled diagram	4
• Demonstrates some understanding of the changes that occur in bonding and/or entropy	2–3
• Demonstrates an understanding of bonding or entropy OR • Draws a labelled diagram	1

Sample answer:

Potassium chloride is an ionic compound soluble in water. Water is a polar molecule with hydrogen bonding between the molecules. The partially negatively charged oxygen in the water attracts the potassium ion and the partially positively charged hydrogen attracts the chloride ion, breaking the ionic bonds and forming ion-dipole bonds. The entropy of the system is increased as the ordered lattice of the salt is broken and the ions disperse randomly throughout the solution.





Mod 5 – Question 11 (3 marks)

Draw a labelled diagram to show the dissociation of sodium chloride in water. **3**

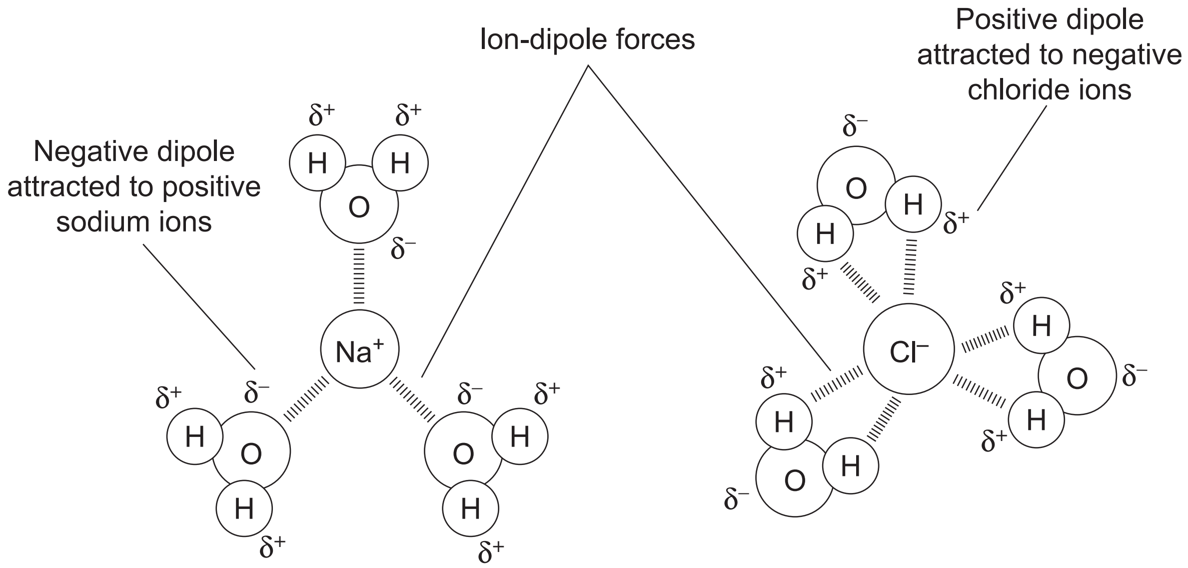
Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 5 Static and Dynamic Equilibrium Mod 5 Solution Equilibria	CH12–4, CH12−12	2–4

Marking guidelines:

Criteria	**Marks**
• Draws a labelled diagram that clearly shows the dissociation of NaCl into ions, the dipole on water molecules and the formation of ion-dipole bonds	3
• Provides a substantially correct labelled diagram	2
• Provides some relevant information	1

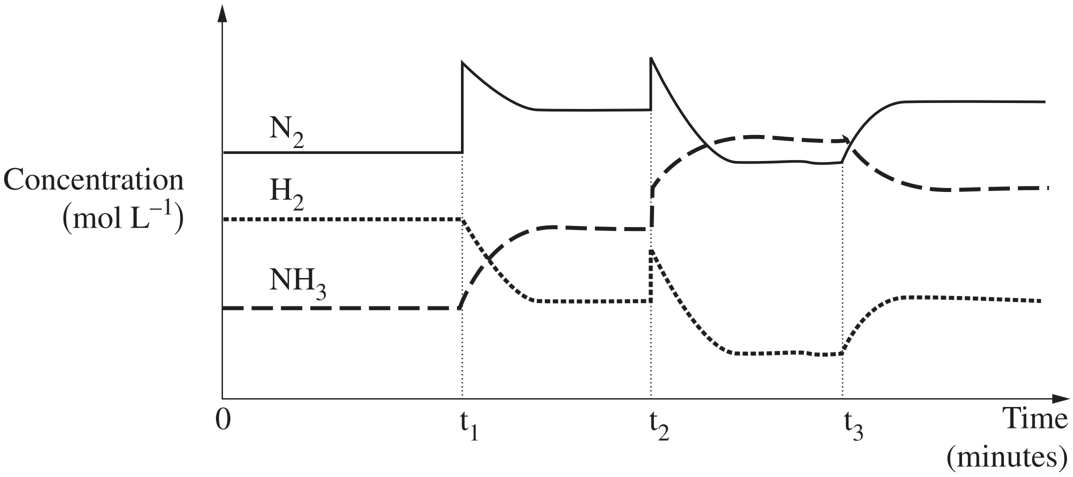
Sample answer:



Mod 5 – Question 12 (5 marks)

An industrial plant makes ammonia from nitrogen gas and hydrogen gas. The reaction is exothermic. **5**

The graph shows the adjustments made to increase the yield of ammonia.



Account for the changes in conditions that have shaped the graph during the time the system was observed. Include a relevant chemical equation in your answer.

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 5 Factors that Affect Equilibrium	CH12–5, CH12–6, CH12−12	2–6

Marking guidelines:

Criteria	Marks
• Provides reasons for the changes in conditions for all intervals • Relates changes to Le Chatelier’s principle • Includes a relevant chemical equation	5
• Relates the specific changes in conditions for two intervals to Le Chatelier’s principle • Includes a relevant chemical equation	4
• Outlines the specific changes in conditions that result in changes at t_1, t_2 and t_3	3
• Outlines changes that occurred OR • Provides reason(s) for a change that occurred	2
• Provides some relevant information	1

Question 12 continues on page 19

Question 12 (continued)

Sample answer:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1}$$

From $t = 0$ to $t = t_1$, the system is at equilibrium. At t_1 there is a sharp increase in the concentration of nitrogen which is likely to be due to more nitrogen being introduced to the system. According to Le Chatelier’s principle, when a system at equilibrium is disturbed, the equilibrium will shift in the direction that minimises the change. So the equilibrium will shift to the right to use up more nitrogen which will produce a greater yield of ammonia until equilibrium is re-established.

At t_2, the concentration of both reactants and products increases sharply, most likely due to a decrease in volume of the reaction vessel which will produce an increase in pressure on the system. In the above equation, it can be seen that there are 4 moles of gas on the left-hand side of the equation and 2 moles of gas on the right-hand side. An increase in pressure will cause the system to shift to counteract the change and thus move to the side with fewer moles of gas to reduce pressure. This increases the yield of ammonia as the forward reaction is favoured until equilibrium is re-established.

At t_3 there is a change to the system that favours the reverse reaction. As the concentration of reactants and products does not change suddenly, this is most likely to be due to a change in temperature. As this reaction is exothermic, an increase in temperature is likely to have occurred which will favour the reaction that absorbs heat. Thus the reverse reaction is favoured, lowering the yield of ammonia until equilibrium is re-established.

End of Question 12

Mod 5 – Question 13 (3 marks)

Butanoic acid is a natural product and a component of human sweat. **3**

Calculate the value of K_a for butanoic acid if a 0.10 mol L^{-1} solution has a pH of 2.9 at 298 K.

Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 5 Calculating the Equilibrium Constant (K_{eq}) Mod 6 Quantitative Analysis	CH12–4, CH12−6, CH12−12	3–5

Marking guidelines:

Criteria	**Marks**
• Correctly calculates K_a	3
• Provides the main steps of the calculation	2
• Provides some relevant information	1

Sample answer:

$$C_3H_7COOH(aq) \rightleftharpoons C_3H_7COO^-(aq) + H^+(aq) \qquad K_a = \frac{\left[C_3H_7COO^-\right]\left[H^+\right]}{\left[C_3H_7COOH\right]}$$

$$pH = 2.9 = -\log\left[H^+\right]$$

$$\left[H^+\right] = 1.26 \times 10^{-3} \text{ mol L}^{-1} = \left[C_3H_7COO^-\right]$$

$$\left[C_3H_7COO\right] = 0.10 - 1.26 \times 10^{-3} = 0.0987 \text{ mol L}^{-1}$$

$$K_a = \frac{\left(1.26 \times 10^{-3}\right)^2}{0.0987}$$

$$= 1.6 \times 10^{-5}$$

Mod 5 – Question 14 (3 marks)

When a sample of solid silver chloride is added to a 1.00×10^{-2} mol L^{-1} sodium chloride solution, only some of the silver chloride dissolves. **3**

Calculate the equilibrium concentration of silver ions in the resulting solution, given that the K_{sp} of silver chloride is 1.80×10^{-10}.

Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 5 Calculating the Equilibrium Constant (K_{eq}) Mod 5 Solution Equilibria	CH12–5, CH12–6, CH12–12	3–5

Marking guidelines:

Criteria	**Marks**
• Correctly calculates $\left[Ag^+\right]$ and includes appropriate units	3
• Provides the main steps of the calculation	2
• Provides some relevant information	1

Sample answer:

Let $\left[Ag^+\right] = x$ mol L^{-1}

Then, the concentration (in mol L^{-1}) of Ag^+ and Cl^- in the various stages will be:

	$AgCl(s)$	$\rightleftharpoons$	$Ag^+(aq)$	+	$Cl^-(aq)$
Initial			0		1.00×10^{-2}
Change			x		x
At equilibrium			x		$1.00 \times 10^{-2} + x$

$$K_{sp} = \left[Ag^+\right]\left[Cl^-\right] = 1.80 \times 10^{-10}$$

$$x\left(1.00 \times 10^{-2} + x\right) = 1.80 \times 10^{-10}$$

Assuming that x is small compared to initial $\left[Cl^-\right]$, $\left(1.00 \times 10^{-2} + x\right) \approx 1.00 \times 10^{-2}$

$$x\left(1.00 \times 10^{-2}\right) \approx 1.80 \times 10^{-10}$$

$$x \approx 1.80 \times 10^{-8}$$

$$\left[Ag^+\right] \approx 1.80 \times 10^{-8} \text{ mol L}^{-1}$$

Mod 5 – Question 15 (3 marks)

The diagrams represent equipment used in an investigation to determine the chloride ion concentration in a water sample. **3**

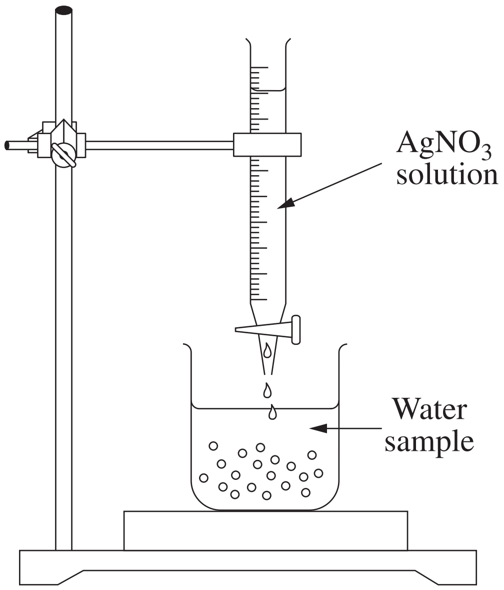


Figure 1

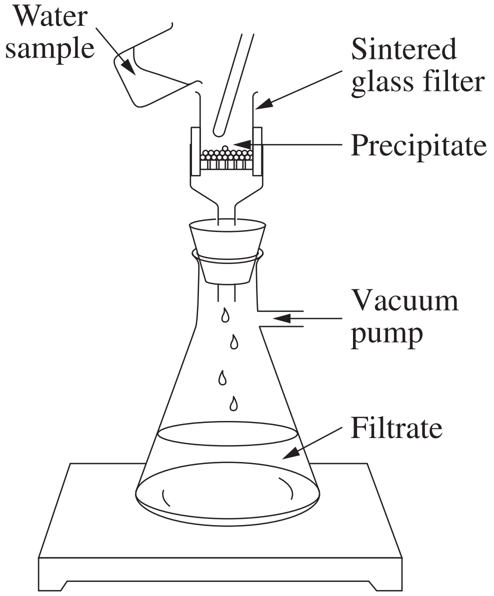


Figure 2

Describe how the chloride ion concentration in a water sample can be determined using the equipment in the diagrams. Include a relevant chemical equation.

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 5 Solution Equilibria Mod 8 Analysis of Inorganic Substances	CH12–2, CH12–12, CH12–15	3–5

Question 15 continues on page 23

Question 15 (continued)

Marking guidelines:

Criteria	Marks
• Describes how the chloride ion concentration in a water sample can be determined • Recognises that $AgNO_3$ is added in excess to the water sample • Shows how AgCl precipitate can be used to calculate mass of Cl • Writes correct balanced equation	3
• Outlines some steps in determining the concentration of chloride ions in a water sample	2
• Provides some relevant information	1

Sample answer:

The set-up shown allows Cl^- to form a precipitate with Ag^+, $Cl^-(aq) + Ag^+(aq) \longrightarrow AgCl(s)$. To ensure that all chloride ions are precipitated, excess silver nitrate is dropped into the solution.

The sintered glass filter together with the vacuum pump could filter the $AgCl(s)$ within an effective time frame. The precipitate should be weighed once it is dry to determine its mass.

We can determine the moles of $AgCl(s)$ using the mass. Since the ratio of Ag^+ and Cl^- is 1 : 1, the moles can be used to determine the mass of the Cl^- ions and therefore its concentration if we know the mass of the water sample.

End of Question 15

Mod 5 – Question 16 (4 marks)

A 100 mL saturated solution of calcium hydroxide at 25°C contains 0.173 g of calcium hydroxide.

(a) Calculate the solubility product (K_{sp}) of this salt at 25°C. **3**

(b) Explain why the undissolved solid is not included in the expression for the solubility product constant. **1**

Mapping grid (a):

Content	**Syllabus outcomes**	**Bands**
Mod 5 Solution Equilibria	CH12–4, CH12–6, CH12–12	3–5

Marking guidelines (a):

Criteria	**Marks**
• Correctly calculates K_{sp} for calcium hydroxide at 25°C	3
• Provides the main steps of the calculation	2
• Provides some relevant information	1

Sample answer:

$Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$

$K_{sp} = [Ca^{2+}]\,[OH^-]^2$

Concentration of $Ca(OH)_2$ = 0.173 g/100 mL

Formula mass of calcium hydroxide = 74.093 g

n = m/M = 0.173/74.093 = 0.00233 moles in 100 mL

Concentration in mol L^{-1} = 0.0233 mol L^{-1}

Concentration of Ca^{2+} = 0.0233 mol L^{-1} and concentration of OH^- = 0.0466 mol L^{-1}

$K_{sp} = 0.0233 \times (0.0466)^2$

$= 5.06 \times 10^{-5}$

Question 16 continues on page 25

Question 16 (continued)

Mapping grid (b):

Content	Syllabus outcomes	Bands
Mod 5 Solution Equilibria	CH12–6, CH12–12	4–5

Marking guidelines (b):

Criteria	Marks
• Correctly explains why the undissolved solid is not included in the K_{sp} expression	1

Sample answer:

The amount of undissolved solid is not included in the K_{sp} expression because it remains constant. There is no change in concentration.

End of Question 16

Mod 5 – Question 17 (6 marks)

The information in the table shows how the solubility of lead chloride is affected by temperature. **6**

Temperature (°C)	*Solubility* (g/100 g water)
0	0.25
20	0.35
40	0.55
60	0.90
80	1.75
100	3.20

Using a graph, calculate the solubility product (K_{sp}) of the dissolution of lead chloride at 50°C. Include a fully labelled graph and a relevant chemical equation in your answer.

Question 17 continues on page 27

Question 17 (continued)

Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 5 Solution Equilibria	CH12−4, CH12−5, CH12−12	2–6

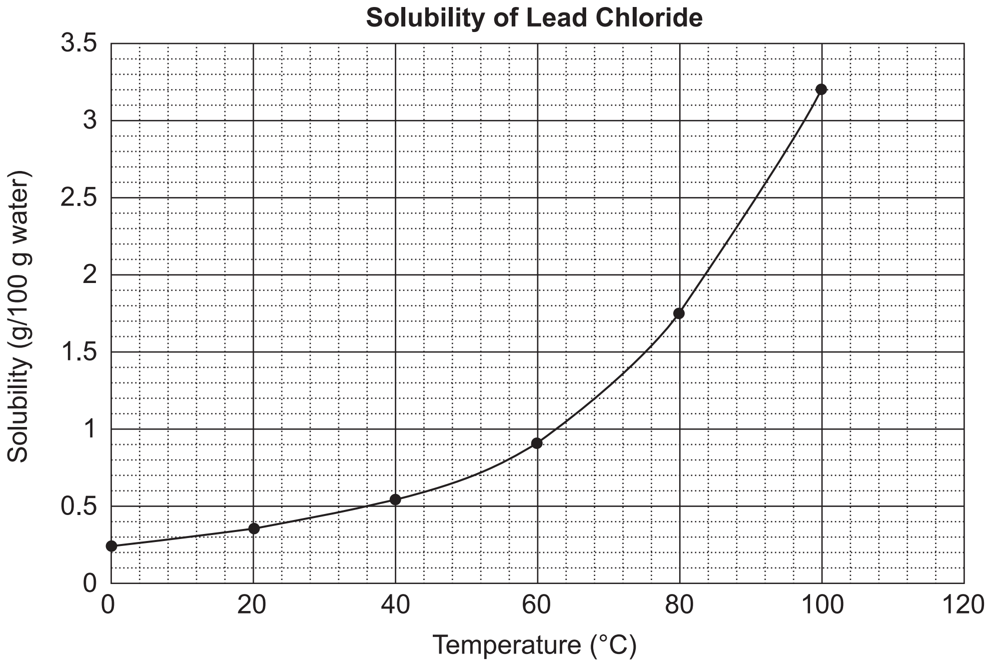
Marking guidelines:

Criteria	**Marks**
• Correctly calculates K_{sp} • Provides a fully labelled graph showing correct scale and line of best fit • Includes a relevant chemical equation	6
• Applies correct process to calculate K_{sp} • Provides a fully labelled graph showing correct scale and line of best fit • Includes a relevant chemical equation	5
• Provides some steps to calculate K_{sp} • Provides a labelled graph showing scale and line of best fit • Includes a relevant chemical equation	4
• Provides a substantially correct graph showing scale and line of best fit OR • Plots some correct points and includes a relevant chemical equation	2–3
• Provides some basic features of the graph	1

Question 17 continues on page 28

Question 17 (continued)

Sample answer:



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

At 50°C, solubility is 0.7g/100 mL, so it is 7 g/L.

Convert this to mol L^{-1}

$$n = \frac{m}{M}$$

$$n = \frac{7}{278.1}$$

$$= 0.0252$$

$\therefore$ 0.0252 mol L^{-1}

$K_{sp} = x \times (2x)^2$

$K_{sp} = 4x^3$

$K_{sp} = 4(0.0252)^3 = 4 \times 1.6 \times 10^{-5}$

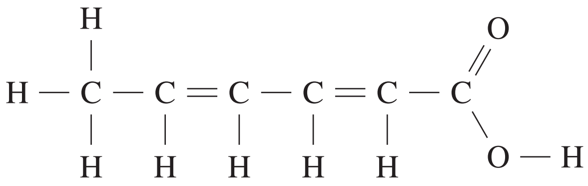
$= 6 \times 10^{-5}$

End of Question 17

Module 6 Acid/base Reactions

Mod 6 – Question 1

The structure of an organic compound is shown.



Which row of the table correctly shows how this compound reacts with bromine water and with blue litmus?

	Bromine water	*Blue litmus*
A.	No reaction	No reaction
B.	No reaction	Turns red
C.	Decolourises	No reaction
D.	Decolourises	Turns red

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 6 Properties of Acids and Bases Mod 8 Analysis of Organic Substances	CH12–13, CH12–15	2–3	D

Mod 6 – Question 2

Which of the following is NOT a Brønsted–Lowry reaction?

A. $NH_4^+ + NH_2^- \rightleftharpoons 2NH_3$

B. $CO_2 + OH^- \rightleftharpoons HCO_3^-$

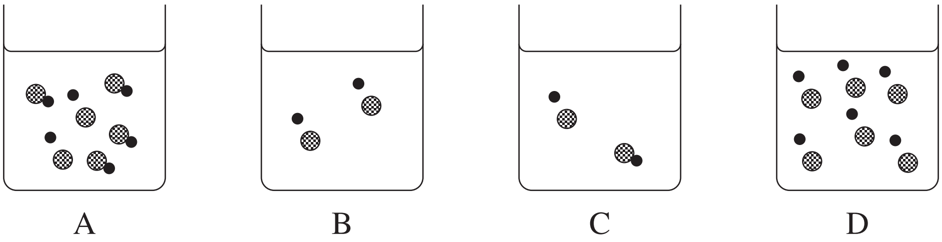
C. $HClO_4 + CH_3COOH \rightleftharpoons CH_3COOH_2^+ + ClO_4^-$

D. $CH_3CH_2O^- + CH_3NH_3^+ \rightleftharpoons CH_3CH_2OH + CH_3NH_2$

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 6 Properties of Acids and Bases	CH12–6, CH12–13	3–4	B

Mod 6 – Question 3

Which beaker contains a concentrated strong acid?



Content	Syllabus outcomes	Bands	Key
Mod 6 Using Brønsted–Lowry Theory	CH12–4, CH12–13	3–4	D

Mod 6 – Question 4

Which of the following is the conjugate base of the dihydrogen phosphate ion ($H_2PO_4^{-1}$)?

A. H_3PO_4

B. HPO_4^{-2}

C. PO_4^{-3}

D. OH^{-1}

Content	Syllabus outcomes	Bands	Key
Mod 6 Using Brønsted-Lowry Theory	CH12–6, CH12−13	4–5	B

Mod 6 – Question 5

The pKa of trichloroacetic acid is 0.70 and the pKa of acetic acid is 4.8.

Which of the following identifies the acid with the higher pH and explain why?

A. Acetic acid as it is less likely to lose a hydrogen ion

B. Acetic acid as it is more likely to lose a hydrogen ion

C. Trichloroacetic acid as it is less likely to lose a hydrogen ion

D. Trichloroacetic acid as it is more likely to lose a hydrogen ion

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 6 Quantitative Analysis	CH12–6, CH12−13	4–5	A

Mod 6 – Question 6

Equal volumes of four different acids are titrated with the same base at 25°C.

Information about these acids is given in the table.

Acid	*Concentration* (mol L^{-1})	pH
HCl	0.1	1.0
H_3PO_4	0.1	1.6
CH_3COOH	0.1	2.9
HCN	0.1	5.1

Which acid requires the greatest volume of base for complete reaction?

A. HCl

B. H_3PO_4

C. CH_3COOH

D. HCN

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 6 Quantitative Analysis	CH12–4, CH12–5, CH12–13	4–5	B

Mod 6 – Question 7

A solution containing potassium dihydrogen phosphate and potassium hydrogen phosphate is a common laboratory buffer with a pH close to 7.

Which row of the table correctly identifies the chemistry of this buffer?

	Buffer equation	*Equilibrium shift*	
		Acid is added to the solution	*Alkali is added to the solution*
A.	$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$	Right	Left
B.	$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$	Left	Right
C.	$H_2PO_4^{-} + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$	Right	Left
D.	$H_2PO_4^{-} + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$	Left	Right

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 6 Quantitative Analysis Mod 6 Using Brønsted–Lowry Theory	CH12–5, CH12–6, CH12–13	4–5	D

Mod 6 – Question 8

Chlorous acid ($HClO_2$) has a pK_a of 1.96. Nitrous acid (HNO_2) has a pK_a of 3.39.

Which of the following solutions has the highest pH?

A. 0.1 M HNO_2

B. 0.1 M $HClO_2$

C. 0.1 M $NaNO_2$

D. 0.1 M $NaClO_2$

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 6 Quantitative Analysis Mod 6 Using Brønsted–Lowry Theory	CH12–5, CH12–6, CH12–13	5–6	C

Mod 6 – Question 9

A neutralisation reaction takes place between 50 mL of 0.1 mol L^{-1} sulfuric acid and 75 mL of 0.15 mol L^{-1} sodium hydroxide.

What is the pH of the solution after the reaction has occurred?

A. pH 2

B. pH 7

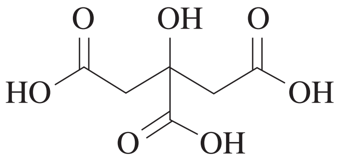
C. pH 12

D. pH 13

Content	Syllabus outcomes	Bands	Key
Mod 6 Quantitative Analysis	CH12–4, CH12–13	5–6	C

Mod 6 – Question 10 (9 marks)

A titration is carried out to determine the citric acid content of 1 L of orange juice. Citric acid, $C_6H_8O_7$, has the following structural formula and is a triprotic weak acid.



First, a solution of sodium hydroxide was standardised by titration against potassium hydrogen phthalate (a weak acid) and found to have a concentration of exactly 0.0540 mol L^{-1}.

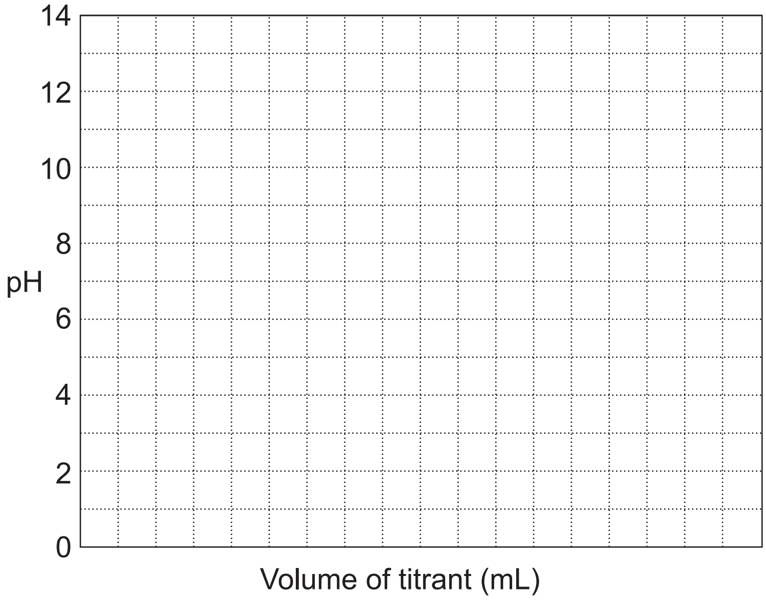
Next, the orange juice was diluted by taking 10 mL of juice and making it up to 50 mL with distilled water. 25 mL samples of the diluted orange juice were placed in clean conical flasks and titrated against the standardised sodium hydroxide. The average amount of sodium hydroxide needed to reach equivalence was 17.3 mL.

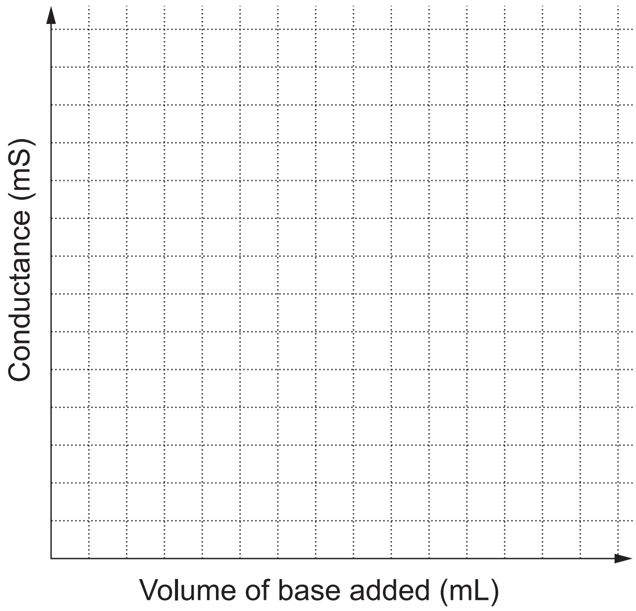
(a) Identify a suitable indicator for this titration and justify your answer. **2**

Question 10 continues on page 35

Question 10 (continued)

(b) Complete the graphs to show the change in pH and the change in conductivity during the titration. Indicate the equivalence point on each graph. **4**





Question 10 continues on page 36

Question 10 (continued)

(c) Calculate the number of grams of citric acid present in 1 L of undiluted orange juice. **3**

Mapping grid (a):

Content	**Syllabus outcomes**	**Bands**
Mod 6 Quantitative Analysis Mod 6 Properties of Acids and Bases	CH12–2, CH12–6, CH12–13	3–4

Marking guidelines (a):

Criteria	**Marks**
• Identifies a suitable indicator • Provides a justification for the choice	2
• Identifies a suitable indicator OR • Provides a justification for the use of an indicator	1

Sample answer:

As the equivalence point will be about pH 8, an indicator that changes colour at this point would be required. Thus phenolphthalein would be a suitable indicator.

Mapping grid (b):

Content	**Syllabus outcomes**	**Bands**
Mod 6 Quantitative Analysis	CH12–4, CH12–6, CH12–13	2–5

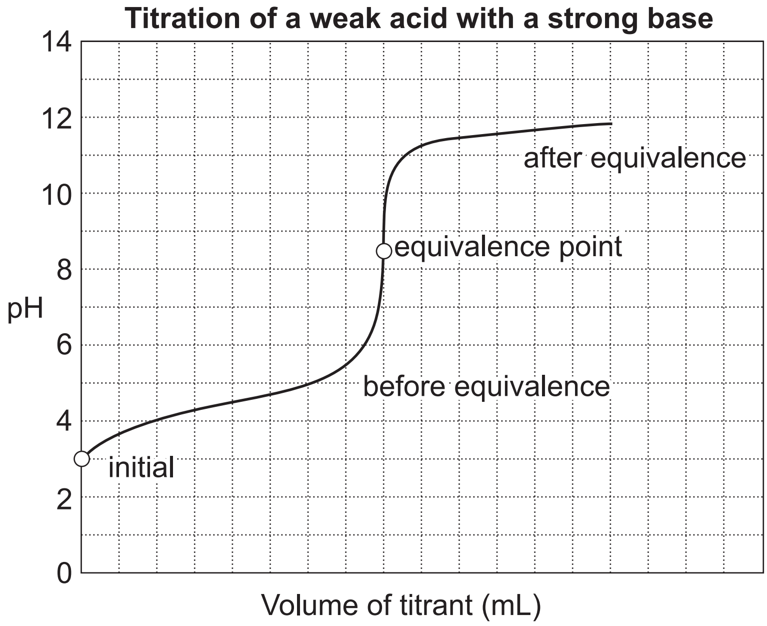
Marking guidelines (b):

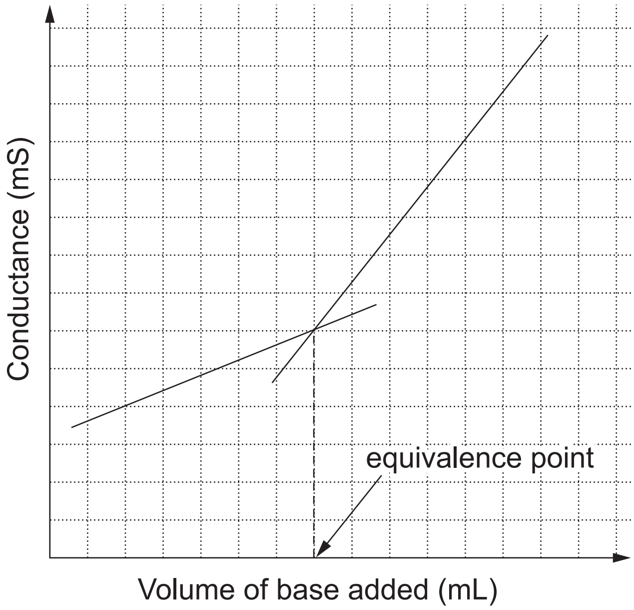
Criteria	**Marks**
• Provides TWO correct graphs with equivalence point indicated for each	4
• Provides TWO substantially correct graphs with an equivalence point indicated OR • Provides TWO correct graphs	3
• Provides a substantially correct graph with an equivalence point indicated OR • Provides TWO substantially correct graphs	2
• Provides some relevant information	1

Question 10 continues on page 37

Question 10 (continued)

Sample answer:





Question 10 continues on page 38

Question 10 (continued)

Mapping grid (c):

Content	Syllabus outcomes	Bands
Mod 6 Quantitative Analysis	CH12–4, CH12–6, CH12–13	3–5

Marking guidelines (c):

Criteria	Marks
• Correctly calculates grams of citric acid present in 1 L of orange juice	3
• Provides some steps of the calculation	2
• Provides some relevant information	1

Sample answer:

$$C_6H_8O_7 + 3NaOH \longrightarrow C_6H_8O_6Na_3 + 3H_2O$$

Average volume used was 17.3 mL of 0.0540 mol L^{-1} sodium hydroxide.

$n = cV$

$= 0.0540 \times 0.0173$

$= 9.342 \times 10^{-4}$ moles

Number of moles in 25 mL diluted orange juice = 3.12×10^{-4} moles.

As this was a 1 in 5 dilution

- 1.56×10^{-3} moles citric acid in 25 mL of undiluted juice
- 0.0624 moles citric acid in 1 L of undiluted juice

Molecular weight of citric acid = 192.124 g

∴ mass of citric acid in 1 L of orange juice

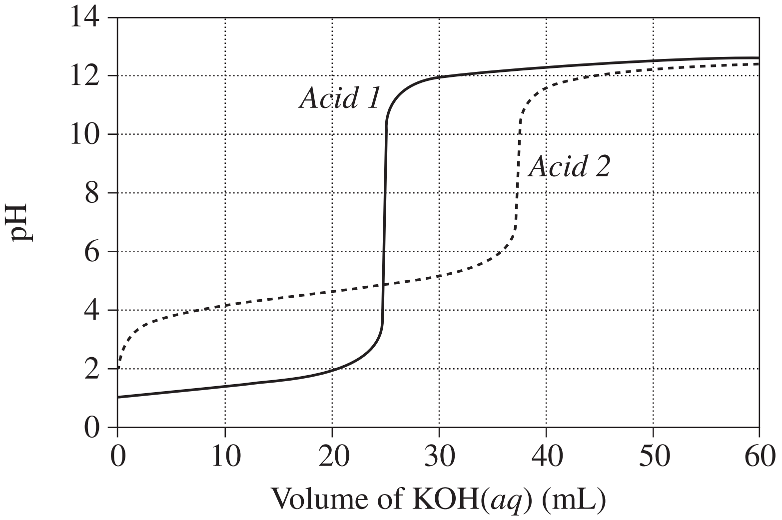
$= 0.0624 \times 192.124$

$= 12$ g

End of Question 10

Mod 6 – Question 11 (3 marks)

The graph shows changes in pH for the titrations of equal volumes of solutions of two monoprotic acids, *Acid 1* and *Acid 2*. **3**



Explain the differences between *Acid 1* and *Acid 2* in terms of their relative strengths and concentrations.

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 6 Quantitative Analysis Mod 6 Using Brønsted–Lowry Theory	CH12–5, CH12–6, CH12–13	4–6

Marking guidelines:

Criteria	Marks
• Explains the differences between *Acid 1* and *Acid 2* in terms of strength and concentration • Relates pH of equivalence point to the nature of each acid • Relates concentration to amount of base used	3
• Explains the difference between *Acid 1* and *Acid 2* in terms of strength or concentration OR • Describes the strengths and concentrations of *Acid 1* and *Acid 2* using information from the graph	2
• Provides some relevant information	1

Sample answer:

Acid 1 is a strong acid as equivalence point is at pH = 7 and initial pH is at 1. *Acid 2* is a weaker acid as pH at equivalence point is >7 and initial pH is >1. *Acid 2* has a higher concentration than *Acid 1* as it doesn't take that much more KOH to neutralise it.

Mod 6 – Question 12 (6 marks)

(a) The pH of a 0.30 M aqueous propanoic acid solution was measured to be 2.7. The dissociation of propanoic acid is represented below. **3**

$$CH_3CH_2COOH(aq) + H_2O(l) \rightleftharpoons CH_3CH_2COO^-(aq) + H_3O^+(aq)$$

Calculate the K_a of the solution.

(b) Explain how the pH of the propanoic acid solution would change if it was diluted. **3**

Mapping grid (a):

Content	**Syllabus outcomes**	**Bands**
Mod 6 Quantitative Analysis	CH12–6, CH12–13	4–6

Marking guidelines (a):

Criteria	**Marks**
• Correctly calculates K_a	3
• Provides the main steps of the calculation	2
• Provides some relevant information	1

Sample answer:

$$pH = -\log_{10}\left[H_3O^+\right] = 2.7$$

$$\therefore \left[H_3O^+\right] = \left[CH_3CH_2COO^-\right] = 10^{-2.7} = 1.995 \times 10^{-3} \text{ mol L}^{-1}$$

$$K_a = \frac{\left[H_3O^+\right]\left[CH_3CH_2COO^-\right]}{\left[CH_3CH_2COOH\right]}$$

$$K_a = \frac{\left(1.995 \times 10^{-3}\right)\left(1.995 \times 10^{-3}\right)}{\left(0.30 - 1.995 \times 10^{-3}\right)}$$

$$K_a = 1.3 \times 10^{-5}$$

Question 12 continues on page 41

Question 12 (continued)

Answers could include:

Concentration (mol L^{-1})	CH_3CH_2COOH	H_3O^+	$CH_3CH_2COO^-$
Initial	0.30	0	0
Change	$-x$	$+x$	$+x$
At equilibrium	$(0.30 - x)$	x	x

$$x = \left[H_3O^+\right]$$

$$\text{pH} = -\log_{10}\left[H_3O^+\right] = 2.7$$

$$x = \left[H_3O^+\right] = 10^{-2.7} = 1.995 \times 10^{-3} \text{ mol L}^{-1}$$

$$K_a = \frac{\left[H_3O^+\right]\left[CH_3CH_2COO^-\right]}{\left[CH_3CH_2COOH\right]}$$

$$= \frac{x^2}{(0.30 - x)}$$

$$= \frac{\left(1.995 \times 10^{-3}\right)^2}{\left(0.30 - 1.995 \times 10^{-3}\right)}$$

$$= 1.3 \times 10^{-5}$$

Question 12 continues on page 42

Question 12 (continued)

Mapping grid (b):

Content	**Syllabus outcomes**	**Bands**
Mod 5 Factors that Affect Equilibrium Mod 6 Using Brønsted–Lowry Theory	CH12–6, CH12–12, CH12–13	2–5

Marking guidelines (b):

Criteria	**Marks**
• Provides an explanation of how the pH would change	3
• Demonstrates some understanding of the relationship between pH and dilution	2
• Provides some relevant information	1

Sample answer:

Propanoic acid is a weak acid and thus will only partially ionise in solution.

$$CH_3CH_2COOH(aq) + H_2O(l) \rightleftharpoons CH_3CH_2COO^-(aq) + H_3O^+(aq)$$

When the acid is diluted, the concentration of all species (including the hydronium ion) decreases. However, the effect of the decreasing concentrations of dissolved species causes the equilibrium to shift to the right (according to Le Chatelier). While there is an increase in ionisation, this is not sufficient to counter the decrease in hydronium ion concentration caused by the addition of water (dilution effect). The net effect is the hydronium ion concentration decreases and the pH increases.

End of Question 12

Mod 6 – Question 13 (5 marks)

(a) Explain why a mixture of acetic acid (1 M) and sodium acetate (1 M) can act as a buffer while a mixture of hydrochloric acid (1 M) and sodium chloride (1 M) cannot. **3**

(b) What determines the pH of a buffer solution? **2**

Mapping grid (a):

Content	Syllabus outcomes	Bands
Mod 6 Quantitative Analysis	CH12–6, CH12–13	4–6

Marking guidelines (a):

Criteria	Marks
• Explains why a mixture of acetic acid and sodium acetate can act as a buffer while a mixture of hydrochloric acid and sodium chloride cannot	3
• Explains why a mixture of acetic acid and sodium acetate can act as a buffer OR • Explains why a mixture of hydrochloric acid and sodium chloride cannot act as a buffer	2
• Provides some relevant information	1

Sample answer:

A mixture of acetic acid and sodium acetate is a mixture of a weak acid and the salt of its conjugate base. As the conjugate base of a weak acid is a moderately strong base, CH_3COO^- will have a tendency to react with H^+ ions in solution according to the following equation:

$$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq).$$

Any addition of H^+ ions will drive the equilibrium to the left absorbing H^+ ions and minimising any change in pH. Any addition of OH^- ions will remove H^+ ions from the above equation and thus drive the reaction in the forward direction generating more H^+ ions and keeping the pH more or less constant.

The conjugate base of a strong acid is a weak base and thus Cl^- ions will have no tendency to react with H^+ ions. Any additional H^+ ions or OH^- ions will simply change the pH.

Question 13 continues on page 44

Question 13 (continued)

Mapping grid (b):

Content	**Syllabus outcomes**	**Bands**
Mod 6 Quantitative Analysis	CH12–6, CH12–13	4–5

Marking guidelines (b):

Criteria	**Marks**
• Correctly identifies what determines the pH of a buffer solution	2
• Provides some relevant information	1

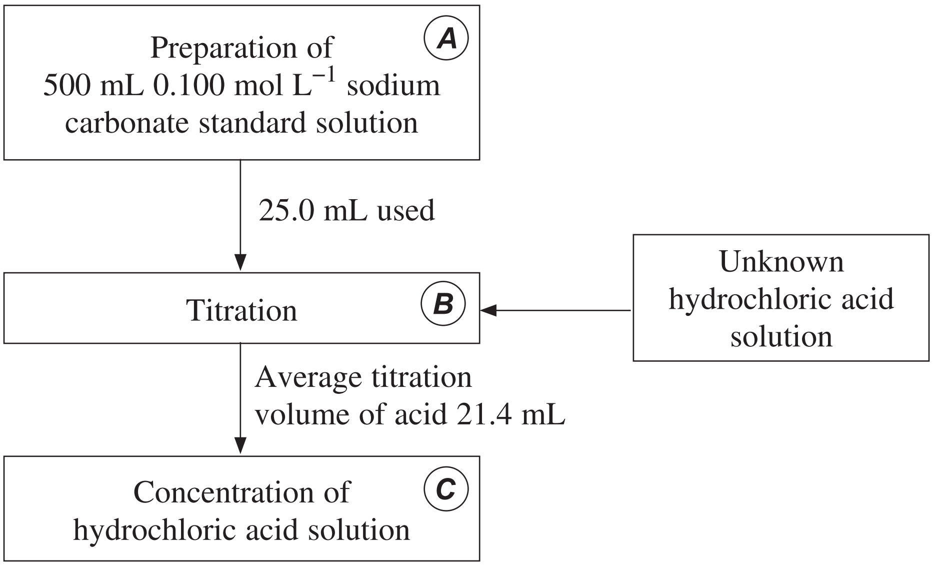
Sample answer:

The pH of the buffer depends on the pK_a of the acid and the relative concentrations of the acid and its conjugate base.

End of Question 13

Mod 6 – Question 14 (8 marks)

The flowchart shown outlines the sequence of steps used to determine the concentration of an unknown hydrochloric acid solution. **8**



Describe steps A, B and C including correct techniques, equipment and appropriate calculations. Determine the concentration of the hydrochloric acid.

Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 6 Quantitative Analysis	CH12–2, CH12–3, CH12–4, CH12–6, CH12–13	2–6

Question 14 continues on page 46

Question 14 (continued)

Marking guidelines:

Criteria	**Marks**
• Demonstrates a comprehensive understanding of all THREE steps by describing features of steps with appropriate reference to techniques and equipment used • Determines concentration of HCl correctly with correct equation	7–8
• Demonstrates a sound understanding of all THREE steps by outlining features of steps with appropriate reference to some techniques and equipment used • Provides ONE correct calculation and correct equation	5–6
• Demonstrates some understanding of all THREE steps. Refers to some techniques and equipment used • Calculates moles or mass of Na_2CO_3 or correct equation	3–4
• Demonstrates a basic understanding of some steps or refers to some techniques or equipment used OR • Calculates formula mass of Na_2CO_3, or titrated moles or mass of Na_2CO_3 with some outline of procedure OR • Calculates correct concentration of HCl OR • Provides correct equation and refers to some techniques or equipment used	1–2

Question 14 continues on page 47

Sample answer:

1. Na_2CO_3 should be initially dried and stored in a dessicator.
2. Weigh out accurately 5.30 g of dried Na_2CO_3.
   Mass of $Na_2CO_3 = 0.1 \times 0.5 \times 105.99$
3. Clean and rinse a 500 mL volumetric flask with distilled water.
4. Add the weighted Na_2CO_3 to the volumetric flask using a funnel and wash using distilled water. Add distilled water to the flask to the bottom of the meniscus.
5. Clean, rinse, and fill a 50 mL burette with the unknown acid and place on a retort stand.
6. Clean a 250 mL conical flask and rinse with distilled water.
7. Clean a 25 mL pipette and rinse with 0.1 M Na_2CO_3 solution. Fill pipette with Na_2CO_3 solution to bottom of meniscus.
8. Add pipette volume into conical flask. Add suitable indicator to the conical flask. Place a white tile under the conical flask.
9. Slowly add acid solution from the burette into the conical flask. When indicator changes colour record the final volume. This initial titration should be taken as a rough test. Three more titrations should be performed with the average titration being used for calculations.
10. Calculate the concentration of HCl

$$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g)$$

$$\text{moles of } Na_2CO_3 = 0.1 \times 0.025$$
$$= 2.5 \times 10^{-3}$$

$$\text{moles of HCl} = 2 \times \text{moles of } Na_2CO_3$$
$$= 5 \times 10^{-3}$$

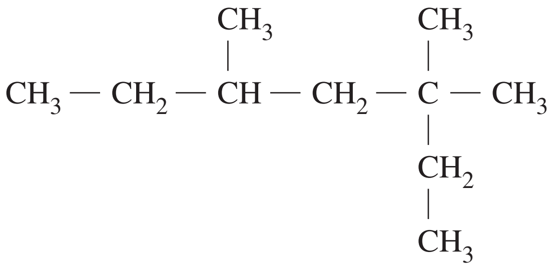
$$\text{Concentration of HCl} = \frac{\text{moles of HCl}}{\text{vol of HCl}}$$
$$= \frac{5 \times 10^{-3}}{21.4 \times 10^{-3}}$$
$$= 0.234 \text{ mol L}^{-1}$$

End of Question 14

Module 7 Organic Chemistry

Mod 7 – Question 1

The formula for a compound is shown.



$$\begin{array}{ccccccccccc}
 & & & & \mathrm{CH_3} & & & & \mathrm{CH_3} & & \\
 & & & & | & & & & | & & \\
\mathrm{CH_3} & - & \mathrm{CH_2} & - & \mathrm{CH} & - & \mathrm{CH_2} & - & \mathrm{C} & - & \mathrm{CH_3} \\
 & & & & & & & & | & & \\
 & & & & & & & & \mathrm{CH_2} & & \\
 & & & & & & & & | & & \\
 & & & & & & & & \mathrm{CH_3} & &
\end{array}$$

What is the name of this compound?

A. 3,3,5-trimethylheptane

B. 3,5,5-trimethylheptane

C. 3,4-dimethyl-5-ethylhexane

D. 2-ethyl-2,4-dimethylhexane

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 7 Nomenclature	CH12–7, CH12–14	2–3	A

Mod 7 – Question 2

How many chain isomers does pentane have?

A. 1

B. 2

C. 3

D. 4

Content	Syllabus outcomes	Bands	Key
Mod 7 Nomenclature	CH12–14	3–4	C

Mod 7 – Question 3

In which of the following pairs are the substances isomers of each other?

A. Pent-1-ene and 2-methylbut-1-ene

B. Pentane and 2,3-dimethylbutane

C. Pentanal and penan-1-ol

D. Dichloromethane and trichloromethane

Content	Syllabus outcomes	Bands	Key
Mod 7 Nomenclature	CH12–6, CH12–14	3–4	A

Mod 7 – Question 4

Which of the following isomeric alkanes has the lowest boiling temperature?

A. 2-methylpentane

B. 2,2-dimethylbutane

C. 3-methylpentane

D. Hexane

Content	Syllabus outcomes	Bands	Key
Mod 7 Nomenclature Mod 7 Hydrocarbons	CH12–6, CH12−14	4–5	B

Mod 7 – Question 5

Within a homologous series such as the alkanes, boiling points

A. are all approximately the same.

B. increase as the molar masses increase.

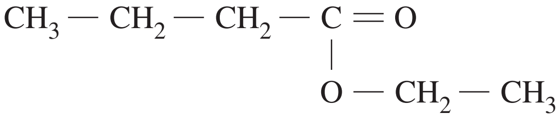
C. are independent of intermolecular forces.

D. decrease as the molecules become larger.

Content	Syllabus outcomes	Bands	Key
Mod 7 Hydrocarbons	CH12–14	2–3	B

Mod 7 – Question 6

The formula for an ester is shown.



$$\begin{array}{l} CH_3-CH_2-CH_2-C=O \\ | \\ O-CH_2-CH_3 \end{array}$$

Which alkanol and alkanoic acid were used to make this ester?

A. Ethanol and butanoic acid

B. Pentanol and ethanoic acid

C. Butanol and propanoic acid

D. Pentanol and pentanoic acid

Content	Syllabus outcomes	Bands	Key
Mod 7 Reactions of Organic Acids and Bases	CH12–7, CH12–14	2–3	A

Mod 7 – Question 7

An esterification reaction is to be performed.

Which of the following substances, when added, would increase the yield of the product?

A. Water

B. Boiling chips

C. More alkanol

D. Dilute sulfuric acid

Content	Syllabus outcomes	Bands	Key
Mod 7 Reactions of Organic Acids and Bases	CH12–3, CH12–14	3–4	C

Mod 7 – Question 8 (7 marks)

(a) Draw the structural formulae and name all possible isomers of hexane. **3**

(b) Primary, unbranched alcohols and alkanes of the same carbon length have quite different boiling points. **4**

Explain the difference in boiling point of these organic compounds, showing all intermolecular forces. Support your answer with diagrams.

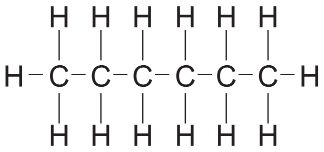
Mapping grid (a):

Content	**Syllabus outcomes**	**Bands**
Mod 7 Hydrocarbons Mod 7 Nomenclature	CH12–4, CH12–14	3–5

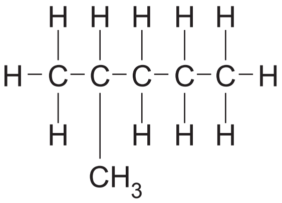
Marking guidelines (a):

Criteria	**Marks**
• Correctly draws and names structural formulae for all 5 isomers	3
• Correctly draws and names some isomers	2
• Provides some relevant information	1

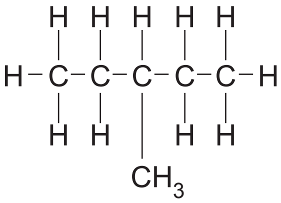
Sample answer:



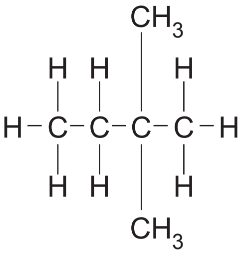
Hexane



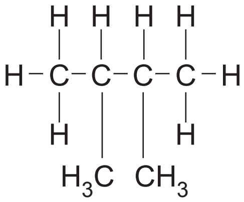
2-methylpentane



3-methylpentane



2,2-dimethylbutane



2,3-dimethylbutane

Question 8 continues on page 53

Question 8 (continued)

Mapping grid (b):

Content	**Syllabus outcomes**	**Bands**
Mod 7 Hydrocarbons Mod 7 Alcohols	CH12–4, CH12–7, CH12–14	2–5

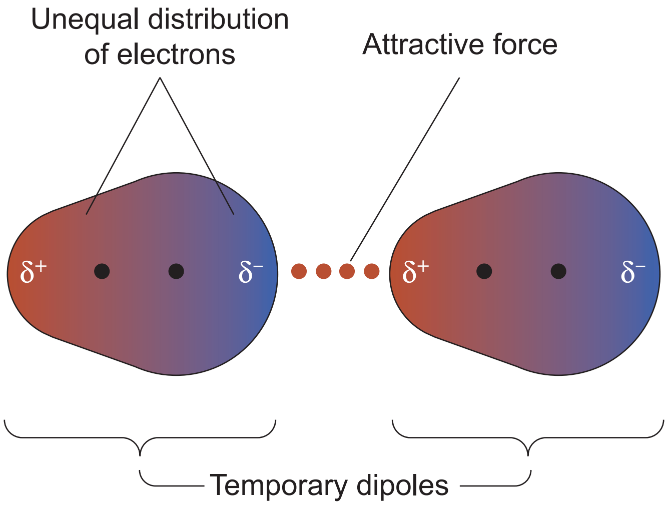
Marking guidelines (b):

Criteria	**Marks**
• Explains the difference in boiling point of the organic compounds • Supports answer with diagrams showing all intermolecular forces	4
• Explains the difference in boiling point of the organic compounds • Supports answer with a diagram showing all intermolecular forces OR • Draws annotated diagrams to explain the difference in boiling point of the organic compounds	3
• Links bonding to boiling points of the organic compounds OR • Links bonding to boiling point of one of the organic compounds and supports answer	2
• Provides some relevant information	1

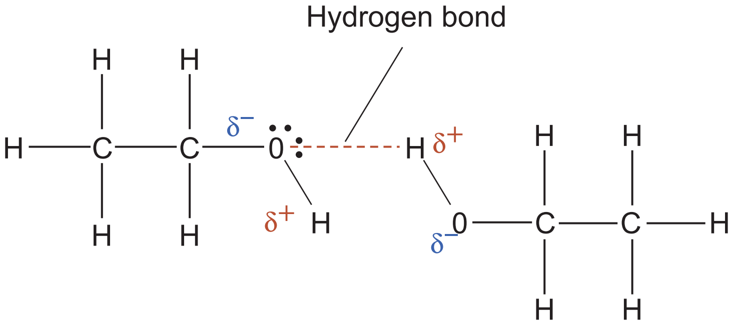
Sample answer:

Alkanes are saturated hydrocarbons consisting of carbon and hydrogen atoms only. All atoms are joined together by single covalent bonds and these bonds are non-polar. The only intermolecular forces holding alkane molecules together are weak dispersion forces (Van der Waals) so alkanes have low boiling points.

Question 8 continues on page 54



In contrast, alcohols have an OH functional group and the OH bond is polar thus the molecule has a dipole where the oxygen atom is slightly negatively charged and the hydrogen is slightly positively charged. The hydrogen atom on one molecule will form an electrostatic bond with the oxygen atom on another atom thus forming a hydrogen bond.

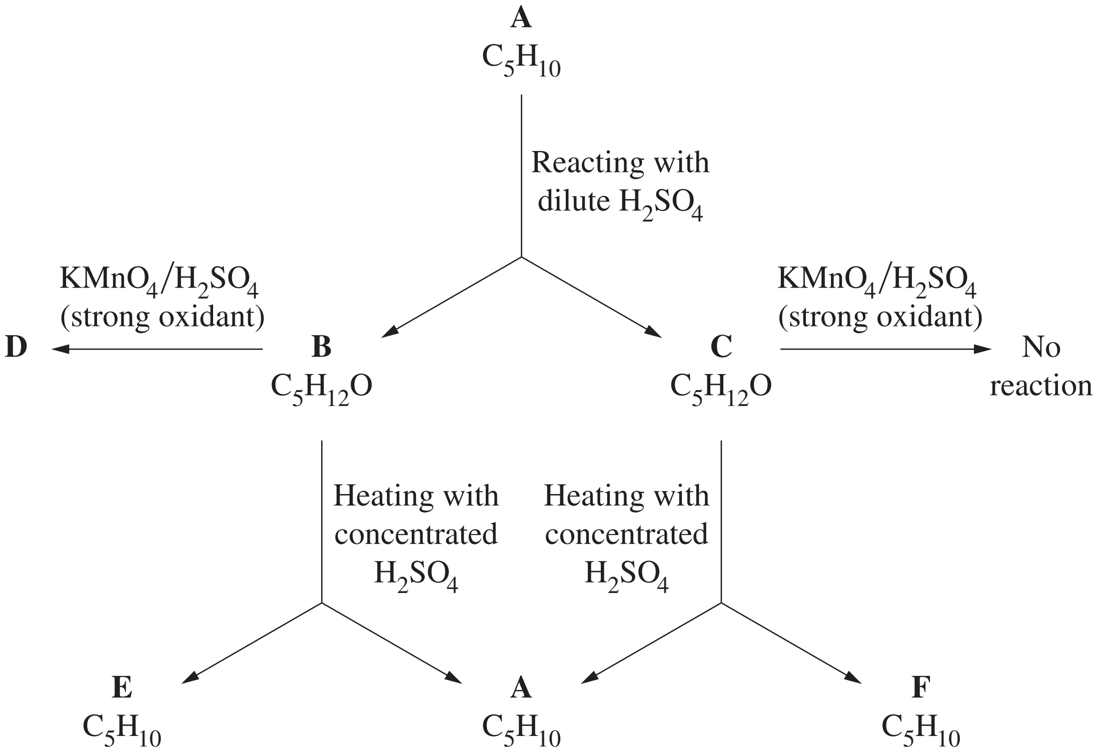


As hydrogen bonds are much stronger intermolecular forces than dispersion forces, the boiling points of alcohols are much higher than their corresponding alkanes.

End of Question 8

Mod 7 – Question 9 (7 marks)

This flow chart shows reactions involving six different organic compounds (**A** to **F**). **7**



Draw the structures of compounds **A** to **F**, justifying your diagrams with reference to the information provided.

Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 7 Products of Reactions Involving Hydrocarbons	CH12–5, CH12–6, CH12–14	2–6

Marking guidelines:

Criteria	**Marks**
• Correctly draws the structures of the six compounds and provides a justification for each compound	7
• Correctly draws most of the structures with relevant justifications	6
• Correctly draws some of the structures with relevant justifications	4–5
• Identifies some characteristics of the compound(s)	2–3
• Provides some relevant information	1

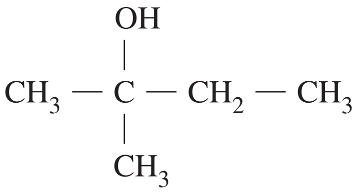
Question 9 continues on page 56

Question 9 (continued)

Sample answer:

A undergoes an addition reaction with water to form two alkanols, **B** and **C**. **C** must be a tertiary alcohol since it does not undergo oxidation.

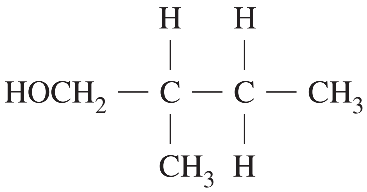
The only tertiary alcohol with a formula of $C_5H_{10}O$ is:



$CH_3-C(OH)(CH_3)-CH_2-CH_3$

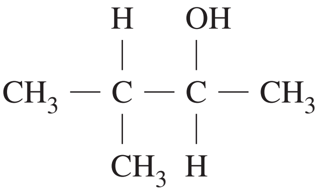
which is **C**.

B is another alcohol formed by addition of water to **A**. Given the structure of **C**, **B** could be either 2-methylbutan-1-ol:



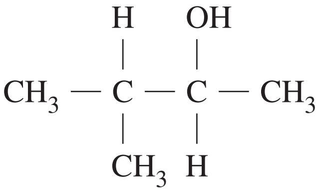
$HOCH_2-CH(CH_3)-CH_2-CH_3$

OR 3-methylbutan-2-ol:



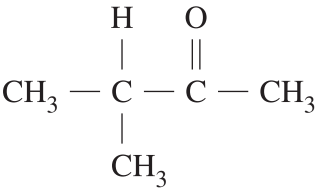
$CH_3-CH(CH_3)-CH(OH)-CH_3$

B gives two products when dehydrated with concentrated H_2SO_4: **A** and **E**. 2-methylbutan-1-ol only gives one dehydration product, whereas 3-methylbutan-2-ol gives two. This means that **B** must be 3-methylbutan-2-ol:



$CH_3-CH(CH_3)-CH(OH)-CH_3$

B is a secondary alkanol. Oxidation produces a ketone **D**.



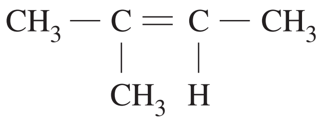
$CH_3-CH(CH_3)-C(=O)-CH_3$

Question 9 continues on page 57

Question 9 (continued)

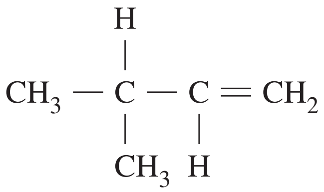
A can be formed by the dehydration of both **B** and **C** using concentrated H_2SO_4.

Therefore **A** is



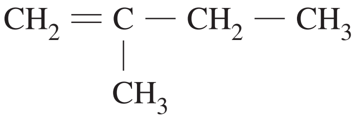
$CH_3-\underset{CH_3}{\underset{|}{C}}=\underset{H}{\underset{|}{C}}-CH_3$

B dehydrates to either **A** or **E**. So **E** is



$CH_3-\overset{H}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}-\underset{H}{\underset{|}{C}}=CH_2$

C dehydrates to either **A** or **F**. So **F** is



$CH_2=\underset{CH_3}{\underset{|}{C}}-CH_2-CH_3$

End of Question 9

Mod 7 – Question 10 (3 marks)

Calculate the mass of methanol that must be burnt to increase the temperature of 250 g of water by 65°C, if exactly half of the heat released by this combustion is lost to the surroundings. **3**

The heat of combustion of methanol is 726 kJ mol^{-1}.

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 7 Alcohols	CH12–5, CH12–6, CH12–14	3–5

Marking guidelines:

Criteria	Marks
• Correctly calculates initial mass of methanol	3
• Provides the main steps of the calculation	2
• Provides some relevant information	1

Sample answer:

$q = mc\Delta T$

$q = 250 \times 10^{-3} \times 4.18 \times 10^{3} \times 65$

67 925 J = 67.925 kJ

1 mole = 726 kJ

$$n_{\text{methanol}} = \frac{67.925}{726}$$

$$m_{\text{methanol}} = \frac{67.925}{726} \times 32.042$$

Since 50% of heat has been lost

$$\text{Initial mass methanol} = 2 \times \frac{67.925}{726} \times 32.042$$

$$\therefore \text{initial mass methanol} = 5.996$$
$$= 6.0 \text{ g}$$

Mod 7 – Question 11 (6 marks)

(a) Design a procedure that can be used to produce the ester, ethyl ethanoate, in a school laboratory. **4**

(b) Describe a safety precaution in the production of an ester in a school laboratory. **2**

Mapping grid (a):

Content	**Syllabus outcomes**	**Bands**
Mod 7 Reactions of Organic Acids and Bases	CH12–2, CH12–14	2–5

Marking guidelines (a):

Criteria	**Marks**
• Provides a suitable procedure for making ethyl ethanoate	4
• Provides a suitable procedure for making an ester	3
• Identifies some steps for making an ester	2
• Provides some relevant information	1

Sample answer:

1. Set up a mantle or hot plate and reflux equipment.

2. Pour 10 mL ethanol into a round bottom flask and add 20 mL of glacial acetic acid.

3. Add 1 mL of concentrated sulfuric acid to the mixture and boiling chips and heat under reflux for 45 minutes.

4. Allow to cool and then transfer contents of the round bottom flask to a separating funnel.

5. Wash with plenty of distilled water to remove any excess alcohol and acetic acid. The ester layer will float on top of the aqueous layer so expel the lower aqueous layer in the separating funnel.

6. Finally, add a solution of 1 mol L^{-1} sodium carbonate to remove any final traces of acid. Once again, the ester will float on top of the aqueous layer which can be let out of the bottom of the separating funnel.

Question 11 continues on page 60

Question 11 (continued)

Mapping grid (b):

Content	Syllabus outcomes	Bands
Mod 7 Reactions of Organic Acids and Bases	CH12–2, CH12–14	3–4

Marking guidelines (b):

Criteria	Marks
• Describes a relevant safety precaution	2
• Provides some relevant information	1

Sample answer:

Ethanol is flammable. Use a heating mantle/hot plate rather than a naked flame to heat the solution to prevent fires.

End of Question 11

Mod 7 – Question 12 (8 marks)

Design a procedure that can be used to produce an ester in a school laboratory. Include a scientific diagram of the set-up and justify safety precautions. **8**

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 7 Reactions of Organic Acids and Bases	CH12–2, CH12–7, CH12–14	2–6

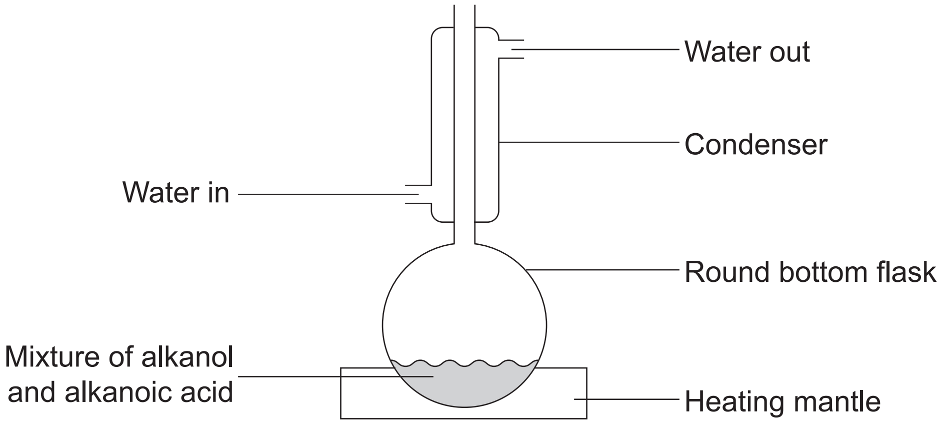
Marking guidelines:

Criteria	Marks
• Provides a suitable procedure specifying chemicals for making an ester including the catalyst • Provides a scientific diagram showing the necessary equipment and the refluxing process • Justifies safety precautions	8
• Provides a suitable procedure for making an ester • Provides a scientific diagram showing the necessary equipment and the refluxing process • Includes safety precautions and justifies one of them	7
• Provides a procedure for making an ester • Provides a scientific diagram showing the equipment and the refluxing process • Includes safety precautions	6
• Provides a procedure for making an ester • Provides a diagram showing the equipment and the refluxing process • Includes one safety precaution	5
• Provides some steps for making an ester • Provides a relevant diagram and/or includes safety precaution(s)	3–4
• Provides some relevant information	1–2

Question 12 continues on page 62

Question 12 (continued)

Sample answer:



Procedure:

1. Set up a mantle or hot plate and reflux equipment.
2. Pour 10 mL ethanol into a round bottom flask and add 20 mL of glacial acetic acid.
3. Add 1 mL of concentrated sulfuric acid to the mixture and boiling chips and heat under reflux for 45 minutes.
4. Allow to cool and then transfer contents of the round bottom flask to a separating funnel.
5. Wash with plenty of distilled water to remove any excess alcohol and acetic acid. The ester layer will float on top of the aqueous layer so expel the lower aqueous layer in the separating funnel.
6. Finally, add a solution of 1 mol L^{-1} sodium carbonate to remove any final traces of acid. Once again, the ester will float on top of the aqueous layer which can be let out of the bottom of the separating funnel.

Safety precautions:

Ethanol is flammable. Use a heating mantle/hot plate rather than a naked flame to heat the solution to prevent fires.

Since there will be a strong unpleasant smell, windows should be opened to ventilate the area. A fume cupboard should be used if available.

End of Question 12

Mod 7 – Question 13 (3 marks)

Explain how soap can be used to remove grease from clothing. Support your answer with a labelled diagram. **3**

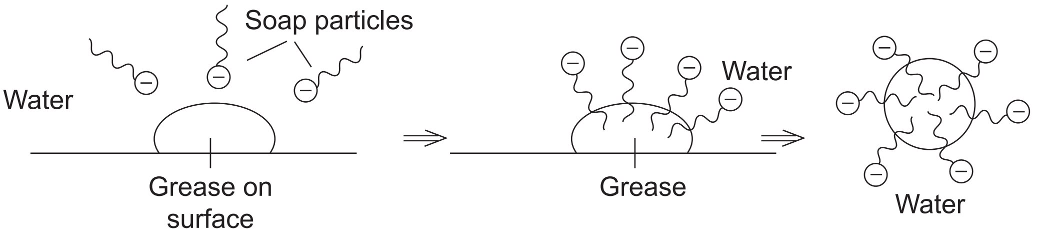
Mapping grid:

Content	Syllabus outcomes	Bands
Mod 7 Reactions of Organic Acids and Bases	CH12–4, CH12–7, CH12–14	2–4

Marking guidelines:

Criteria	Marks
• Explains how soap can be used to remove grease • Supports answer with a labelled diagram	3
• Outlines how soap can be used to remove grease	2
• Provides some relevant information	1

Sample answer:



Soap molecules consist of two parts: a hydrophobic ‘tail’ consisting of fatty acids; and a hydrophilic, charged ‘head’. The grease on dirty clothes will attract the hydrophobic tails which will embed themselves in the grease particle. The hydrophilic heads will be attracted to the water and will lift the grease off the clothes and suspend it in the water as shown in the diagram.

Mod 7 – Question 14 (7 marks)

Contrast ONE addition polymer and ONE condensation polymer in terms of their structures, properties and uses. Include structural formulae in your answers. **7**

Mapping grid:

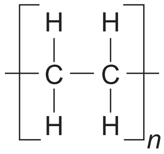
Content	Syllabus outcomes	Bands
Mod 7 Polymers	CH12–7, CH12–14	2–6

Marking guidelines:

Criteria	Marks
• Shows differences between an addition and a condensation polymer in terms of their structures, properties and uses • Includes a structural formula for each	7
• Shows differences between an addition and a condensation polymer in terms of their structures, properties and uses • Includes a structural formula	6
• Shows differences between an addition and a condensation polymer in terms of at least two of these: structures, properties or uses	4–5
• Outlines features of an addition and/or a condensation polymer	2–3
• Identifies an addition or a condensation polymer	1

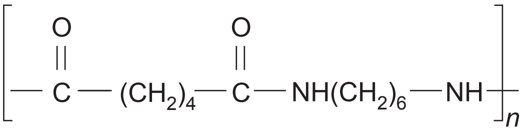
Answers could include:

- Polyethylene is an addition polymer made by the addition of ethylene monomers with the following structural formula.



$$-\left[\begin{matrix} H & & H \\ | & & | \\ C & - & C \\ | & & | \\ H & & H \end{matrix}\right]_n-$$

- Nylon is a condensation polymer made from 1,6-diaminohexane and adipic acid by splitting out water molecules, with the following structural formula.



$$\left[-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-NH(CH_2)_6-NH-\right]_n$$

- Polyethylene is weatherproof, low cost, and has good chemical resistance.
- There are two main types of polyethylene: low density polyethylene (LDPE) which is semi-rigid and is used to produce plastic sauce bottles, flexible water pipe, cling wrap; and high density polyethylene (HDPE) which is fluid and is used to produce shopping bags and plastic drums.
- Nylon is strong, relatively resistant to abrasions and moisture absorptivity, long lasting, resistant to chemicals and is used to make nylon fibre. Nylon is used for a variety of applications including clothing, reinforcement in rubber material like car tyres, for use as a rope or thread, and for a number of injection-moulded parts for vehicles and mechanical equipment.

Module 8 Applying Chemical Ideas

Mod 8 – Question 1

What is the best way to identify whether a solution contains barium ions or calcium ions?

A. Add chloride ions to the solution: barium will precipitate but calcium will not

B. Add carbonate ions to the solution: barium will precipitate but calcium will not

C. Do a flame test: barium produces a scarlet flame and calcium a blue/green flame

D. Do a flame test: barium produces a pale green flame and calcium a brick red flame

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 8 Analysis of Inorganic Substances	CH12–2, CH12−15	2–3	D

Mod 8 – Question 2

It is suspected that a stream is contaminated with metal ions. A sample of water from the stream was analysed.

The results of some tests on the sample are recorded in the table.

Test	*Result*
Add dilute HCl	No change
Add Na_2SO_4 solution	White precipitate formed
Flame test	Pale green colour

What is the most likely contaminant in the water?

A. Ba^{2+}

B. Ca^{2+}

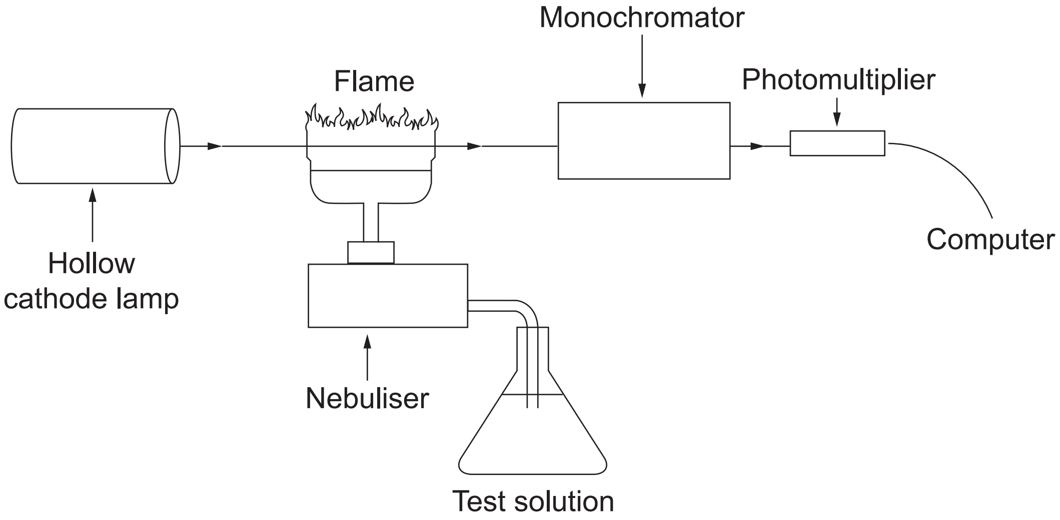
C. Cu^{2+}

D. Fe^{3+}

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 8 Analysis of Inorganic Substances	CH12–5, CH12–15	3–4	A

Mod 8 – Question 3

A diagram of an atomic absorption spectrophotometer is shown.



What is the purpose of the hollow cathode lamp?

A. To excite the sample

B. To atomise the sample

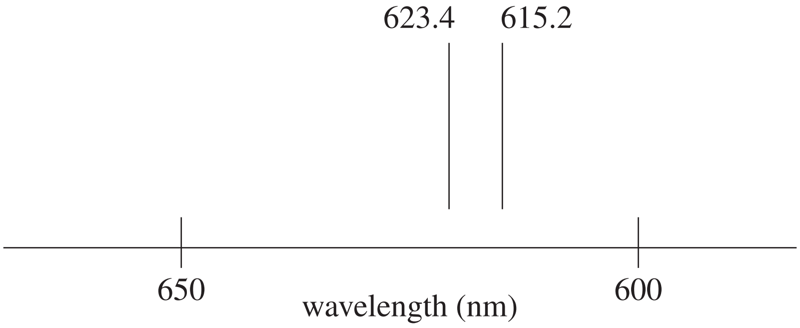
C. To produce white light

D. To produce light of specific wavelengths

Content	Syllabus outcomes	Bands	Key
Mod 8 Analysis of Inorganic Substances	CH12–4, CH12−15	3–4	D

Mod 8 – Question 4

A section of the emission spectrum of a mercury lamp is shown.



Light at 623.4 nm and 615.2 nm from the mercury lamp was passed through a sample of water containing mercury, and the intensities were then measured by a detector.

I (*x* nm) = Intensity of light at a wavelength of *x* nm from the lamp

I_d (*x* nm) = Intensity of light at a wavelength of *x* nm at the detector

Which of the following pairs of intensities can be used in the determination of the amount of mercury in the water sample using atomic absorption spectroscopy (AAS)?

A. I (615.2 nm) and I_d (615.2 nm)

B. I (615.2 nm) and I_d (623.4 nm)

C. I (615.2 nm) and I (623.4 nm)

D. I_d (615.2 nm) and I_d (623.4 nm)

Content	Syllabus outcomes	Bands	Key
Mod 8 Analysis of Inorganic Substances	CH12–5, CH12–15	5–6	A

Mod 8 – Question 5

All the lead ions present in a 50.0 mL solution were precipitated by reaction with excess chloride ions. The mass of the dried precipitate was 0.595 g.

What was the concentration of lead in the original solution?

A. 8.87 $g\,L^{-1}$

B. 10.2 $g\,L^{-1}$

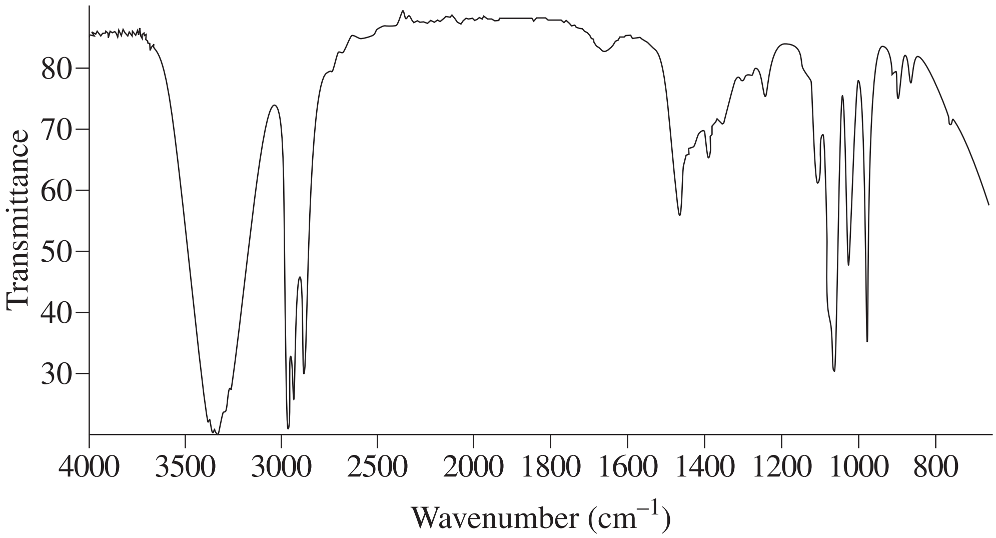
C. 11.9 $g\,L^{-1}$

D. 16.0 $g\,L^{-1}$

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 8 Analysis of Inorganic Substances	CH12–6, CH12–15	5–6	A

Mod 8 – Question 6

The diagram shows the infrared spectrum of a compound.



Which compound was analysed?

A. Butane

B. Propanol

C. Propanal

D. Butanoic acid

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 8 Analysis of Organic Substances	CH12−4, CH12−7, CH12−15	3–4	B

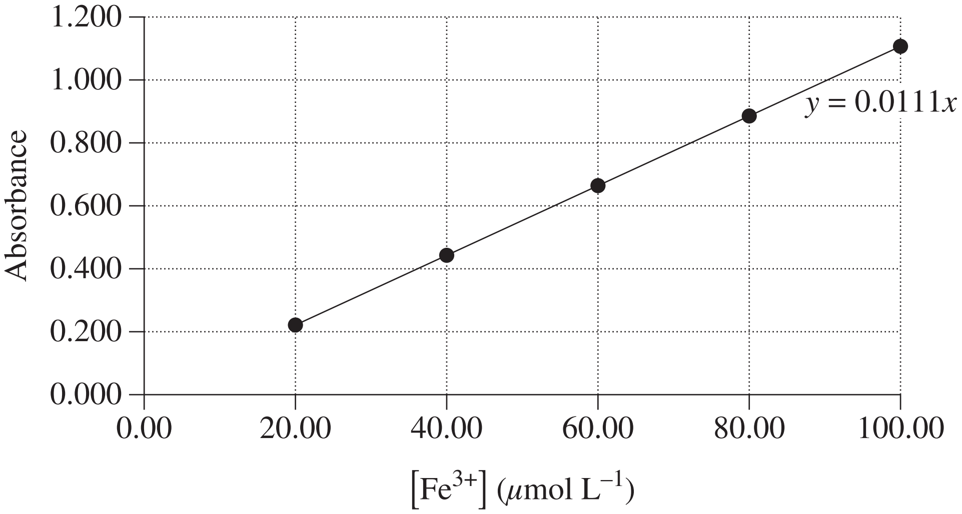
Mod 8 – Question 7

A colorimeter was used to calculate the percentage of iron in a 0.200 gram tablet. The tablet was dissolved and oxidised, then reacted with thiosulfate according to the equation

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightarrow [FeSCN]^{2+}(aq).$$

The resulting solution was made up to 200 mL with distilled water. The absorbance of the final solution was measured to be 0.6105.

The calibration curve shows the absorbance of various concentrations of Fe^{3+}.



How much iron was in the tablet?

A. 1.10×10^{-5} g

B. 5.50×10^{-5} g

C. 6.14×10^{-4} g

D. 3.07×10^{-3} g

Content	**Syllabus outcomes**	**Bands**	**Key**
Mod 8 Analysis of Organic Substances	CH12−5, CH12−7, CH12−15	4–5	C

Mod 8 – Question 8

Phosgene is prepared from the reaction of carbon monoxide and chlorine in the presence of a catalyst.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H = -9.93 \text{ kJ mol}^{-1}$$

Which set of conditions would produce the highest yield of phosgene?

A. Low temperature, low pressure

B. Low temperature, high pressure

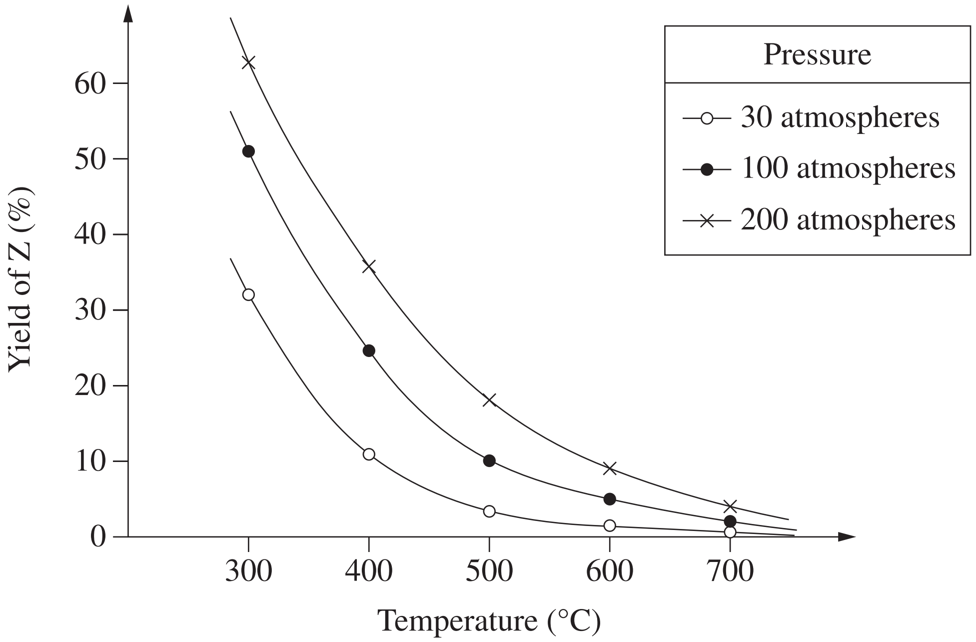
C. High temperature, low pressure

D. High temperature, high pressure

Content	Syllabus outcomes	Bands	Key
Mod 8 Chemical Synthesis and Design Mod 5 Factors that Affect Equilibrium	CH12–5, CH12–6 CH12–15	4–5	B

Mod 8 – Question 9

The graph represents the yield of an equilibrium reaction, Z, at different temperature and pressure conditions inside a reaction vessel.



Which reaction could produce the trends shown in the graph?

A. $X(g) + Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = +100$ kJ

B. $X(g) + Y(g) \rightleftharpoons 2Z(g)$ $\Delta H = -100$ kJ

C. $2X(g) + 2Y(g) \rightleftharpoons Z(g)$ $\Delta H = +100$ kJ

D. $4X(g) + 2Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = -100$ kJ

Content	Syllabus outcomes	Bands	Key
Mod 8 Chemical Synthesis and Design Mod 5 Factors that Affect Equilibrium	CH12–5, CH12–6, CH12–15	5–6	D

Mod 8 – Question 10 (4 marks)

A common antacid tablet contains aluminium hydroxide to neutralise stomach acid. In order for the antacid to be effective, each 500 mg tablet must contain a minimum of 200 mg of aluminium hydroxide. **4**

Two antacid tablets were crushed and reacted with 70 mL of 0.60 mol L^{-1} hydrochloric acid. After the antacid had reacted with the acid, the remaining hydrochloric acid was titrated against 0.60 mol L^{-1} sodium hydroxide. The average volume of sodium hydroxide used was 35 mL.

Calculate the amount of aluminium hydroxide present in each tablet and justify whether the tablets will be effective as an antacid.

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 8 Chemical Synthesis and Design Mod 8 Analysis of Inorganic Substances Mod 6 Quantitative Analysis	CH12–4, CH12–6, CH12–13, CH12–15	2–5

Marking guidelines:

Criteria	Marks
• Calculates the amount of aluminium hydroxide in each tablet • Justifies why the tablets will be effective as an antacid	4
• Applies the correct process to calculate the amount of aluminium hydroxide in each tablet and draws a relevant conclusion OR • Correctly calculates the amount of aluminium hydroxide in each tablet	3
• Provides some steps of the calculation	2
• Provides some relevant information	1

Question 10 continues on page 73

Question 10 (continued)

Sample answer:

Number of moles of hydrochloric acid in 70 mL $n = cV$

$= 0.60 \times 0.070$

$= 0.042$ moles

35 mL of the sodium hydroxide contains $0.60 \times 0.035 = 0.021$ moles. Thus 0.021 moles of hydrochloric acid remaining. Therefore 0.021 moles must have reacted with the antacid in the tablets.

$$3HCl(aq) + Al(OH)_3(aq) \longrightarrow AlCl_3(s) + 3H_2O(l)$$

As the mole ratio is 3 : 1 there must be 0.021 / 3 moles of aluminium hydroxide in the tablets. This = 0.007 moles in 2 tablets.

Formula weight of aluminium hydroxide = 78 g. The mass of aluminium hydroxide in 2 tablets = $0.007 \times 78 = 0.546$ g thus each 500 mg tablet would contain 273 mg of aluminium hydroxide. The tablets are effective as 273 mg is more than the required 200 mg.

End of Question 10

Mod 8 – Question 11 (9 marks)

Limestone ($CaCO_3$) contributes to the hardness of water by releasing Ca^{2+} ions. The following chemical equation represents this reaction. **9**

$$CaCO_3(s) + H_2O(l) + CO_2(g) \rightleftharpoons Ca^{2+}(aq) + 2HCO_3^-(aq) \qquad (\Delta H < 0)$$

It has been suggested that heating water reduces its hardness.

Explain how this suggestion can be tested accurately, validly and reliably.

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 8 Analysis of Inorganic Substances Mod 5 Factors that Affect Equilibrium	CH12–2, CH12–6, CH12–7, CH12–15	2–6

Marking guidelines:

Criteria	Marks
• Explains how the suggestion can be tested • Includes measures to ensure accuracy, validity and reliability of data	9
• Describes a process for testing the suggestion • Addresses at least two of these areas: accuracy, validity, reliability	7–8
• Outlines relevant steps for testing the suggestion • Shows some understanding of accuracy, validity or reliability	5–6
• Outlines relevant step(s) for testing the suggestion AND/OR • Shows some understanding of accuracy, validity or reliability	3–4
• Identifies relevant step(s) for testing the suggestion AND/OR • Shows a basic understanding of accuracy, validity or reliability	1–2

Question 11 continues on page 75

Question 11 (continued)

Sample answer:

Atomic absorption spectroscopy (AAS), which is used to detect concentrations of metal ions in solutions, can be used to test the suggestion. AAS can be used to determine the concentration of Ca^{2+} in both heated and non-heated samples of water. If heating water can reduce its hardness, the concentration of Ca^{2+} should be less for the heated sample.

To do this, prepare a series of standard solutions of known concentrations of Ca^{2+} and measure their absorbance. Plot the concentrations and absorbance of the standard solutions and draw a line of best fit (the calibration curve). Next, measure the absorbance of two water samples – one before heating and one after. Using the absorbance and the calibration curve, calculate the concentration of Ca^{2+} in each sample and compare the concentrations between the heated and unheated samples.

AAS when calibrated correctly is very accurate. Concentrations of calcium ions at the parts per million level (ppm) can be easily measured. To ensure that AAS is correctly calibrated, the standard solutions need to be accurately prepared. Solids should be carefully weighed and solutions can be transported using a pipette or a similar tool to ensure accuracy. Tap water is usually full of ions such as Na+ and Ca^{2+}, so deionised water should be used.
To enhance reliability, ensure that sufficient calibration samples are used and that the measurement of absorbance is repeated and averaged. It is possible to produce reliable results that fall closely to the line of best fit of the calibration curve with only a very small margin of error.

To further improve reliability, many samples of heated and non-heated water can be used to make sure that the concentrations of Ca^{2+} in the heated water samples are consistently lower than the concentrations of Ca^{2+} in the unheated water samples.

AAS also allows the suggestion to be validly tested. When a specific lamp for calcium is shone through the solution, only calcium ions will absorb the specific frequency as each element has its own unique fingerprint. This enables the experiment to measure what is intended so that an accurate and valid conclusion can be made.

Answers could include:

Use of gravimetric analysis or other chemical analysis.

End of Question 11

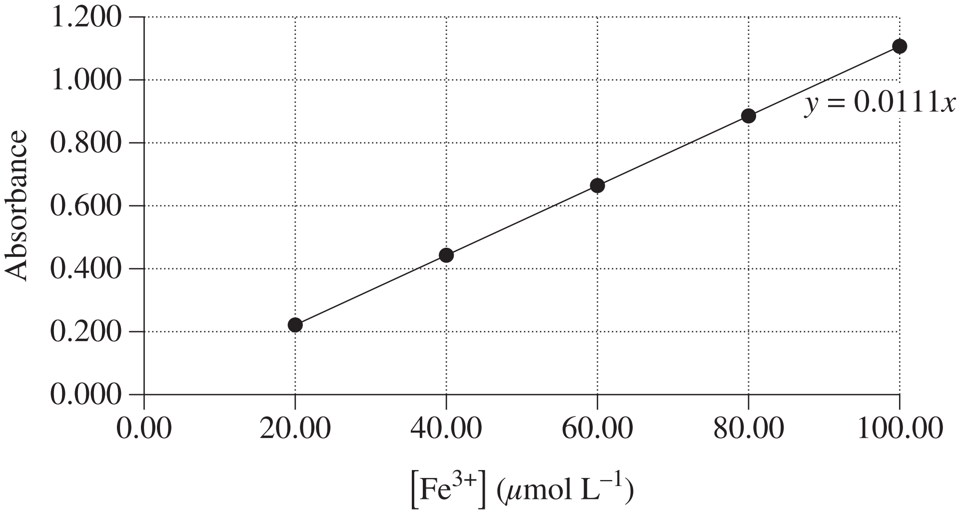
Mod 8 – Question 12 (3 marks)

A colorimeter was used to calculate the percentage of iron in a 0.200 gram tablet. The tablet was dissolved and oxidised, then reacted with thiosulfate according to the equation **3**

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightarrow [FeSCN]^{2+}(aq).$$

The resulting solution was made up to 200 mL with distilled water. The absorbance of the final solution was measured to be 0.6105.

The calibration curve shows the absorbance of various concentrations of Fe^{3+}.



Calculate the percentage of iron in the tablet.

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 8 Analysis of Inorganic Substances	CH12–5, CH12–7, CH12–15	3–5

Question 12 continues on page 77

Question 12 (continued)

Marking guidelines:

Criteria	**Marks**
• Correctly calculates the percentage of iron showing appropriate working	3
• Provides the main steps of the calculation	2
• Provides some relevant information	1

Sample answer:

From graph, absorbance of 0.615 ∴ initial $\left[\text{Fe}^{3+}\right] = 5.5 \times 10^{-5}\ \text{mol L}^{-1}$ in 200 mL solution.

To calculate moles of Fe^{3+}: $n = cV$

$$= 5.5 \times 10^{-5}\ \text{mol L}^{-1} \times 0.2\ \text{L}$$

$$= 1.1 \times 10^{-5}\ \text{mol}$$

Mass of iron $= 55.85\ \text{g mol}^{-1} \times 1.1 \times 10^{-5}\ \text{mol}$

$$= 6.14 \times 10^{-4}\ \text{g}$$

Percentage of iron $= \dfrac{6.14 \times 10^{-4}}{0.200} \times 100$

$$= 0.307\%$$

End of Question 12

Mod 8 – Question 13 (6 marks)

Fe^{2+} and X react to form an ionic compound according to the general equation

$$a\,\mathrm{Fe}^{2+} + b\,\mathrm{X} \rightleftharpoons \left[\mathrm{Fe}_a(\mathrm{X})_b\right]^{2a+}$$

where *a* and *b* are numbers representing the ratio in which Fe^{2+} and X combine.

Spectrophotometry was used to determine the stoichiometric ratio between Fe^{2+} and X. To do this, eight 10 mL samples were prepared by reacting solutions of Fe^{2+} with solutions of X in varying ratios. All Fe^{2+} and X solutions had the same concentration. The absorbance of the samples is tabulated below.

	Samples							
Volume of Fe^{2+} solution (mL)	0.00	1.00	2.00	3.00	4.00	5.00	6.00	10.00
Volume of X solution (mL)	10.00	9.00	8.00	7.00	6.00	5.00	4.00	0.00
Absorbance at 508 nm	0.00	0.42	0.84	0.98	0.84	0.70	0.56	0.00

(a) On the grid, construct a graph of absorbance against volume of Fe^{2+} solution from 0.00 mL to 6.00 mL, and draw TWO lines of best fit. **3**

Question 13 continues on page 79

(b) The reaction proceeds according to the general equation **3**

$$a\text{Fe}^{2+} + b\text{X} \rightleftharpoons [\text{Fe}_a(\text{X})_b]^{2a+}.$$

Find the values of a and b. Justify your answer with reference to the data given and the graph in part (a).

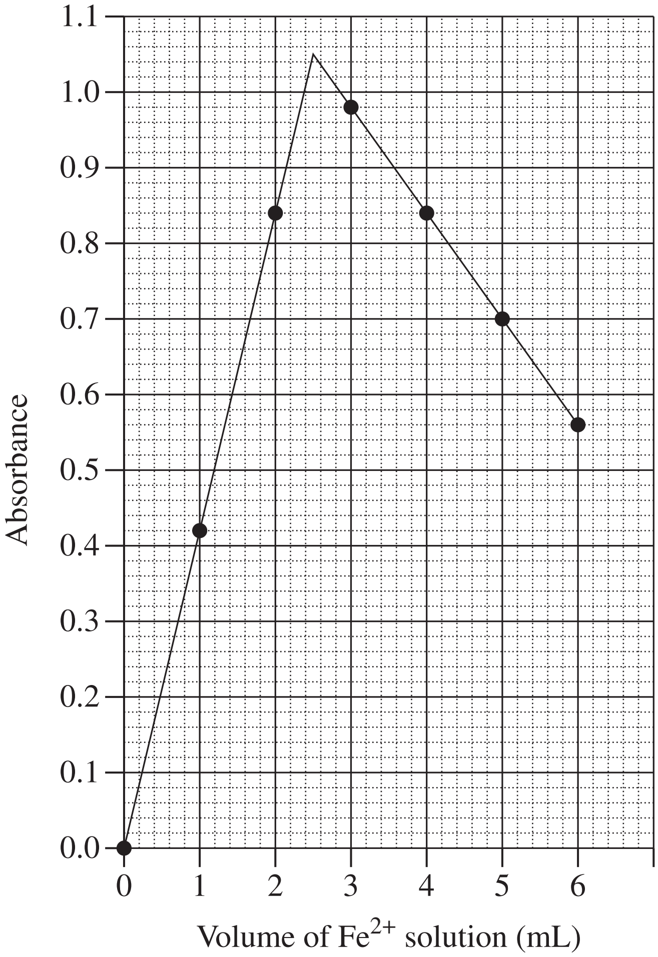
Mapping grid (a):

Content	Syllabus outcomes	Bands
Mod 8 Analysis of Inorganic Substances	CH12–4, CH12–15	2–5

Marking guidelines (a):

Criteria	Marks
• Uses appropriate scale • Labels axes correctly with units • Plots points accurately • Draws lines of best fit	3
• Provides a substantially correct graph	2
• Provides some basic features of the graph	1

Sample answer:



Question 13 continues on page 80

Question 13 (continued)

Mapping grid (b):

Content	**Syllabus outcomes**	**Bands**
Mod 8 Analysis of Inorganic Substances	CH12–5, CH12–6, CH12–15	4–6

Marking guidelines (b):

Criteria	**Marks**
• Finds the values of *a* and *b* • Justifies answer with reference to the data given and the graph	3
• Finds the values of *a* and *b* with some justification OR • Provides some explanation of the reactions with reference to the data given and/or the graph	2
• Provides some relevant information	1

Sample answer:

The graph shows an increase in Fe^{2+} ions as the amount of compound X decreases, indicating an excess of Fe^{2+} ions limiting the products. It reaches a maximum when the correct stoichiometric ratio for the equation is obtained. This occurs when 2.5 mL Fe^{2+} to 7.5 mL compound X are reacted. As the concentrations of the initial solutions are equal, equal volumes produce equal moles. Hence $a = 1$ and $b = 3$. The curve then decreases as there is less Fe^{2+}.

End of Question 13

Mod 8 – Question 14 (4 marks)

A bottle of solution is missing its label. It is either $Pb(NO_3)_2$, $Ba(NO_3)_2$ or $Fe(NO_3)_2$. **4**

Using only HCl, NaOH and H_2SO_4 solutions, outline a sequence of steps that could be followed to confirm the identity of the solution in the bottle. Include observed results and ionic equations in your answer.

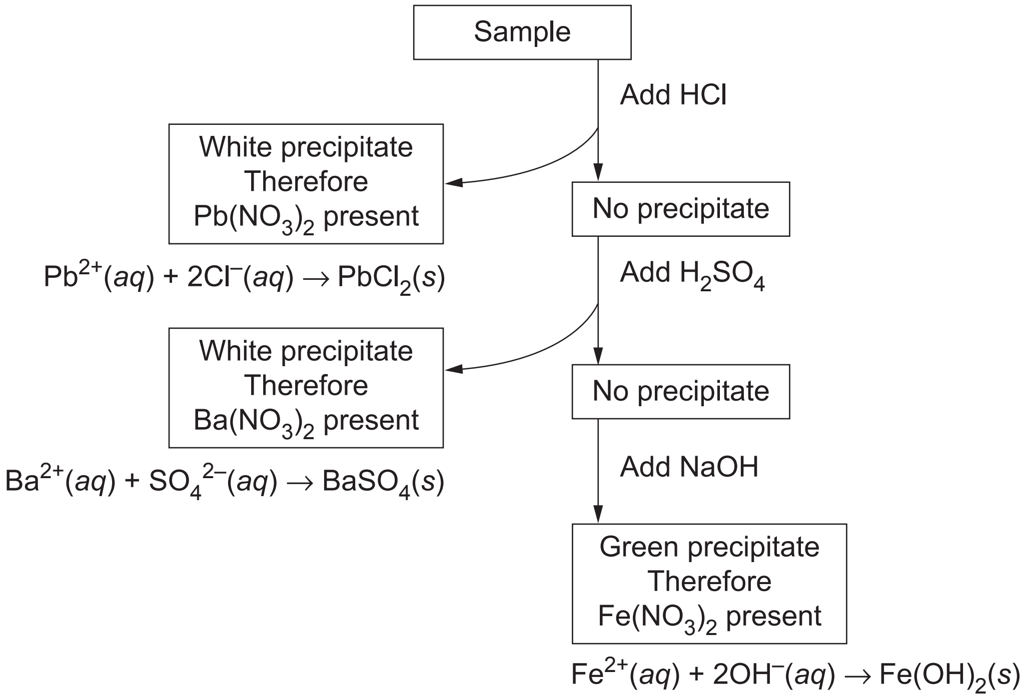
Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 8 Analysis of Inorganic Substances	CH12–2, CH12–4, CH12–15	2–5

Marking guidelines:

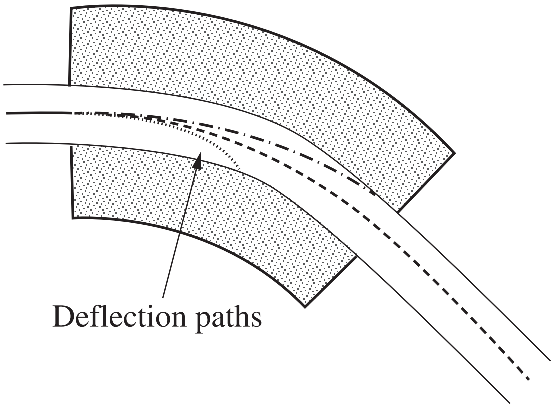
Criteria	**Marks**
• Provides clear logical sequence of steps to identify the solution • Provides observations and conclusions • Provides correct ionic equations	4
• Provides a sequence of steps that could identify the solution • Provides some observations • Provides ONE ionic equation	3
• Provides a step to identify the solution • Includes ONE observation or equation	2
• Provides some relevant information	1

Sample answer:



Mod 8 – Question 15 (3 marks)

The diagram shows the deflection paths of different ions through a mass spectrometer. **3**



Account for the different deflection paths.

Mapping grid:

Content	Syllabus outcomes	Bands
Mod 8 Analysis of Organic Substances	CH12–6, CH12–15	2–4

Marking guidelines:

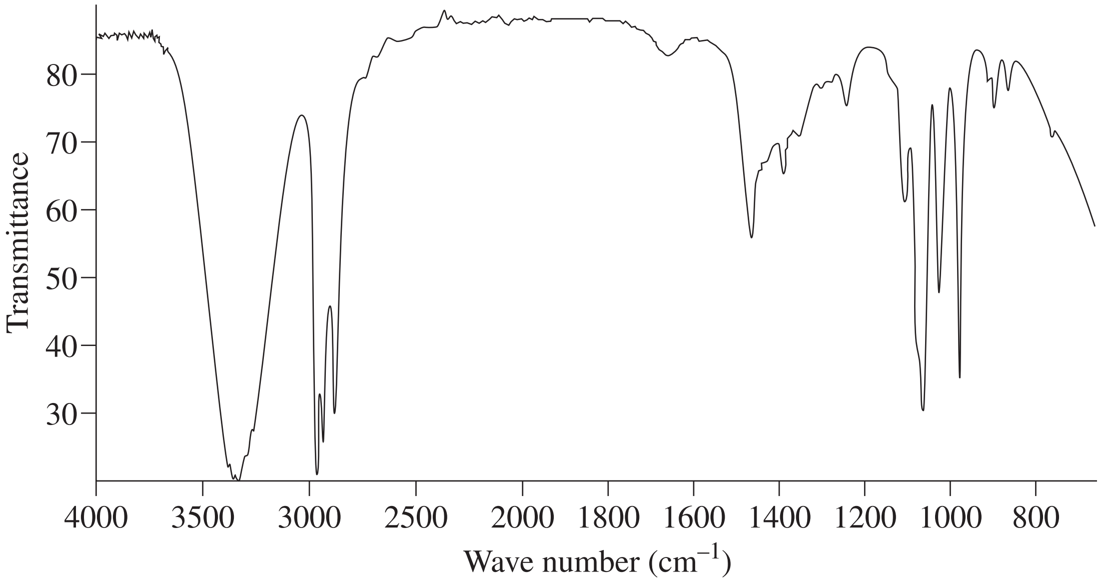
Criteria	Marks
• Provides reasons for the different paths	3
• Outlines a reason for the different paths	2
• Provides some relevant information	1

Sample answer:

The positively charged ions are accelerated through an electric field before passing into a magnetic field. This causes the ions to travel in a curved path where the curvature is dependent upon the *mass to charge* ratio and the speed at which the ions enter the magnetic field. Lighter ions have less momentum and are deflected more strongly than heavier ions.

Mod 8 – Question 16 (4 marks)

The diagram shows the infrared spectrum of a compound. **4**



The molecular weight of the compound analysed is approximately 60 g mol^{-1}. Suggest TWO possible compounds that could fit this spectrum and justify your selection.

Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 8 Analysis of Organic Substances	CH12–4, CH12–7, CH12–15	2–5

Question 16 continues on page 84

Question 16 (continued)

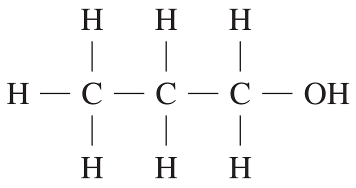
Marking guidelines:

Criteria	**Marks**
• Suggests two possible compounds with justification	4
• Suggests at least one possible compound and shows a sound understanding of infrared spectra and functional groups	3
• Suggests possible compound(s) and/or shows some understanding of infrared spectra and/or functional groups	2
• Provides some relevant information	1

Sample answer:

The first set of absorbance forms a broad trough maximising at around 3400 cm^{-1} and spread from around 3100−3600 cm^{-1}. Based on the infrared absorption data provided, this suggests that a hydroxyl group is likely to be present. The second trough occurs between 2700 and 3100 cm^{-1} and the intensity trough is not broad, which closely matches the data for the C—H bond. There is little absorbance between 2500−1500 cm^{-1}, suggesting the lack of a C═0 group. Therefore, neither a carboxylic acid nor ketone is being analysed. The peak for the C—O bond occurs at 1250−1050 cm^{-1}, suggesting it is present.

The structural formula for propanol is



$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & — & C & — & C & — & C & — & OH \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

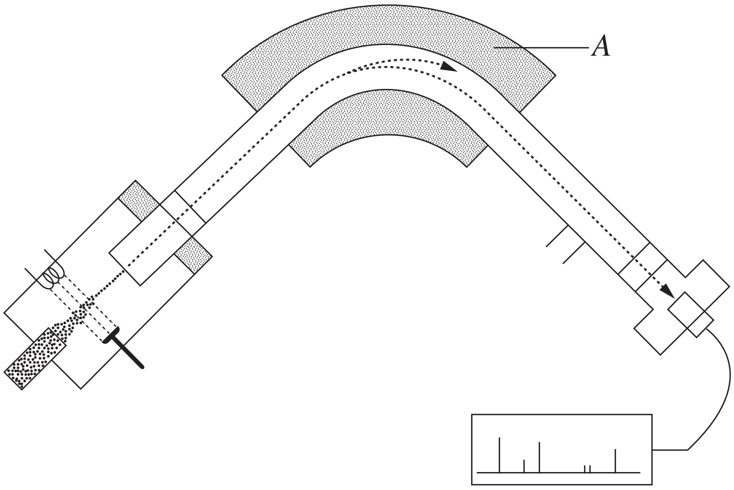
and contains bonds as shown.

The molecular weight of propanol is 60.01 g mol^{-1}, again consistent with the data. There are 2 isomers of propanol. The spectrum could therefore be of either propan-1-ol or propan-2-ol. Each would give a similar spectrum.

End of Question 16

Mod 8 – Question 17 (5 marks)

The diagram is a schematic representation of a mass spectrometer.



(a) Name and outline the function of the part labelled *A* in the diagram. **2**

(b) Outline the advantages of using mass spectrometry for analysis of a compound. **3**

Mapping grid (a):

Content	Syllabus outcomes	Bands
Mod 8 Analysis of Organic Substances	CH12–15	2–3

Marking guidelines (a):

Criteria	Marks
• Correctly identifies the part labelled *A* • Outlines the function of the part labelled *A*	2
• Provides some relevant information	1

Sample answer:

A is a magnet. It is required to separate/bend the stream of charged particles.

Question 17 continues on page 86

Question 17 (continued)

Mapping grid (b):

Content	**Syllabus outcomes**	**Bands**
Mod 8 Analysis of Organic Substances	CH12–15	2–4

Marking guidelines (b):

Criteria	**Marks**
• Outlines advantages of using mass spectrometry for analysis of a compound	3
• Identifies some advantages of mass spectrometry OR • Outlines an advantage	2
• Provides some relevant information	1

Sample answer:

The mass spectrometer is able to quickly identify components of a mixture or components in a compound by their mass/charge ratio. Mass spectrometers are able to identify different isotopes of elements in a compound which allows the compound to be matched to a sample. Mass spectrometry is both qualitative and quantitative, requires only small quantities and is accurate, fast and sensitive.

End of Question 17

Mod 8 – Question 18 (3 marks)

Explain how infrared spectroscopy is used in the analysis and identification of organic substances. **3**

Mapping grid:

Content	**Syllabus outcomes**	**Bands**
Mod 8 Analysis of Organic Substances	CH12–15	2–4

Marking guidelines:

Criteria	**Marks**
• Explains how infrared spectroscopy is used to analyse and identify chemicals	3
• Outlines how infrared spectroscopy is used to analyse and/or identify chemicals	2
• Provides some relevant information	1

Sample answer:

Bonds between certain atoms in a molecule will absorb specific wavelengths of IR radiation depending on the length of the bond. Therefore, using the complete IR spectrum, the particular bonds in a molecule can be identified. The relative number of each specific bond can be determined by the degree of absorption.

An organic substance will have a characteristic spectrum that can be used for its identification, by comparison with published data.

End of sample questions

2019 HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

FORMULAE SHEET

$n = \frac{m}{MM}$ $\quad$ $c = \frac{n}{V}$ $\quad$ $PV = nRT$

$q = mc\Delta T$ $\quad$ $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\quad$ $\mathrm{pH} = -\log_{10}\left[\mathrm{H}^+\right]$

$pK_a = -\log_{10}\left[K_a\right]$ $\quad$ $A = \varepsilon lc = \log_{10}\frac{I_o}{I}$

Avogadro constant, N_A	6.022×10^{23} mol^{-1}
Volume of 1 mole ideal gas: at 100 kPa and at 0°C (273.15 K)	22.71 L
at 25°C (298.15 K)	24.79 L
Gas constant	8.314 J mol^{-1} K^{-1}
Ionisation constant for water at 25°C (298.15 K), K_w	1.0×10^{-14}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

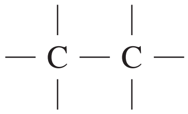
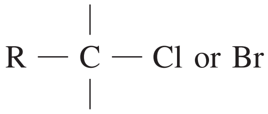
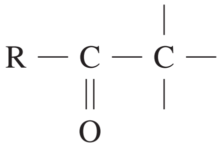
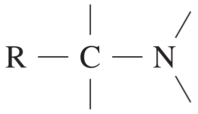
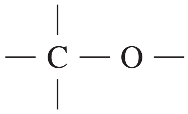
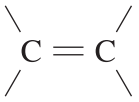
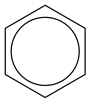
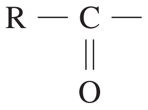
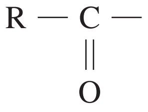
Solubility constants at 25°C

Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
 $-\overset{\vert}{\underset{\vert}{C}}-\overset{\vert}{\underset{\vert}{C}}-$		5–40
 $R-\overset{\vert}{\underset{\vert}{C}}-Cl$ or Br		10–70
 $R-\underset{\underset{O}{\Vert}}{C}-\overset{\vert}{\underset{\vert}{C}}-$		20–50
 $R-\overset{\vert}{\underset{\vert}{C}}-N\begin{smallmatrix}/\\ \backslash\end{smallmatrix}$		25–60
 $-\overset{\vert}{\underset{\vert}{C}}-O-$	alcohols, ethers or esters	50–90
 $>C=C<$		90–150
$R-C\equiv N$		110–125
		110–160
 $R-\underset{\underset{O}{\Vert}}{C}-$	esters or acids	160–185
 $R-\underset{\underset{O}{\Vert}}{C}-$	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4{}^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7{}^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4{}^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for the standard potentials. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number: 79
Symbol: Au
Standard Atomic Weight: 197.0
Name: Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.