Neap

Trial Examination 2021

HSC Year 12 Chemistry

General Instructions	• Reading time – 5 minutes • Working time – 3 hours • Write using black pen • Draw diagrams using pencil • Calculators approved by NESA may be used • A formulae sheet, data sheet and Periodic Table are provided at the back of this paper
Total Marks: 100	**Section I – 20 marks (pages 2–9)** • Attempt Questions 1–20 • Allow about 35 minutes for this section **Section II – 80 marks (pages 11–30)** • Attempt Questions 21–35 • Allow about 2 hours and 25 minutes for this section

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2021 HSC Year 12 Chemistry examination.

SECTION I

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

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

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1 Hydrogen can be produced from methane. The equation for the reaction is shown.

$$2H_2O(g) + CH_4(g) \rightleftharpoons CO_2(g) + 4H_2(g)$$

What is the correct equilibrium expression (K_{eq}) for this reaction?

A. $\dfrac{[H_2O]^2[CH_4]}{[CO_2][H_2]^4}$

B. $\dfrac{[CO_2][H_2]^4}{[H_2O]^2[CH_4]}$

C. $\dfrac{2[H_2O][CH_4]}{[CO_2]4[H_2]}$

D. $\dfrac{[CO_2]4[H_2]}{2[H_2O][CH_4]}$

2 As the temperature of a particular reaction was increased, the rate of the reaction increased. Which statement best explains why this occurred?

A. The product molecules collided more frequently.

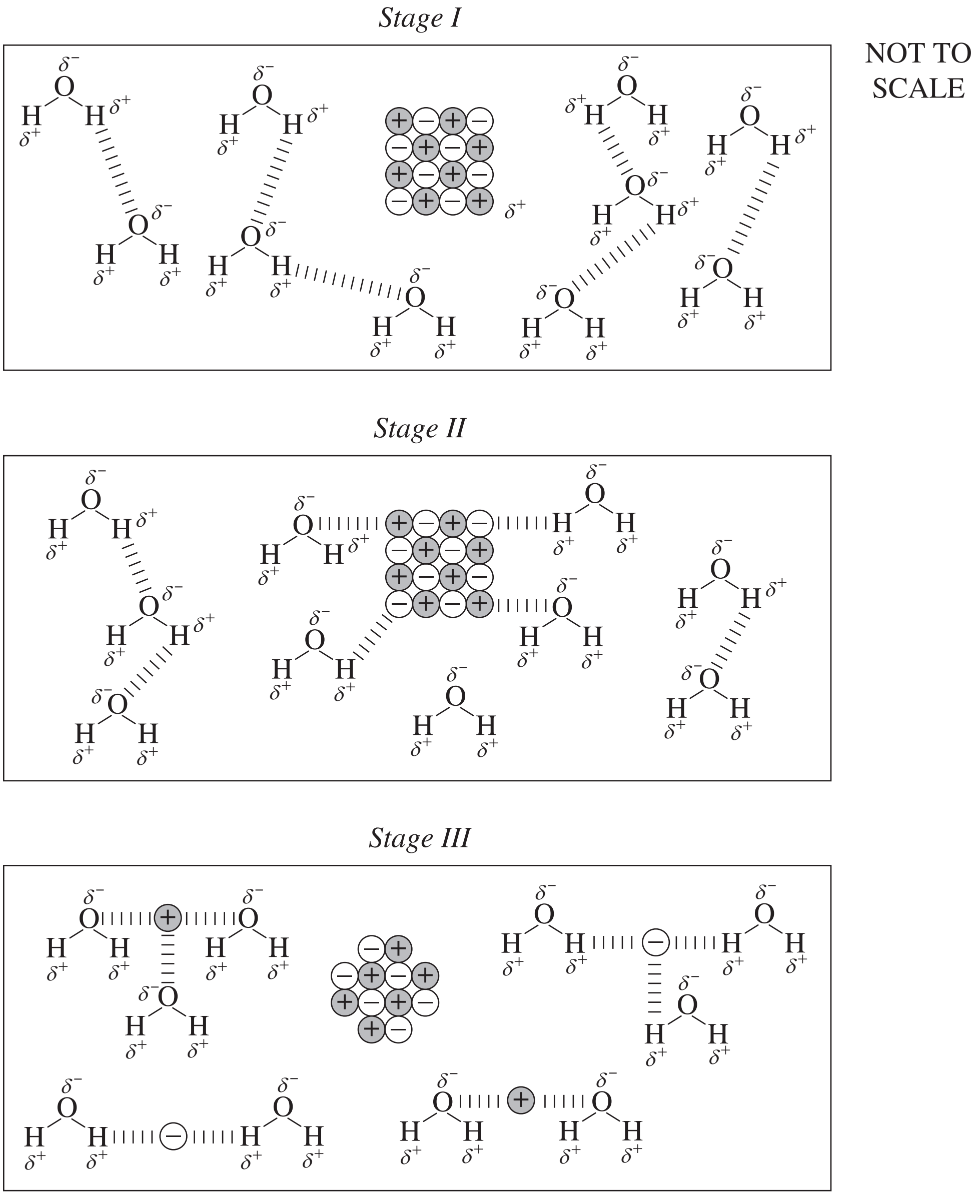
B. The product molecules collided with the correct orientation.

C. The reactant molecules collided with greater energy per collision.

D. The reactant molecules collided less frequently.

 HSC Chemistry Yr12_QB_2021

3 The diagram shows three stages of a process.



What process is shown?

A. the dissociation of an ionic substance

B. the dissociation of an acid

C. the dissociation of a base

D. the precipitation of a salt

4 Hydrogen and iodine react according to the following equilibrium reaction.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H < 0$$

A mixture of hydrogen gas and iodine gas was placed in a container, sealed and allowed to reach equilibrium. Changes were made to the mixture and the mole amounts of reactants and product were measured.

I The volume of the container was increased with the temperature remaining constant.

II Hydrogen gas was added to the container with the volume and temperature remaining constant.

III An inert gas was added to the container with the volume increasing and temperature remaining constant.

IV The temperature of the gases was decreased with the volume remaining constant.

Which changes would result in an increase in the number of moles of hydrogen iodide formed?

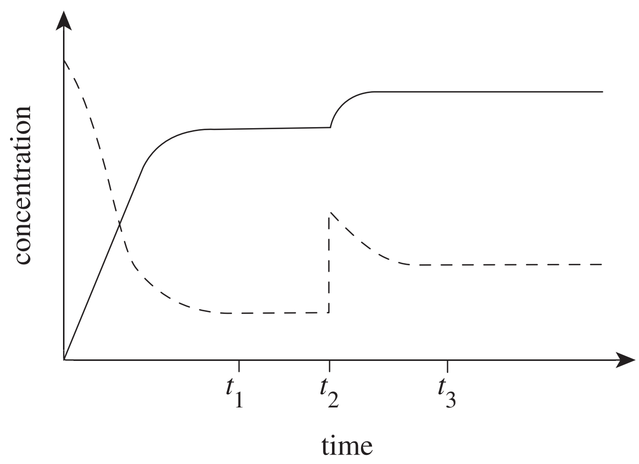
A. I and III only

B. I and IV only

C. II and III only

D. II and IV only

5 The graph shows the progress of an equilibrium reaction (reactants $\rightleftharpoons$ products).



Which row of the table correctly identifies what is happening at t_1, t_2 and t_3?

	t_1	t_2	t_3
A.	at equilibrium	reactants added	new equilibrium position
B.	at equilibrium	products added	new equilibrium position
C.	no reaction occurring	reaction proceeding	reaction occurring
D.	only forward reaction occurring	forward and reverse reactions occurring	only reverse reaction occurring

6 Which statement about 100.0 mL of 0.10 mol L^{-1} hydrochloric acid and 100.0 mL of 0.10 mol L^{-1} acetic (ethanoic) acid solutions is correct?

A. Each solution will react completely with 100.0 mL of 0.10 mol L^{-1} sodium hydroxide solution.

B. The solutions will have the same electrical conductivity.

C. Each solution will react at the same rate with 1.00 g of magnesium ribbon.

D. The concentration of H_3O^+ ions will be the same in both solutions.

7 A mixture was prepared containing equal amounts of 0.10 mol L^{-1} ammonia solution and 0.10 mol L^{-1} ammonium nitrate.

Which statement about this mixture is correct?

A. The mixture is strongly acidic.

B. The mixture has a pH of approximately 7.

C. The mixture will resist changes in pH when other solutions are added to it.

D. The mixture will not change in pH when other solutions are added to it.

8 The pH of two solutions, X and Y, of the same concentration were measured. The pH of solution X was 2.00 and the pH of solution Y was 4.00.

Which statement about solutions X and Y is correct?

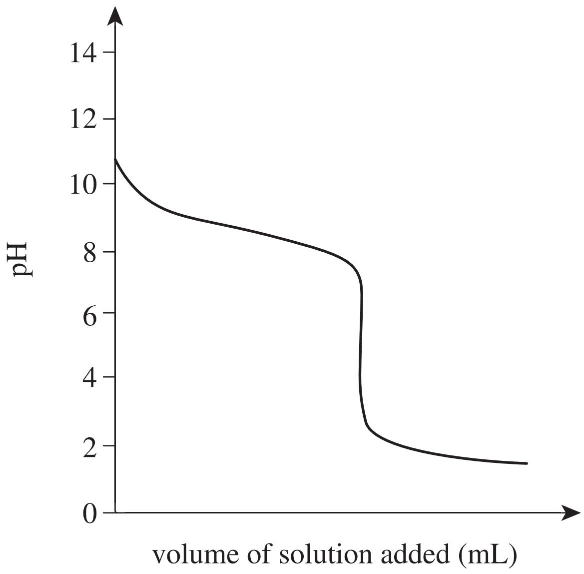
A. Solution Y must contain a stronger acid than solution X.

B. The concentration of H^+ in solution X is two times greater than the concentration of H^+ in solution Y.

C. The concentration of H^+ in solution X is 100 times greater than the concentration of H^+ in solution Y.

D. The concentration of OH^- in solution Y is two times greater than the concentration of OH^- in solution X.

9 The graph shows how pH changes in the reaction between a particular acid and a particular base.



Which of the following is closest to the pH of the equivalence point?

A. 2

B. 5

C. 7

D. 10.5

10 The reaction $CN^- + H_2O \rightleftharpoons HCN + OH^-$ contains conjugate acid/base pairs.

Which of the following shows a conjugate acid/base pair in this reaction?

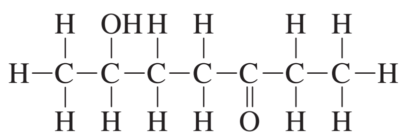
A. HCN/CN^-

B. CN^-/H_2O

C. H_2O/HCN

D. HCN/OH^-

11 The structure of a compound is shown.



What is the preferred IUPAC name of this compound?

A. 2-hydroxyheptan-5-one

B. 5-oxo-heptan-2-ol

C. heptan-2-ol-5-one

D. 6-hydroxyheptan-3-one

12 Which of the following lists the compounds from lowest to highest boiling point?

A. 2-methylbutane, ethyl ethanoate, butan-1-ol, butanoic acid

B. ethyl ethanoate, 2-methylbutane, butanoic acid, butan-1-ol

C. 2-methylbutane, butan-1-ol, butanoic acid, ethyl ethanoate

D. butanoic acid, butan-1-ol, ethyl ethanoate, 2-methylbutane

13 A thermochemical reaction is shown.

$$CH_3CH_2CH_2CH_2OH(g) + 7.5O_2(g) \rightarrow 5CO_2(g) + 5H_2O(l) \qquad \Delta H = -2676 \text{ kJ mol}^{-1}$$

How much heat is released when 1.00 g of butanol is reacted?

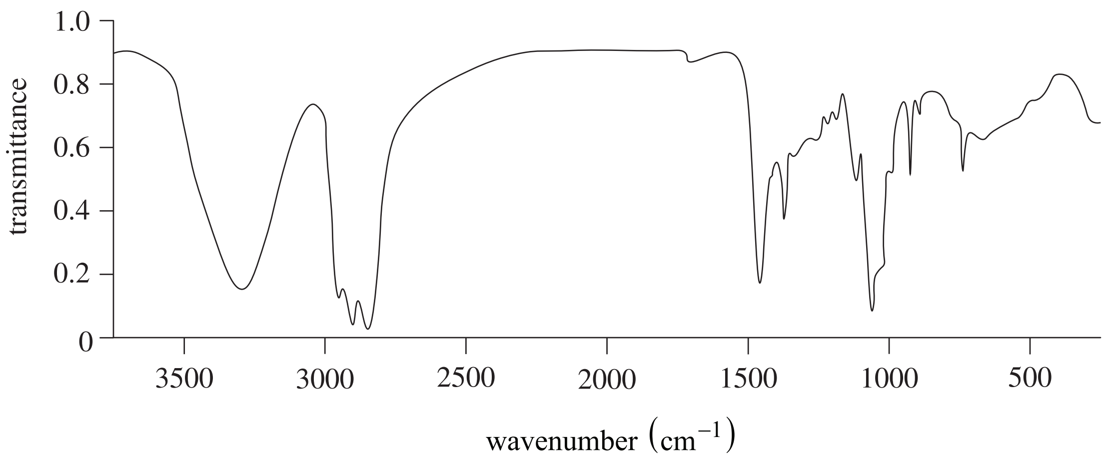
A. 30.4 kJ

B. 36.1 kJ

C. 145 kJ

D. 198 kJ

14 An infrared spectrum is shown.



Which compound gives rise to this spectrum?

A. hexan-1-ol

B. hexan-2-one

C. hexanal

D. hexanoic acid

15 Consider the isomeric alcohols.

butan-1-ol butan-2-ol 2-methylpropan-2-ol 2-methylpropan-1-ol

Which of the following instrumental methods would most effectively differentiate between these isomeric alcohols?

A. atomic absorption spectroscopy

B. ultraviolet-visible spectrophotometry

C. infrared spectroscopy

D. ^{1}H NMR spectroscopy

16 The structures of butanoic acid and methyl propanoate are shown.

$$CH_3-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH \qquad\qquad CH_3-CH_2-\overset{\overset{O}{\|}}{C}-O-CH_3$$

butanoic acid methyl propanoate

Which statement best explains why butanoic acid has a higher boiling point than methyl propanoate?

A. Butanoic acid has more covalent bonds than methyl propanoate.

B. Butanoic acid has a smaller size than methyl propanoate.

C. Butanoic acid has dipole–dipole forces.

D. Butanoic acid has hydrogen bonds.

17 A portion of a polymer chain is shown.

$$-NH-CH_2-CH_2-NH-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-NH-CH_2-CH_2-NH-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-$$

Which of the following pairs of monomers would react to form this polymer?

A. CH_2-CH_2 and HNCO

B. $HO-CH_2-CH_2-OH$ and $NH_2-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-NH_2$

C. $CH_2{=}CH_2$ and $NH_2-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-NH_2$

D. $NH_2-CH_2-CH_2-NH_2$ and $HO-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

18 Which of the following molecules has bond angles closest to 180°?

A. ethane

B. ethanol

C. ethyne

D. ethene

19 Which of the following compounds is the most basic?

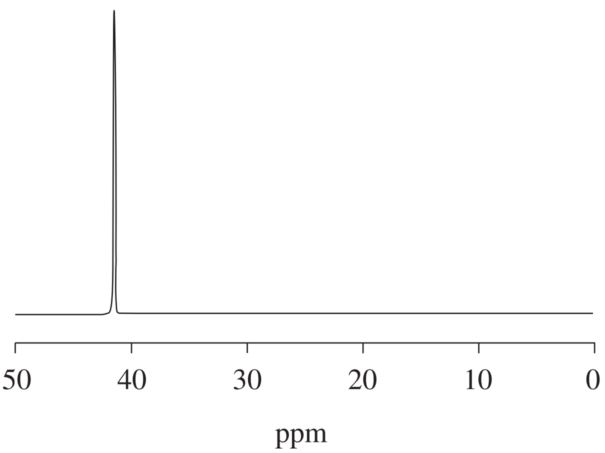
A. $CH_3-CH_2-CH_2-CH_2-OH$

B. $CH_3-CH_2-CH_2-CH_2-NH_2$

C. $CH_3-CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-O-CH_2-CH_3$

D. $CH_3-CH_2-CH_2-CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-O-H$

20 A ^{13}C NMR spectrum is shown.



Which compound gives rise to this spectrum?

A. chloroethane

B. 1-chloropropane

C. 1,2-dichloroethane

D. 1,3-dichloropropane

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HSC Year 12 Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–35
Allow about 2 hours and 25 minutes for this section

Instructions

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

Please turn over

Question 21 (4 marks)
A non-equilibrium system is shown. **4**

$$C_8H_{18}(l) + 12\frac{1}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$$

Discuss why this is a non-equilibrium system with reference to the effect of Gibbs free energy, enthalpy and entropy.

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Question 22 (7 marks)
Nitrogen dioxide can dimerise to form dinitrogen tetroxide according to the following equation.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -52 \text{ kJ mol}^{-1}$$

(a) Using Le Châtelier's principle, explain what would happen to the position of equilibrium if the pressure were increased with all other conditions remaining the same. **2**

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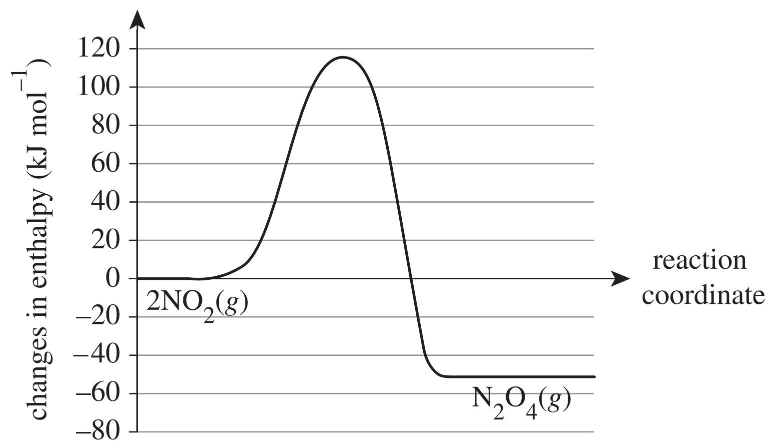
(b) The energy profile diagram for this reaction is shown. **2**



Determine the activation energies of the forward and reverse direction for $2NO_2(g) \rightleftharpoons N_2O_4(g)$.

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(c) Explain the effect of increasing the temperature on this equilibrium, all other conditions being kept constant. **3**

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Question 23 (6 marks)

Iron(III) ions and thiocyanate ions react to form a complex ion according to the following equation. **6**

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

10.0 mL of a 0.00200 mol L^{-1} solution of iron(III) was added to 10.0 mL of a 0.00200 mol L^{-1} solution of thiocyanate ions and mixed. The mixture was tested after a period of time and the concentration of the iron thiocyanate complex was found to be 1.45×10^{-4} mol L^{-1}. Under the conditions used, the theoretical value of the equilibrium constant (K_{eq}) is 2.05×10^{2}.

Determine in which direction the reaction must proceed to reach equilibrium. Include the relevant calculations in your answer.

Question 24 (7 marks)

A student was looking for an alternative to the cleaning agent they used at home. They found the information shown.

> *Vinegar – an alternative to harsh chemical cleaning agents?*
>
> Vinegar is a solution of acetic (ethanoic) acid in water. Vinegar has been used as a cleaning agent for centuries. Studies have shown that the vinegar needs to have a concentration of 7–12% w/v* before it is an effective cleaning agent. Vinegar that has this concentration can be used as an alternative to synthetic cleaning agents.
>
> * $w/v = \dfrac{\text{weight}}{\text{volume}} \times 100$

The student showed this information to their Chemistry class, and the class decided to analyse a sample of 'white vinegar' from the supermarket to determine the concentration of acetic acid (CH_3COOH).

A conductimetric titration was carried out.

A 25.00 mL sample was taken of the vinegar and diluted to 250 mL in a volumetric flask. A 25.0 mL portion of this diluted solution was titrated using standardised 0.120 mol L^{-1} sodium hydroxide solution. The conductivity of the diluted vinegar solution was taken.

1.00 mL of NaOH solution was then added in increments, the mixture stirred, and the new conductivity was taken after each addition.

The results of the titration are shown in the table.

NaOH added (mL)	*Conductivity (S m^{-1})*
0	130
1.0	110
2.0	104
3.0	97
4.0	90
5.0	84
6.0	76
7.0	70
8.0	65
9.0	70
10.0	98
11.0	122
12.0	148
13.0	171
14.0	198
15.0	220

Question 24 continues on page 16

Question 24 (continued)

By drawing a best-fit conductivity graph of the data in the table and performing relevant calculations, determine whether the vinegar was of the required concentration to be an effective cleaning agent. **7**

End of Question 24

Question 25 (5 marks)

A student added 1.78 g of $Ca(OH)_2(s)$ to 0.250 L of 0.200 mol L^{-1} $HNO_3(aq)$. The mixture was carefully stirred until no further reaction occurred.

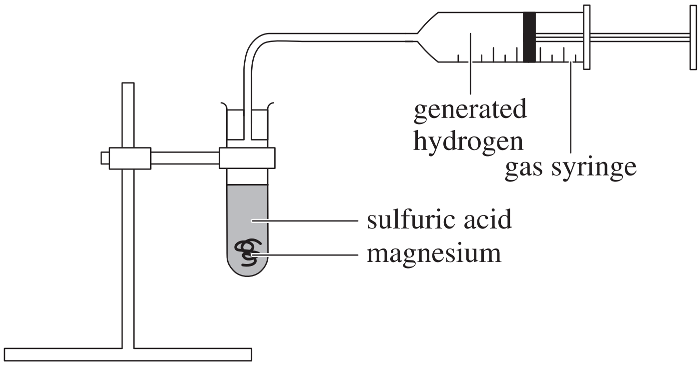
(a) Assuming that the total volume of the solution remains unchanged, calculate the pH of the resulting solution. **3**

(b) Explain how nitric acid can be regarded as both an Arrhenius acid and a Brønsted–Lowry acid. **2**

Question 26 (5 marks)

Magnesium reacts vigorously with mineral acids to produce a salt and hydrogen gas in an exothermic reaction.

A student reacted 0.361 g of magnesium with excess sulfuric acid and measured the volume of hydrogen generated. When the magnesium had completely reacted, there was 385 mL of gas in the syringe. The apparatus used by the student is shown.



(a) Write a balanced chemical equation for this reaction between magnesium and sulfuric acid. **1**

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(b) Calculate the volume of hydrogen that is generated at 25.0°C and 100 kPa. **3**

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(c) Assuming that the method was valid and the gas syringe was accurate, give ONE reason why there might be a difference between theoretical yield and the amount recorded. **1**

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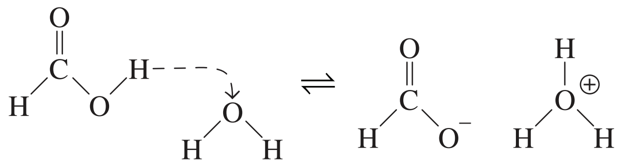
Question 27 (4 marks)

Formic acid is an organic acid, found in the venom of ants and bees. The diagram shows a molecule of formic acid dissociating in water.



(a) Determine the dissociation constant of a 0.100 mol L^{-1} formic acid solution that has a pH of 2.38. **3**

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(b) Use the dissociation constant calculated in part (a) to identify the strength of this acid. **1**

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Question 28 (3 marks)

In an aqueous solution, the colourless weak acid p-nitrophenol ($C_6H_5NO_3$) undergoes hydrolysis to produce yellow-coloured p-nitrophenoxide ions. The absorbance of this solution was measured at 410 nm and found to be 0.433 when using a sample cell with a pathlength of 1.00 cm. Only p-nitrophenoxide ions absorb at this wavelength. Its molar attenuation coefficient, at this wavelength, is 18 600 L mol^{-1} cm^{-1}.

(a) Complete the equilibrium equation. **1**

$$C_6H_5NO_3(aq) + H_2O(l) \rightleftharpoons \boxed{}(aq) + \boxed{}(aq)$$

(b) Determine the concentration of p-nitrophenoxide in the solution. **2**

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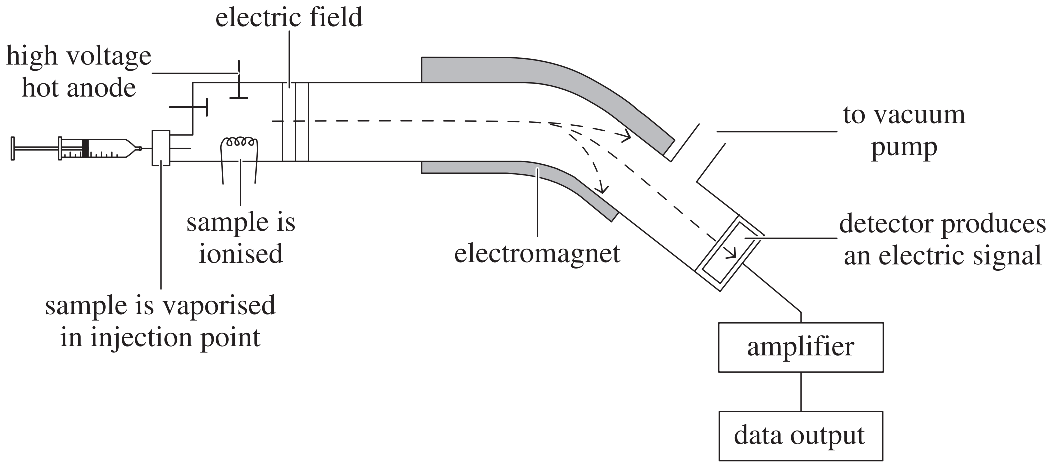
Question 29 (6 marks)

Mass spectroscopy is a technique that measures the mass-to-charge ratio (m/z) of charged particles. The instrument used is called a mass spectrometer, in which electric signals produce a mass spectrum on a screen. The diagram shows a mass spectrometer.



A sample is injected into the mass spectrometer and the particles pass through an electric field, and then through a magnetic field.

(a) (i) What is the purpose of the electric field? **1**

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(ii) What is the purpose of the magnetic field? **1**

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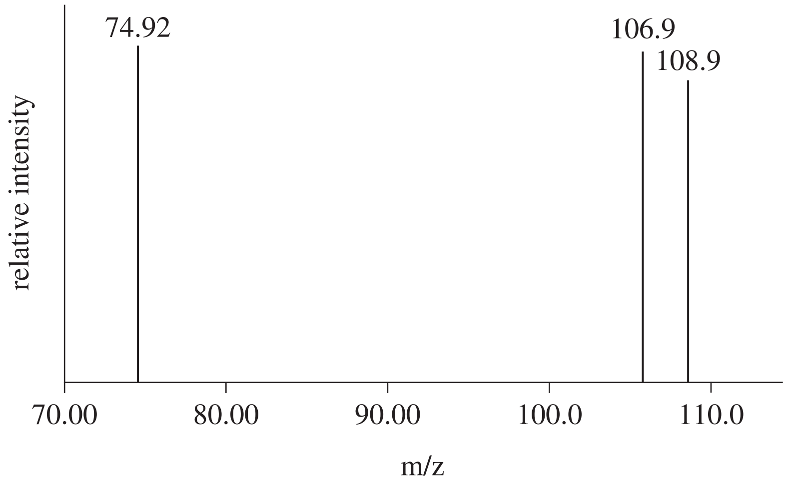
Question 29 continues on page 22

Question 29 (continued)

A common use for mass spectroscopy is to identify elements and their isotopes.

(b) The mass spectrum of a mixture of elements is shown. **2**



What elements are present and how many isotopes does each element have?

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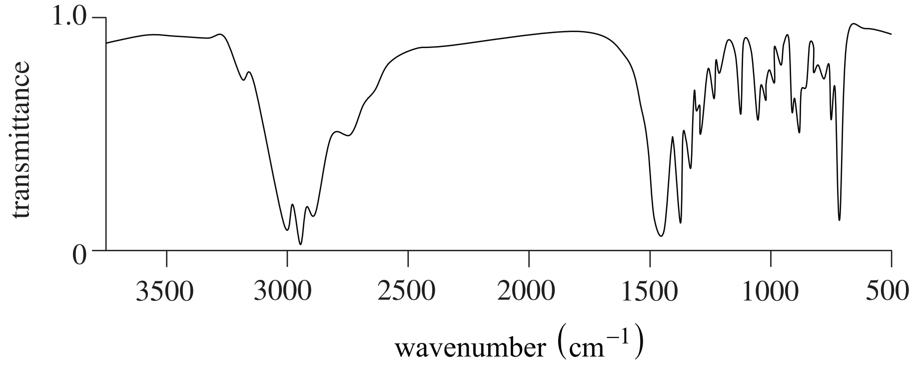
Question 29 continues on page 23

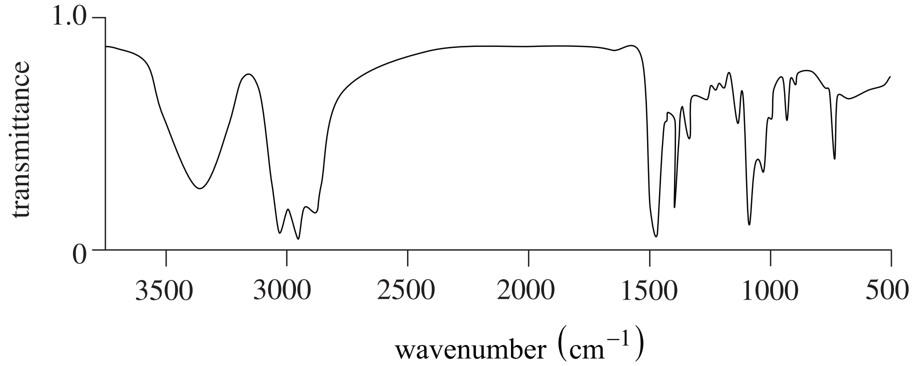
Question 29 (continued)

(c) Mass spectroscopy is often used with other spectroscopic techniques to identify the components of mixtures. Infrared spectroscopy is one such technique that aids in identifying the functional groups contained within a molecule. The infrared spectra of hexane and hexan-1-ol are shown. **2**

Infrared spectrum for hexane



Infrared spectrum for hexan-1-ol



Identify the bonds in hexan-1-ol that account for the differences between the two IR spectra and identify the relevant absorption peaks.

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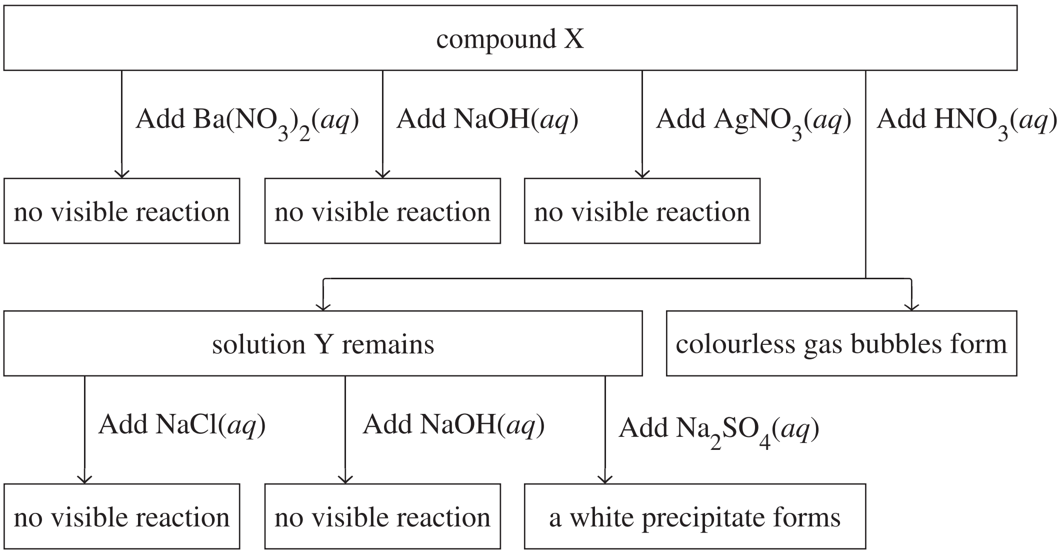
End of Question 29

Question 30 (4 marks)

Compound X is an insoluble white ionic compound. A student performed a series of experiments on compound X to determine its identity. A flow chart is shown summarising their results. **4**



Use the information provided to identify compound X and justify your choice. Include net ionic equations where appropriate.

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Question 31 (7 marks)
Compound B is formed when an alcohol, compound A, is reacted with reagent X as shown in the equation.

$$\underset{\text{compound A}}{C_4H_9OH} + \text{reagant X} \xrightarrow{\text{heat}} \underset{\text{compound B}}{C_4H_8O_2}$$

(a) (i) Identify whether compound A is a primary, secondary or tertiary alcohol, and explain your choice. **2**

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(ii) Identify a reagent that could function as reagent X. **1**

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But-1-ene is the only alkene produced when compound A is reacted under appropriate conditions.

(b) Identify the systematic name of compound B and draw its structural formula. **2**

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(c) Compound C, a sweet-smelling liquid, is one of two products formed when compound A reacts with compound B in the presence of a catalytic amount of sulfuric acid. **2**

Identify the systematic name of compound C and draw its structural formula.

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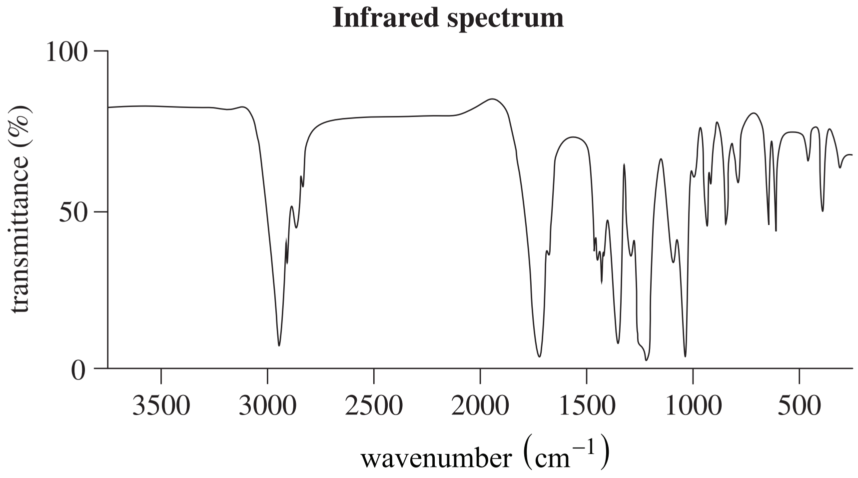
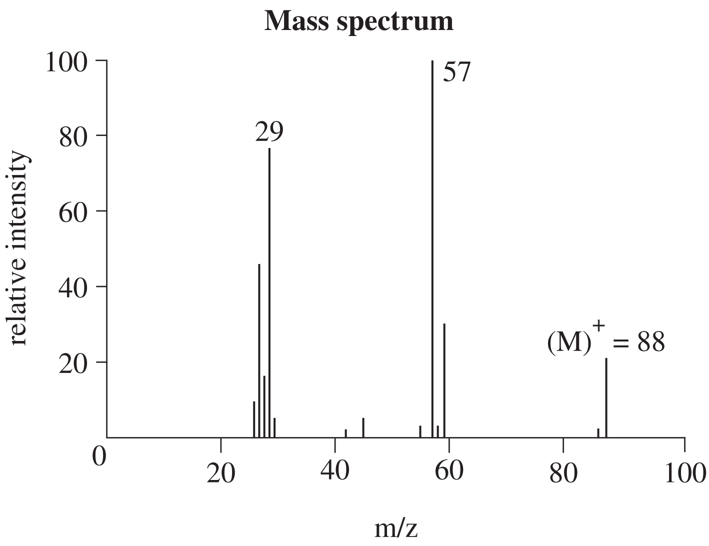
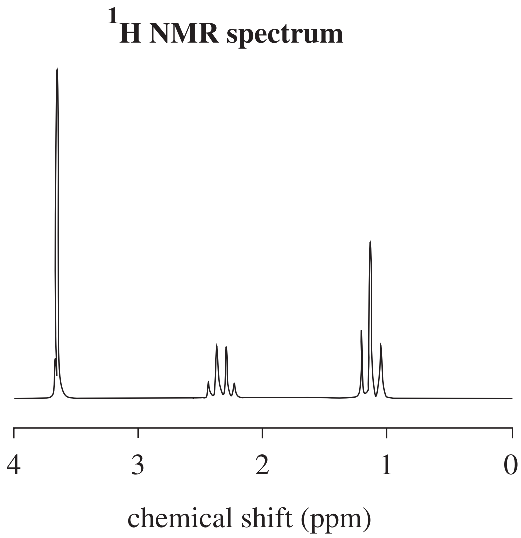
Question 32 (8 marks)

Compound X was found to have the molecular formula $C_4H_8O_2$. To confirm the molecular structure of the compound, mass spectrometry, infrared spectroscopy and ^{1}H NMR spectrometry were performed. The resulting spectra are shown.







(a) What does the peak at m/z = 88 in the mass spectrum indicate? **1**

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Question 32 continues on page 27

Question 32 (continued)

(b) Use the spectra provided to identify compound X. Justify your answer with reference to the data provided. **7**

End of Question 32

Question 33 (5 marks)

(a) C_3H_5Cl has several structural isomers containing an alkene functional group. **3**

Complete the table by stating the systematic names and drawing the structural formulae of THREE structural isomers of C_3H_5Cl.

Systematic name	*Structural formula*

(b) A chemical test can be performed quickly in a school laboratory to distinguish between cyclohexanol and 1-methylcyclohexanol. **2**

Identify the reagent used in this test and describe the expected observations.

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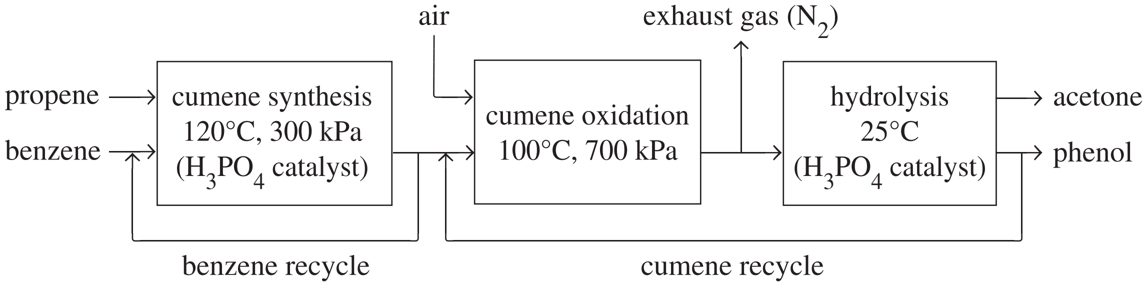
Question 34 (4 marks)

A chemist has proposed a reaction process for the industrial production of phenol, a compound used in the manufacture of a wide range of industrial chemicals. This process has been shown to result in 98% conversion of benzene to phenol. The process is shown in the flow chart. **4**



Using the information provided, outline THREE factors that may have been considered in the design of this industrial process.

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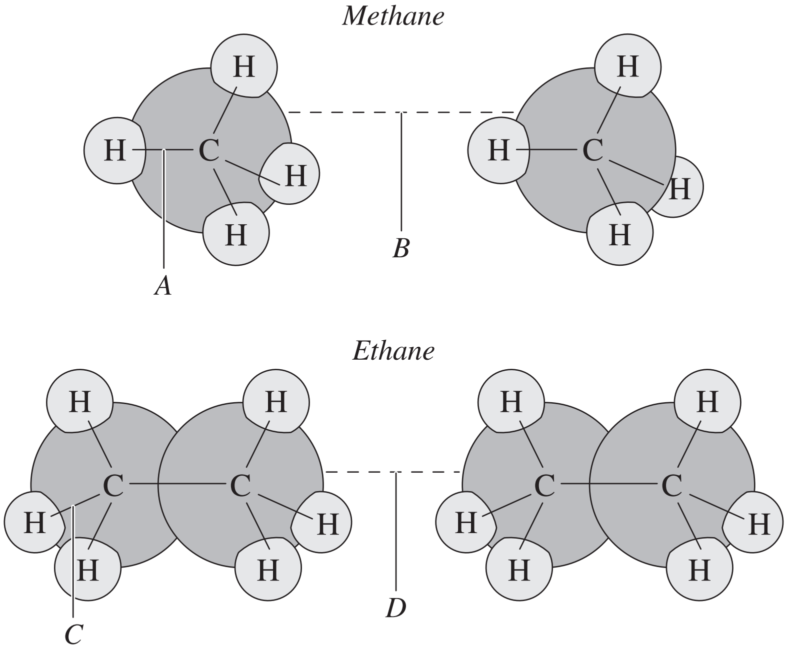
Question 35 (5 marks)

The diagrams show the bonding within and between methane and ethane molecules. **5**



Compare the strengths of bonds *A* and *C* AND compare the strengths of bonds *B* and *D*. In your response, evaluate the significance of these bonds in determining the physical properties of the homologous series represented in the diagrams.

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Section II extra writing space

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Section II extra writing space

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

FORMULAE SHEET

$n = \dfrac{m}{MM}$	$c = \dfrac{n}{V}$	$PV = nRT$
$q = mc\Delta T$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	$\mathrm{pH} = -\log_{10}\left[\mathrm{H}^+\right]$
$pK_a = -\log_{10}\left[K_a\right]$	$A = \varepsilon lc = \log_{10}\dfrac{I_o}{I}$	

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

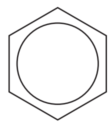
Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
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
—C—C—	5–40
R—C—Cl or Br	10–70
R—C(=O)—C—	20–50
R—C—N<	25–60
—C—O— alcohols, ethers or esters	50–90
>C=C<	90–150
R—C≡N	110–125
	110–160
R—C(=O)— esters or acids	160–185
R—C(=O)— aldehydes or ketones	190–220

UV absorption

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

Chromophore	**λ_{max} (nm)**
C—H	112
C—C	135
C=C	162

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

 HSC Chemistry Yr12_QB_2021

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.

Neap

Trial Examination 2021

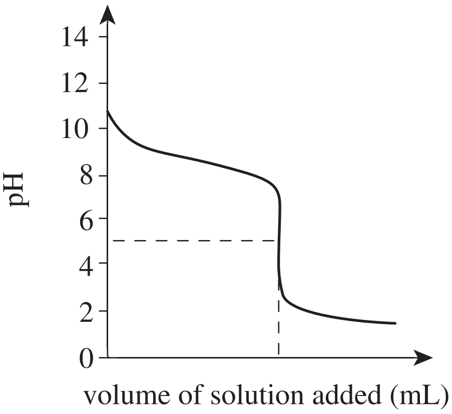
HSC Year 12 Chemistry

Solutions and marking guidelines

SECTION I

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 1 B **B** is correct. For a reaction such as $aA + bB \rightleftharpoons cC + dD$, the equilibrium expression is $K_{eq} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$. Hence, for the reaction $2H_2O(g) + CH_4(g) \rightleftharpoons CO_2(g) + 4H_2(g)$, $K_{eq} = \frac{[CO_2][H_2]^4}{[H_2O]^2[CH_4]}$. **A**, **C** and **D** are incorrect. These options do not show suitable equilibrium expressions.	Mod 5 Calculating the Equilibrium Constant CH12–6, 12–12 Band 2
Question 2 C **C** is correct. Increased reaction rate is caused by heat increasing the kinetic energy of reactant molecules, causing them to collide more frequently and with more energy. Hence, there are more collisions that create the product. **A** and **B** are incorrect. Collision of product molecules cannot produce any more product. **D** is incorrect. Reactant molecules collide more frequently when heated.	Mod 5 Factors that Affect Equilibrium CH12–12 Band 3
Question 3 A **A** is correct. The diagram shows an ionic lattice being broken down, with polar water molecules being attracted to anions (negative) and cations (positive). **B** is incorrect. An acid would produce hydronium ions (H_3O^+), which is not shown in the diagram. **C** is incorrect. Hydroxide ions are not produced. **D** is incorrect. Precipitation involves oppositely charged ions coming together and forming an insoluble compound.	Mod 5 Solution Equilibria CH12–12 Band 3
Question 4 C **C** is correct. The only changes that meet the criteria for an increase in product (hydrogen iodide) are II and IV. The reaction is exothermic (H is less than zero) and a decrease in temperature would favour formation of products. Adding hydrogen, a reactant, will increase formation of products. **A** and **B** are incorrect. As this reaction involves two volumes of gas on each side of the equation, changing volume or pressure will have no effect on position of equilibrium. **D** is incorrect. Adding an inert gas while changing the volume will have no effect on the position of equilibrium.	Mod 5 Factors that Affect Equilibrium CH12–6, 12–12 Bands 4–5

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 5 **A** **A** is correct. From the commencement of the process, both forward and reverse reactions are taking place. At t_1, the first equilibrium has been reached and forward and reverse reactions are occurring at the same rate. At t_2, there is a sharp increase in reactant concentration. Immediately after t_2, the system favours the forward reaction, as indicated by the slow rise in products and simultaneous slow decrease in reactants. At t_3, a new equilibrium has been reached with forward and reverse reactions occurring at the same rate. **B**, **C** and **D** are incorrect. These options do not reflect the criteria above.	Mod 5 Factors that Affect Equilibrium CH12–6, 12–12 Bands 5–6
Question 6 **A** **A** is correct. Neutralisation goes to completion with the same stoichiometric ratio between hydrochloric acid and sodium hydroxide as acetic acid and sodium hydroxide because they are both monoprotic acids. Hydrochloric acid is a strong acid and ethanoic acid is a weak acid. **B**, **C** and **D** are incorrect. Hydrochloric acid will have a greater electrical conductivity, will react more vigorously with magnesium ribbon and will have more hydrated hydrogen (H_3O^+) ions present.	Mod 6 Using Brønsted–Lowry Theory CH12–6, 12–13 Band 4
Question 7 **C** **C** is correct. As the mixture consists of a weak base (ammonia solution) and its salt (ammonium chloride), it is a buffer. **A** is incorrect. The mixture is weakly basic. **B** is incorrect. The mixture has a pH above 7. **D** is incorrect. Being a buffer, the mixture will resist changes in pH, but this may change depending on what solution is added.	Mod 6 Quantitative Analysis CH12–6, 12–13 Bands 3–4
Question 8 **C** **C** is correct. Because pH is a logarithmic scale, $[H^+]_X = 10^{-2}$ mol L^{-1} and $[H^+]_Y = 10^{-4}$ mol L^{-1}, giving $[H^+]_X = 100[H^+]_Y$. **A** is incorrect. As solution X has the lower pH, it is the stronger acid (both solutions are of equal concentration). **B** is incorrect. $[H^+]_X = 100[H^+]_Y$. **D** is incorrect. As pOH = 14 – pH, the pOH of solution X = 12 and the pOH of solution Y = 10. Hence, $[OH^-]$ in solution X is 10^{-12} mol L^{-1} and $[OH^-]$ in solution Y is 10^{-10} mol L^{-1}. This means that $[OH^-]$ in solution X is 100 times that of $[OH^-]$ in solution Y.	Mod 6 Quantitative Analysis CH12–6, 12–13 Bands 4–5

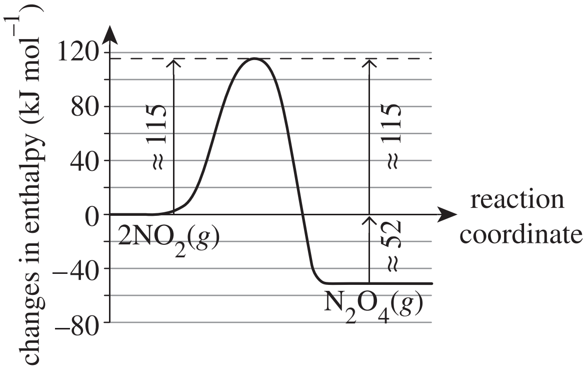
Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 9 **B** **B** is correct. The equivalence point is the midpoint of the vertical section of the titration curve. A line drawn from this point to the pH axis gives the pH of the equivalence point, which, in this case, is approximately 5.  **A**, **C** and **D** are incorrect. These options are not supported by the graph.	Mod 6 Quantitative Analysis CH12–6, 12–13 Bands 3–4
Question 10 **A** **A** is correct. An acid and its conjugate base differ by a single proton. In this reaction, the conjugate acid/base pairs are HCN/CN^- and H_2O/OH^-. CN^- + H_2O $\rightleftharpoons$ HCN + OH^- base acid conugate acid conugate base **B**, **C** and **D** are incorrect. These options do not differ by a transferable hydrogen ion.	Mod 6 Using Brønsted–Lowry Theory CH12–6, 12–13 Band 4
Question 11 **D** **D** is correct. The 'one' suffix identifies the highest priority functional group, which is the C=O. The longest carbon chain to include the C=O group contains seven carbons, so it is a heptanone. The OH group is indicated by the prefix 'hydroxy'. The number system starts at the end of the carbon chain closest to the ketone functional, placing the C=O group at carbon-3 and the OH group at carbon-6, giving the correct name as 6-hydroxyheptan-3-one. **A** is incorrect. The number system should start at the end of the carbon chain closest to the most important functional group (C=O). **B** is incorrect. In IUPAC naming, the C=O functional group is of higher priority than the OH functional group and the suffix is therefore 'one' not 'ol'. **C** is incorrect. When both the OH and C=O groups are present, the lower priority OH group is identified by the prefix 'hydroxy'.	Mod 7 Nomenclature CH12–7, 12–14 Bands 2–3

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 12 **A** **A** is correct. Butanoic acid is the most polar molecule (as it contains two oxygen atoms) so it will form stronger dipole–dipole forces and stronger H-bonds, giving it the highest boiling point. The only non-polar molecule, 2-methylbutane, will only have dispersion forces, resulting in it having the lowest boiling point. Ethyl ethanoate and butan-1-ol are both polar and will both form dipole–dipole forces. However, only butan-1-ol can form H-bonds. So, butan-1-ol will have the higher boiling point. **B**, **C** and **D** are incorrect. These options do not show the compounds arranged in order of increasing boiling points.	Mod 7 Alcohols Mod 7 Reactions of Organic Acids and Bases CH12–6, 12–14 Bands 4–5
Question 13 **B** The mass of one mole of C_4H_9OH is 74.12 g. $\text{heat released} = \frac{2676}{74.12} = 36.1\text{ kJ}$	Mod 7 Alcohols CH12–6, 12–14 Bands 2–3
Question 14 **A** **A** is correct. The broad band at approximately 3200 cm^{-1} is characteristic for an OH group, so the compound could be either hexan-1-ol or hexanoic acid. The absence of a strong sharp absorbance between 1700 cm^{-1} and 1800 cm^{-1} rules out the presence of C=O, which leaves hexan-1-ol as the only possibility. **B**, **C** and **D** are incorrect. These compounds are not supported by the infrared spectrum.	Mod 8 Analysis of Organic Substances CH12– 6, 2, 3, 4, 15 Bands 4–5
Question 15 **D** **D** is correct. Each compound would produce an easy-to-identify pattern of peaks in their ^{1}H NMR spectrum. **A** is incorrect. Atomic absorption spectroscopy is a technique used to detect low amounts of metal ions in a solution and would not be applicable for analysing the carbon compounds listed. **B** and **C** are incorrect. All four compounds are isomeric alcohols and will have similar absorbances in ultraviolet-visible spectrophotometry and infrared spectroscopy.	Mod 8 Analysis of Organic Substances CH12–1, 2, 3, 4, 15 Bands 5–6

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 16 **D** **D** is correct. Butanoic acid and methyl propanoate are similar sized molecules and will have similar sized dispersion forces. Both are polar molecules and will form dipole–dipole forces. However, the OH group present in butanoic acid enables hydrogen bonding to form between butanoic acid molecules. **A** is incorrect. Butanoic acid and methyl propanoate have the same number of covalent bonds. **B** is incorrect. Butanoic acid and methyl propanoate are similar in size. **C** is incorrect. As butanoic acid and methyl propanoate are polar molecules, both will form dipole–dipole forces.	Mod 7 Reactions of Organic Acids and Bases CH12–6, 12–7 Band 3
Question 17 **D** **D** is correct. The polymer is a type of nylon – a condensation polymer formed by the reaction between, in this example, a diacid and a diamine. **A** is incorrect. Alkanes do not react with HCNO. **B** is incorrect. Alcohols do not react with amides. **C** is incorrect. Alkenes do not react with amides.	Mod 8 Polymers CH12–14 Bands 3–4
Question 18 **C** **C** is correct. Ethyne has a triple-bond and the shape around a triple-bond is linear with a bond angle of 180°. **A** and **B** are incorrect. Carbons bonded to four other atoms are tetrahedral in shape with a bond angle of 109.5°. **D** is incorrect. The shape around an alkene double-bond is triangular (trigonal) planar with a bond angle of 120°.	Mod 7 Hydrocarbons CH12–6, 14, 15 Bands 5–6
Question 19 **B** **B** is correct. The compound shown in **B** contains an NH_2 functional group, an amine, which is basic because hydrolysis results in the formation of hydroxide ions. **A** and **C** are incorrect. **A** is an alcohol and **C** is an ester; both these functional groups are neutral when dissolved in water. **D** is incorrect. **D** is an alkanoic acid and will be the least basic of the compounds.	Mod 7 Reactions of Organic Acids and Bases CH12–5, 12–7 Band 3
Question 20 **C** **C** is correct. The 1,2-dichloroethane ($ClCH_2CH_2Cl$) is symmetrical and contains only one unique type of carbon atom. Therefore, its ^{13}C NMR will display a single peak. **A** is incorrect. The ^{13}C NMR for chloroethane ($ClCH_2CH_3$) will show two peaks. **B** is incorrect. The ^{13}C NMR for 1-chloropropane ($ClCH_2CH_2CH_3$) will show three peaks. **D** is incorrect. The ^{13}C NMR for 1,3-dichloropropane ($ClCH_2CH_2CH_2Cl$) will show two peaks.	Mod 8 Analysis of Organic Substances CH12–1, 3, 4, 15 Band 4

SECTION II

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 21	
For example: The combustion of octane is an example of a non-equilibrium reaction. The rate of the forward reaction does not equal the rate of the reverse reaction. $C_8H_{18}(l) + 12\frac{1}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$ The Gibbs free energy (G), enthalpy (H), temperature (T) and entropy (S) are related by the equation $\Delta G° = \Delta H° - T\Delta S°$. G is negative for all spontaneous reactions (reactions that strongly favour the forward direction). It is negative for non-spontaneous reactions (reactions that strongly favour the reverse direction). Enthalpy is a measure of the energy content of a system and reactions favour the forward direction, which is at a lower energy. The combustion of octane is an exothermic reaction (ΔH is negative) because heat is released. Therefore, the forward reaction is strongly favoured. The entropy change is positive as the system becomes more disordered (more gas molecules produced). Reactions will spontaneously favour the direction of reaction in which the system is most disordered. The forward reaction in the combustion of octane contains more gas molecules and is more disordered. Therefore, entropy also strongly favours the forward reaction. Both enthalpy and entropy considerations favour the forward reaction, so the combustion of octane does not reach an equilibrium state as neither enthalpy nor entropy changes favour the reverse reaction. An engine is an open system in which octane is drawn from a fuel tank and oxygen is taken from the air. Hence, the forward reaction can occur as long as fuel remains. In addition, carbon dioxide is 'lost' to the surroundings, making the possibility of a reverse reaction impossible.	Mod 5 Static and Dynamic Equilibrium CH12–7, 12–12 Bands 5–6 • Describes enthalpy changes for the named reaction. AND • Describes entropy changes for the named reaction. AND • Discusses the Gibbs free energy changes of the named reaction. AND • Identifies that equilibrium can only be achieved in a closed system . . . . 4 • Any THREE of the above points . . . 3 • Any TWO of the above points. . . . . 2 • Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 22	
(a) There are two gas molecules on the left-hand side of the equation, and one gas molecule on the right-hand side. Le Châtelier's principle states that the system will shift in such a way to minimise the change; that is, it will shift to minimise the increase in pressure. The pressure is due to gas molecules and so the minimum pressure is achieved by shifting the reaction from the left (two moles of gas) to the right (one mole of gas), resulting in a decrease in reactants and an increase in products.	Mod 5 Factors that Affect Equilibrium CH12–6, 12–12 Band 3 • Correctly states what will happen to the position of equilibrium. AND • Gives a suitable explanation . . . . . . 2 ——— • Correctly states what will happen to the position of equilibrium 1
(b) The activation energy of the forward reaction is approximately 115 kJ mol^{-1}. The activation energy of the reverse reaction is approximately $(115 + 52) = 167$ kJ mol^{-1}.  *Note: Accept responses that correctly represent the activation energies on the diagram.*	Mod 5 Factors that Affect Equilibrium CH12–6, 12–12 Bands 2–3 • Correctly determines the TWO activation energies . . . . 2 ——— • Correctly determines ONE activation energy 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(c) *For example:* Increasing temperature increases the rate of both forward and reverse reactions, so an equilibrium position will be reached more rapidly at a higher temperature. Le Châtelier's principle predicts the system will shift to minimise the effect of increasing temperature. The system minimises the increase in heat content that occurs when increasing temperature by favouring the endothermic reaction, as this shift absorbs heat. The reverse reaction is the endothermic reaction, so the equilibrium shifts to the left-hand side and there will be a greater proportion of reactants in the new equilibrium mixture that forms at the higher temperature. The equilibrium constant changes when temperature is changed and, in this case, as the new equilibrium position has an increased proportion of reactants, the equilibrium constant decreases when temperature is increased. *Note: A suitable alternative answer may include references to the Gibbs free energy.*	Mod 5 Factors that Affect Equilibrium CH12–6, 12–12 Bands 2–3 • Explains the effect of temperature on reaction rates. AND • Uses Le Châtelier's theory to predict the effect of temperature on the equilibrium position. AND • Explains the effect of temperature on the magnitude of the equilibrium constant . . . . 3 • Any TWO of the above points. . . . . 2 • Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 23	
initial total volume $= 20.0$ mL $= 0.0200$ L initial moles of $Fe^{3+} = 0.0100 \times 0.00200 = 0.0000200 = 2.00 \times 10^{-5}$ mol initial $[Fe^{3+}] = \frac{2.00 \times 10^{-5}}{0.0200} = 0.0100 \text{ mol L}^{-1}$ $[SCN^-] = 0.0100 \text{ mol L}^{-1}$ initial moles of $FeSCN^{2+} = 0$ mol final $[FeSCN^{2+}] = 1.45 \times 10^{-4} \text{ mol L}^{-1}$	Mod 5 Calculating the Equilibrium Constant CH12–6, 12–12 Band 6 • Correctly calculates the reaction quotient. AND • Shows ALL relevant working. AND • Compares equilibrium constant to reaction quotient. AND • Determines the direction of the reaction . . . . .5–6 • Correctly calculates the reaction quotient. AND • Shows SOME relevant working. AND • Compares equilibrium constant to reaction quotient. OR • Determines the direction of the reaction . . . . 4 • Correctly calculates the reaction quotient. AND • Shows SOME relevant working. AND • Refers to equilibrium constant AND reaction quotient. OR • Determines the direction of the reaction . . . . .3 • Shows SOME relevant working. AND • Refers to equilibrium constant AND reaction quotient. . . . . .2 • Shows SOME relevant working. OR • Refers to equilibrium constant AND reaction quotient. 1

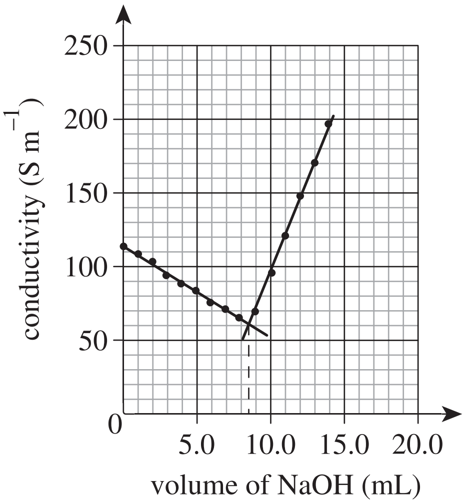
	Fe^{3+}	SCN^-	$FeSCN^{2+}$
Initial number of moles	2×10^{-5}	2×10^{-5}	0
Change	-2.9×10^{-6}	-2.9×10^{-5}	$+2.9 \times 10^{-6}$
Final number of moles	1.71×10^{-5}	1.71×10^{-5}	2.9×10^{-6}
Final concentration	8.55×10^{-4}	8.55×10^{-4}	1.45×10^{-4}

$$Q = \frac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^-]} = \frac{[1.45 \times 10^{-4}]}{[8.55 \times 10^{-4}][8.55 \times 10^{-4}]} = 198$$

In this case, $Q = 1.98 \times 10^2$ is less than $K = 2.05 \times 10^2$. Therefore, the reaction must shift to the right to reach equilibrium.

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 24	

$NaOH(aq) + CH_3COOH(aq) \rightarrow CH_3COONa\ (aq) + H_2O(l)$



$$\text{end point} = 8.5 \text{ mL}$$
$$= 0.0085 \text{ L NaOH}$$

For dilute solution:

$$\text{moles of NaOH} = 0.0085 \times 0.12$$
$$= 0.00102 \text{ mol}$$
$$\text{moles of } CH_3COOH = 0.00102 \text{ mol}$$

For original sample:

$$\text{moles of } CH_3COOH = 0.00102 \times \frac{250}{25}$$
$$= 0.0102 \text{ mol}$$
$$\text{molar mass of } CH_3COOH = 2 \times 12.01 + 4 \times 1.008 + 2 \times 16.00$$
$$= 60.052 \text{ g mol}^{-1}$$
$$\text{mass of } CH_3COOH = 0.0102 \times 60.052$$
$$= 0.613 \text{ g}$$
$$\%\ CH_3COOH = \frac{0.613}{25.00} \times 100$$
$$= 2.45$$
$$= 2.5\%$$

The concentration of the vinegar is less than the 7% minimum required concentration to be an effective cleaning agent.

Note: Accept responses within reasonable ranges that vary due to the endpoint read from the drawn graph. End point values between 8.3 and 8.7 are acceptable.

Mod 6 Quantitative Analysis
CH12–4, 12–6, 12–12 Band 6

- Correctly graphs the data showing lines of best fit.

AND
- Extrapolates equivalence point.

AND
- Calculates concentration accurately.

AND
- Shows working.

AND
- Makes the correct conclusion based on concentration 6–7

- Correctly graphs the data showing lines of best fit.

AND
- Extrapolates equivalence point.

AND
- Calculates concentration accurately OR shows working.

AND
- Makes a conclusion based on concentration 4–5

- Correctly graphs the data showing lines of best fit.

AND
- Extrapolates equivalence point OR calculates concentration accurately OR shows working.

AND
- Makes a conclusion based on concentration 2–3

- Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 25	
(a) Equation for reaction: $2HNO_3(aq) + Ca(OH)_2(aq) \rightarrow Ca(NO_3)_2(aq) + 2H_2O(l)$ $\text{molar mass} = 40.08 + 2(16.00 + 1.008) = 74.10\text{ g}$ $\text{initial moles of } Ca(OH)_2 = \frac{\text{mass}}{\text{molar mass}} = \frac{1.78}{74.10} = 0.0240\text{ mol}$ $\therefore \text{initial moles of } OH^- = 0.0480\text{ mol}$ $\text{initial moles of nitric acid } (HNO_3) = 0.250 \times 0.200 = 0.0500\text{ mol}$ Nitric acid is in excess; therefore, the final number of moles of HNO_3 $(0.0500 - 0.0480) = 0.002$ mol. $[HNO_3] \text{ in excess} = \frac{0.002}{0.250} = 0.008\text{ mol L}^{-1}$ $pH = -\log[H^+] = -\log[0.008] = 2.097 = 2.10$	Mod 6 Properties of Acids and Bases Mod 6 Using Brønsted–Lowry Theory CH12–6, 12–13 Bands 5–6 • Uses correct stoichiometry. AND • Shows relevant calculations. AND • Calculates pH correctly . . . . 3 • Uses correct stoichiometry. AND • Shows relevant calculations OR calculates pH correctly . . . . 2 • Shows relevant calculations. OR • Calculates pH correctly 1
(b) Nitric acid can be regarded as both an Arrhenius acid and a Brønsted–Lowry acid. An Arrhenius acid is a substance that dissociates in solution to produce hydrogen ion. For nitric acid: $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$ A Brønsted–Lowry acid is a substance that undergoes a hydrolysis reaction to produce $H_3O^+(aq)$. For nitric acid: $\underset{\text{acid}}{HNO_3(aq)} + \underset{\text{base}}{H_2O(l)} \rightarrow \underset{\text{conugate acid}}{H_3O^+(aq)} + \underset{\text{conugate base}}{NO_3^-(aq)}$	Mod 6 Properties of Acids and Bases CH12–13 Band 3 • Explains how nitric acid can be regarded as an Arrhenius acid. AND • Explains how nitric acid can be regarded as a Brønsted–Lowry acid . . . . 2 • Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 26	
(a) $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$	Mod 6 Properties of Acids and Bases CH12–13 Band 2 • Writes an appropriate equation 1
(b) The stoichiometry of the equation shows one mole of hydrogen gas is generated for one mole of magnesium reacted. $\text{moles of magnesium} = \frac{\text{actual mass}}{\text{molar mass}}$ $= \frac{0.361}{24.31}$ $= 0.01485 \text{ mol}$ $\text{volume of } H_2 = \text{moles} \times \text{molar volume}$ $= 0.01485 \times 24.79$ $= 0.368$ or 368 mL (to 3 significant figures)	Mod 6 Properties of Acids and Bases CH12–6, 12–13 Band 3 • Uses correct stoichiometry. AND • Shows relevant calculations. AND • Calculates volume correctly . . . . 3 • Shows relevant calculations. AND • Calculates volume correctly . . . . 2 • Shows relevant calculations. OR • Calculates volume correctly 1
(c) *Any one of:* • Standard conditions (25°C and 100 kPa) might not be in place. That is, it may be warmer than 25°C and/or the pressure may be less than 100 kPa. • Heat might be generated in the exothermic reaction, causing the gas to expand. • The sample of hydrogen collected might not have been pure (for example, if some of the sample was not hydrogen, but water vapour).	Mod 6 Properties of Acids and Bases CH12–6, 12–13 Band 4 • Gives ONE appropriate reason 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide

Question 27

(a) Equation for reaction:

$HCOOH(aq)\ H_2O(l) \rightleftharpoons HCOO^-(aq) + H_3O^+(aq)$

Equilibrium expression:

$$K_a = \frac{[HCOOH^-][H_3O^+]}{[HCOOH]}$$

$$pH = 2.38$$
$$= -\log[H_3O^+]$$

Hence, $[H_3O^+] = 4.169 \times 10^{-3}$.

Initial (I), change (C), equilibrium (E) table:

	HCOOH(aq)	*$HCOO^-(aq)$*	*$H_3O^+(aq)$*
I	0.100	0	0
C	$0.100 - 4.169 \times 10^{-3}$	$+4.169 \times 10^{-3}$	$+4.169 \times 10^{-3}$
E	0.0958	4.169×10^{-3}	4.169×10^{-3}

Note: Water is omitted from the table as the number of hydrogen ions produced by the self-ionisation of water is negligible.

Because so little dissociation takes place, we can approximate the final concentration of formic acid to the initial concentration.

$$K_a = \frac{[4.169 \times 10^{-3}][4.169 \times 10^{-3}]}{[0.0958]}$$
$$= 1.81 \times 10^{-4}$$

Mod 6 Quantitative Analysis
CH12–6, 12–13 Bands 4–5

- Uses correct equilibrium expression.

AND

- Shows relevant calculations.

AND

- Calculates dissociation constant correctly. 3

- Uses correct equilibrium expression.

AND

- Shows relevant calculations.

OR

- Calculates dissociation constant correctly. 2

- Uses correct equilibrium expression.

OR

- Shows relevant calculations.

OR

- Calculates dissociation constant correctly. 1

(b) As the value of the dissociation constant calculated in part (a) is very small, the strength of this acid is weak.

Note: Consequential on answer to Question 27(a).

Mod 6 Quantitative Analysis
CH12–6, 12–13 Band 2

- Correctly identifies the strength of the acid. 1

Question 28

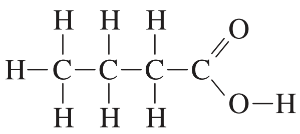
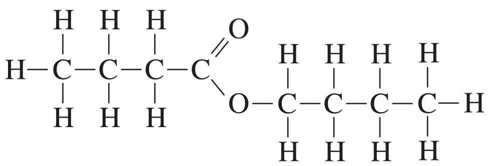
(a) $C_6H_5NO_3(aq) + H_2O(l) \rightleftharpoons \mathbf{C_6H_4NO_3}^-(aq) + \mathbf{H_3O}^+(aq)$

Mod 6 Quantitative Analysis
CH12–6, 12–13 Band 2

- Correctly completes the equilibrium equation 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) The Beer–Lambert law relates absorbance and concentration. $A = \varepsilon lc$ $0.433 = 18\,600 \times c \times 1.00$ $c = 2.32 \times 10^{-5}$ mol L^{-1}	Mod 8 Analysis of Inorganic Substances CH12–4 Bands 3–4 • Correctly determines the value of the concentration. AND • Expresses the answer to the correct number of significant figures . . . . 2 • Provides some relevant information 1
Question 29	
(a) (i) The electric field accelerates all ions to the same speed.	Mod 8 Analysis of Organic Substances CH12–7, 12–15 Bands 3–4 • Correctly identifies the purpose of the electric field 1
(ii) The magnetic field sorts ions according to the mass-to-charge ratio.	Mod 8 Analysis of Organic Substances CH12–7, 12–15 Bands 3–4 • Correctly identifies the purpose of the magnetic field 1
(b) The element that has an atomic mass of 74.92 amu is arsenic. As there is only one peak at this point, arsenic consists of a single isotope. The two peaks at 106.9 amu and 108.9 amu suggest an element with two isotopes. The element that has an average atomic mass between these two values is silver.	Mod 8 Analysis of Organic Substances CH12–6, 12–7, 12–14 Bands 4–5 • Identifies both elements present in the mixture. AND • Correctly determines the number of isotopes for each element. . . . . 2 • Identifies at least ONE element present in the mixture. OR • Correctly determines the number of isotopes for each element. 1
(c) Hexane and hexan-1-ol both contain C–H and C–C bonds. However, hexan-1-ol contains C–O and O–H bonds. The O–H bond shows a broad absorbance between 3200 cm^{-1} and 3600 cm^{-1} and the C–O bond shows a strong absorbance at approximately 1100 cm^{-1}.	Mod 8 Analysis of Organic Substances CH12–6, 12–7, 12–14 Bands 4–5 • Identifies that hexan-1-ol contains C–O and O–H bonds AND • Correctly identifies the relevant absorption peaks . . . . 2 • Any ONE of the above points 1

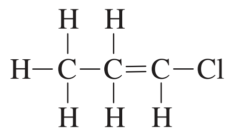
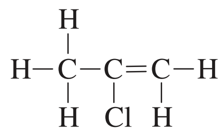
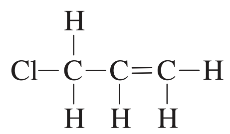
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 30	
As compound X is insoluble, it is unlikely to be a nitrate salt. As compound X is a white solid, it is unlikely to be a transition metal salt. A colourless gas is produced when nitric acid is added to compound X, suggesting that it is a carbonate. Solution Y is the nitrate salt of the cation present in compound X. Solution Y does not form a precipitate with NaCl(*aq*), so the cation is not Ag^+ or Pb^{2+}. Solution Y forms a precipitate with Na_2SO_4, so the cation could be either Ba^{2+} or Ca^{2+}. As solution Y does not precipitate with NaOH, the cation is not Ca^{2+}. Therefore, compound X is barium carbonate. The relevant net ionic equations are: $BaCO_3(s) + 2H^+(aq) \rightarrow Ba^{2+}(aq) + H_2O(l) + CO_2(g)$ $Ba^{2+}(aq) + SO_4^{2-} \rightarrow BaSO_4(s)$	Mod 5 Solubility Equilibria Mod 8 Analysis of Inorganic Substances CH12–3, 4, 5, 6 Bands 5–6 • Correctly identifies compound X. AND • Provides detailed reasons drawn from the information provided. AND • Provides relevant net ionic equations . . . . 3–4 • Partially identifies compound X. AND • Outlines some reasons drawn from the information provided. OR • Provides relevant net ionic equations . . . . 2 • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 31	
(a) (i) The oxidation product, compound B, contains two oxygen atoms, which suggests that compound B is an acid. Oxidation of primary alcohols yields acids, indicating that compound A must be a primary alcohol.	Mod 7 Alcohols CH12–6, 12–14 Band 4 • Correctly identifies that compound A is a primary alcohol. AND • Provides a suitable supporting explanation . . . . 2 • Correctly identifies that compound A is a primary alcohol 1
(ii) *For example, any one of:* • acidified potassium dichromate solution • acidified potassium permanganate solution	Mod 7 Hydrocarbons CH12–6, 12–14 Bands 2–3 • Identifies an appropriate oxidising agent. 1
(b) butanoic acid 	Mod 7 Alcohols CH12–6, 12–14 Bands 3–4 • Correctly names compound B. AND • Draws an appropriate structural formula. OR • Equivalent merit . . . . 2 • Any ONE of the above points 1
(c) 1-butyl butanoate 	Mod 7 Alcohols CH12–6, 12–14 Bands 3–4 • Correctly names compound C. AND • Draws an appropriate structural formula. OR • Equivalent merit . . . . 2 • Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 32	
(a) The peak at m/z = 88 is the molecular ion. molar mass $C_4H_8O_2 = 4 \times 12.01 + 8 \times 1.008 + 2 \times 16.00$ $= 88.10$	Mod 8 Analysis of Organic Substances CH12–4, 12–7, 12–15 Bands 2–3 • Correctly identifies the peak at m/z = 88. 1
(b) Compound X is methyl propanoate, $CH_3CH_2COOCH_3$. The infrared spectrum shows a strong peak at around 1700 cm^{-1}, which suggests a carbonyl (C=O) group. The lack of a broad band between 3000 cm^{-1} and 3500 cm^{-1} indicates that the compound does not contain an OH group. Therefore, the compound is not an alkanoic acid. The compound could be an ester, aldehyde or ketone. The quartet signal in the ^{1}H NMR is due to hydrogens on a carbon adjacent to CH_3 (giving a partial structure of CH_xCH_2). The triplet signal is due to hydrogens on a carbon adjacent to CH_2 (giving a partial structure of CH_xCH_2). A quartet and triplet combination indicates the compound contains the CH_3CH_2 partial structure. Methyl propanoate, $CH_3CH_2COOCH_3$, contains the CH_3CH_2 partial structure indicated by the proton NMR. In addition, the singlet for the CH_3O hydrogens is present, as would be expected. The ester function agrees with the IR data. The parent ion in the mass spectrum would appear at m/z = 88 amu and this ester would be expected lose a CH_3O fragment with a peak then appearing at m/z = 88 – 81 = 57 amu in the mass spectrum, as is the case. The other possible ester, ethyl ethanoate, would lose a CH_3CH_2O fragment with a peak showing at m/z = 45 amu.	Mod 8 Analysis of Organic Substance CH12–4, 12–7, 12–15 Bands 5–6 • Correctly identifies compound X. AND • Provides a detailed justification with reference to ALL of the data . . . . .6–7 • Correctly identifies compound X. AND • Provides justification with reference to some of the data. . . .4–5 • Justifies a partially correct structure with reference to ALL of the data . . . . .2–3 • Correctly identifies compound X. OR • Justifies a partially correct structure with reference to some of the data. 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 33	
(a) see table below	Mod 7 Organic Chemistry CH12–4, 12–7, 12–15 Bands 2–3 • Correctly identifies THREE isomeric chloroalkenes. AND • Correctly draws all THREE isomeric chloroalkenes. OR • Equivalent merit . . . . 3 — • Correctly identifies THREE isomeric chloroalkenes. OR • Correctly draws TWO isomeric chloroalkenes. OR • Equivalent merit . . . . 2 — • Provides some relevant information 1
(b) The reagent is acidified permanganate solution. It would be expected that cyclohexanol (a secondary alcohol) would decolourise permanganate solutions. There would be no visible reaction with 1-methylcyclohexanol (a tertiary alcohol).	Mod 7 Alcohols CH12–6, 12–14 Bands 3–4 • Identifies the appropriate test reagent. AND • Describes the test results . . . . 2 — • Provides some relevant information 1

Question 33 (a):

Systematic name	*Structural formula*
1-chloroprop-1-ene OR 1-chloropropene	
2-chloroprop-1-ene OR 2-chloropropene	
3-chloroprop-1-ene OR 3-chloropropene	

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 34	
Any three of: • The two reagents (propene and benzene) are reacted in high yield to produce two valuable products (acetone and phenol). • The design process includes two recycle loops that ensure no loss of starting materials. • Two of the three chemical steps use a cheap catalyst of phosphoric acid (H_3PO_4) to reduce the temperature and pressure, which is needed to make these steps occur at a reasonable rate. • The only exhaust produced is harmless nitrogen gas, so no environmental pollutants are produced. • The reaction conditions are low temperature and low pressure, so the capital cost of building the plant will be low. • The plant could be located near sources of benzene and propene to reduce transport costs of raw materials. • The plant could be located near a port or transport hub to facilitate economical transport to target markets.	Mod 8 Analysis of Organic Substances CH12–4, 12–7, 12–15 Bands 2–3 • Outlines THREE factors relevant to the design of the industrial process. AND • Makes specific reference to the information provided . . . . 4 • Outlines THREE relevant factors without specific reference to the information provided. OR • Outlines TWO relevant factors with specific reference to the information provided . . . . 3 • Gives THREE relevant factors in limited detail with limited reference to the information provided. OR • Outlines ONE relevant factor with specific reference to the information provided . . . . 2 • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 35	
A and *C* represent covalent bonds. *B* and *D* represent dispersion forces. The covalent bonding between a carbon and a hydrogen atom within a methane molecule is similar to the covalent bonding between the C and H atoms in an ethane molecule. The dispersion force between these non-polar molecules is related to molecular size. Therefore, dispersion force *D* is stronger than dispersion force *B*. The physical properties of members of the homologous series of alkanes represented in the diagram is determined by the strength of the dispersion forces.	Mod 8 Hydrocarbons CH12–6, 12–14 Bands 3–4 • Correctly compares the strength of the covalent bonds *A* and *C*. AND • Correctly compares the strength of the dispersion forces *B* and *D*. AND • Relates physical properties to the strength of the intermolecular forces . . . . 4–5 • Correctly compares the strength of the covalent bonds *A* and *C*. AND • Correctly compares the strength of the dispersion forces *B* and *D*. OR • Relates physical properties to the strength of the intermolecular forces . . . . 2–3 • Provides some relevant information 1