CRANBROOK SCHOOL

1	2	5

Centre Number

Student Number

2020

TRIAL EXAMINATION

Chemistry

General Instructions

- Assessment Task 3 – Weighting 50%
- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formula sheet, data sheet and Periodic Table are provided separately

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 11-27)

- Attempt Questions 21-34
- Allow about 2 hours and 25 minutes for this section

Section I

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

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

1. Which of the following best describes a chemical system that is in equilibrium?

   A. All reactions have stopped

   B. The concentrations of the reactants and products are the same

   C. The rate of conversion of reactants to products is minimal

   D. The rates of the forward and reverse reactions are the same

2. Atomic absorption spectroscopy (AAS) is an analytical technique that uses the visible light region of the electromagnetic spectrum.

Analytical technique	Part of electromagnetic spectrum used
AAS	Visible light
NMR	I
Colourimetry	II
IR	III

   Which part of the electromagnetic spectrum is used by the other analytical techniques in the table above in the order I, II and III?

   A. Radio waves, visible light, infrared

   B. Visible light, UV light, infrared

   C. Radio waves, infrared, infrared

   D. X-rays, visible light, infrared

3. Nylon is a condensation polymer made up of hexanedioic acid and 1,6-diaminohexane. Which type of linkage is present in nylon?

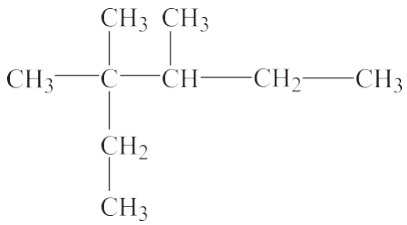
   A. Amide

   B. Ester

   C. Amine

   D. Carboxyl

4. What is the IUPAC name of the following compound?



   A. 3,4,4-trimethylhexane

   B. 3,3,4-trimethylhexane

   C. 4-ethyl-3,4-dimethylpentane

   D. 2-ethyl-2,3-dimethylpentane

5. Consider the following equilibrium reaction in a closed container at 350 °C.

$$SO_{2\,(g)} + Cl_{2\,(g)} \rightleftharpoons SO_2Cl_{2\,(g)} \qquad \Delta H = -85 \text{ kJ mol}^{-1}$$

   Which statement is correct?

   A. Decreasing the temperature will increase the amount of $SO_2Cl_{2\,(g)}$

   B. Increasing the volume of the container will increase the amount of $SO_2Cl_{2\,(g)}$

   C. Increasing the temperature will increase the amount of $SO_2Cl_{2\,(g)}$

   D. Adding a catalyst will increase the amount of $SO_2Cl_{2\,(g)}$

6. A 1.0 L reaction vessel initially contains only 6.0 mol of **P** and 6.0 mol of **Q**. At equilibrium 4.0 mol of **R** is present. What is the value of K_{eq} for the following reaction?

$$P_{(g)} + Q_{(g)} \rightleftharpoons R_{(g)} + S_{(g)}$$

A. 0.11

B. 0.25

C. 0.44

D. 4.00

7. A student analysed a sample of water from a local creek that was suspected of being contaminated by a metallic ion. The student added dilute hydrochloric acid to the sample and noted that no reaction occurred. Addition of sulfuric acid caused the formation of a white precipitate. He then carried out a flame test and observed a distinctive orange colour in the flame.

   Which of the following metallic ions could it be?

A. Pb^{2+}

B. Ba^{2+}

C. Ca^{2+}

D. Fe^{2+}

8. The pK_a values of four acids are shown below.

W	4.87
X	4.82
Y	4.86
Z	4.85

   What is the correct order when these acids are arranged in order of **increasing** acid strength?

A. X, Z, Y, W

B. X, Y, Z, W

C. W, Y, Z, X

D. W, Z, Y, X

9. In complete combustion, a sample of a hydrocarbon compound produces 1.5 mol of carbon dioxide and 2.0 mol of water. What is the molecular formula of this hydrocarbon?

   A. C_2H_2

   B. C_2H_4

   C. C_3H_4

   D. C_3H_8

10. What is the minimum volume of 0.500 mol L^{-1} sulfuric acid solution is required to react completely with 10.0 g of calcium carbonate according to the equation below?

$$CaCO_{3\,(s)} + H_2SO_{4\,(aq)} \rightarrow CaSO_{4\,(aq)} + H_2O_{\,(l)} + CO_{2\,(g)}$$

   A. 100 mL

   B. 200 mL

   C. 300 mL

   D. 400 mL

11. Solutions of hydrochloric acid ($HCl_{(aq)}$) and ethanoic acid ($CH_3COOH_{(aq)}$) of the same concentration reacted completely with 5.0g of calcium carbonate in separate containers. Which statement is correct?

   A. $CH_3COOH_{\,(aq)}$ reacted slower because it has a lower pH than $HCl_{\,(aq)}$.

   B. A smaller volume of $CO_{2\,(g)}$ was produced with $CH_3COOH_{\,(aq)}$ than with $HCl_{\,(aq)}$.

   C. A greater volume of $CO_{2\,(g)}$ was produced with $CH_3COOH_{\,(aq)}$ than with $HCl_{(aq)}$.

   D. The same volume of $CO_{2\,(g)}$ was produced with both $CH_3COOH_{\,(aq)}$ and $HCl_{(aq)}$.

12. Ammonia (NH_3) is a weak base in aqueous solution with an ionisation constant K_b. A relevant equation is shown below:

$$NH_4^+{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons NH_3{}_{(aq)} + H_2O_{(l)}$$

Which of the following is the correct expression for K_b for ammonia?

A. $\dfrac{[NH_4^+][OH^-]}{[NH_3][\ H_2O]}$

B. $\dfrac{[NH_3][\ H_2O]}{[NH_4^+][OH^-]}$

C. $\dfrac{[NH_4^+][OH^-]}{[NH_3]}$

D. $\dfrac{[NH_3]}{[NH_4^+][OH^-]}$

13. 10mL of 0.01 mol L^{-1} nitric acid (HNO_3) is diluted with 90 mL of water. What is the pH of the resulting solution?

A. 1

B. 2

C. 3

D. 4

14. A base of concentration 0.10 mol L^{-1} is titrated with 25 mL of an acid of concentration 0.01 mol L^{-1}. Which acid-base pair would have the highest pH at equivalence point?

A. $NaOH_{(aq)}$ and $CH_3COOH_{(aq)}$

B. $NaOH_{(aq)}$ and $HNO_{3\ (aq)}$

C. $NH_{3\ (aq)}$ and $HNO_{3\ (aq)}$

D. $NH_{3\ (aq)}$ and $CH_3COOH_{(aq)}$

15. An organic compound **X** reacts with excess acidified potassium dichromate to form compound **Y**, which reacts with sodium carbonate to produce $CO_{2\,(g)}$.

What is a possible formula for compound **X**?

A. CH_3CH_2COOH

B. $CH_3CH_2CH_2OH$

C. $CH_3CH(OH)CH_3$

D. $(CH_3)_3COH$

16. A student carried out a precipitation titration to determine the amount of $BaSO_4$ precipitate formed when excess $BaCl_{2(aq)}$ was added to a sample of $Fe(NH_4)_2(SO_4)_{2(aq)}$. In their experiment, the number of moles of $BaSO_4$ obtained was 5.02×10^{-3} mol.

How many moles of sulfate and iron ions were present in the sample of $Fe(NH_4)_2(SO_4)_{2(aq)}$?

	Amount of sulfate ions (mol)	Amount of iron ions (mol)
A.	5.02×10^{-3}	2.51×10^{-3}
B.	10.04×10^{-3}	5.02×10^{-3}
C.	2.51×10^{-3}	5.02×10^{-3}
D.	10.04×10^{-3}	2.51×10^{-3}

17. Chromium (II) hydroxide has a K_{sp} value of 2.00×10^{-16} at 25°C.What is the molar solubility of chromium (II) hydroxide at 25°C?

A. 2.00×10^{-16}

B. 1.41×10^{-8}

C. 3.68×10^{-6}

D. 4.64×10^{-6}

18. A student carried out an investigation to monitor the mass changes during fermentation of glucose to produce ethanol. The equation for the reaction is shown below:

$$C_6H_{12}O_{6\,(aq)} \rightarrow 2C_2H_6O_{\,(aq)} + 2CO_{2\,(g)}$$

The student connected the fermentation flask to a conical flask fitted with a cork and a delivery tube. The conical flask contained limewater. She recorded the mass of the flask containing limewater every day for 5 days and noted that the mass increased.

Limewater flask	
Day	*Mass (g)*
1	503.12
2	505.68
3	509.88
4	512.16
5	515.67

Which of the following would be closest to the mass of ethanol produced over the 5-day period?

A. 12.55 g

B. 13.15 g

C. 25.01 g

D. 26.30 g

19. The mass spectrum of a molecule C_3H_6O shows major peaks at m/z values of 58, 43, 29 and 15.

Which is the most likely structural formula of this compound?

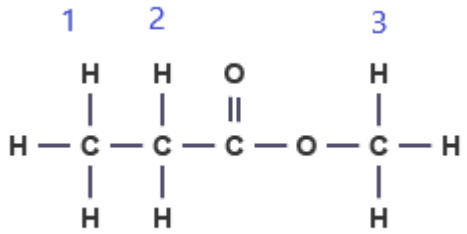
A. CH_3CH_2CHO

B. CH_3COCH_3

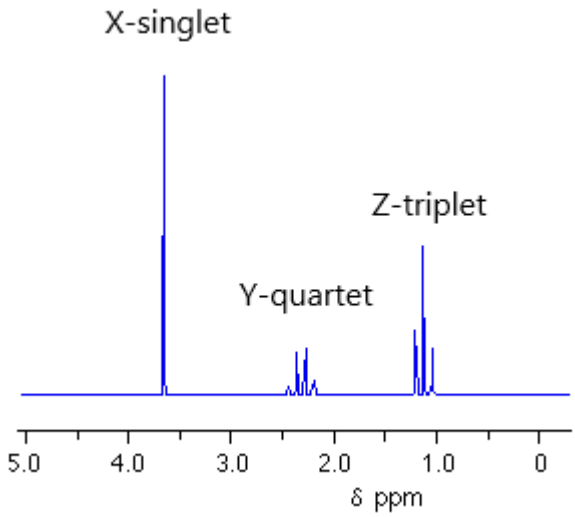
C. $CH_3CH_2OCH_3$

D. $CH_3CH_2CH_2OH$

20. The diagram below shows the structural formula of methyl propanoate. The three different hydrogen environments that are used in ^{1}H NMR analysis are numbered as 1, 2 and 3.



The diagram below is the high resolution ^{1}H NMR spectrum for methyl propanoate. The three peaks have been labelled X, Y and Z and the number of splits given.



Which of the following answers matches the peaks X, Y and Z with their correct hydrogen environments in the methyl propanoate molecule numbered 1, 2 and 3?

A. 3, 1, 2

B. 2, 1, 3

C. 3, 2, 1

D. 1, 2, 3

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TRIAL

EXAMINATION

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21-34
Allow about 2 hours and 25 minutes for this section

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

Question 21 (3 marks)

150.0 mL of a 0.100 mol L^{-1} $Pb(NO_3)_2$ solution is added to 100.0 mL of 0.200 mol L^{-1} NaCl solution. Predict mathematically if a precipitate will form.

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Question 22 (6 marks)

a) Explain the processes involved in the dissolution of ionic compounds in water. **3**

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b) Describe how Aboriginal and Torres Strait Islander Peoples use solubility equilibria to remove toxicity from foods. **3**

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Question 23 (7 marks)

Calcium carbonate is a highly insoluble ionic compound.

a) Calculate the molar solubility of calcium carbonate at 25ºC. **2**

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b) If the calcium carbonate is added to a 0.150 mol L^{-1} solution of calcium chloride at the same temperature, calculate its solubility. **2**

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c) Explain the difference between the solubility of calcium carbonate in water and in calcium chloride. **3**

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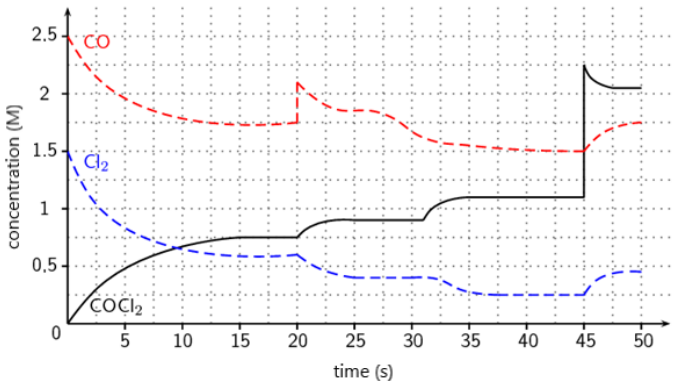
Question 24 (5 marks)

Carbon monoxide gas reacts with chlorine gas to form the toxic gas phosgene ($COCl_2$) in a reversible reaction. The concentration v time graph below shows the pathway of this reaction inside a closed container.



a) Identify what occurred at t=32s. **1**

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b) Explain the response of the system at t=45s. **2**

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c) Calculate K at t=15s. **2**

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Question 25 (4 marks)

A student added 50.00 mL of 0.1000 mol L^{-1} HCl to 25.00 mL of a commercial ammonia-based cleaner. They then carried out a titration of the excess HCl using a standardised solution of 0.1000 mol L^{-1} NaOH. The average titre value was 21.50 mL.

Calculate the concentration of the ammonia in the cleaner.

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Question 26 (7 marks)

Buffers are very important in industry and in natural systems.

a) What is a buffer? **1**

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b) A basic buffer solution is represented by the generic equation below:

$$A^-_{(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + HA_{(aq)}$$

Explain how this buffer solution responds to the addition of:

i) A strong base. **2**

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ii) A strong acid. **2**

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c) Outline the importance of a named buffer in a natural system. **2**

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Question 27 (3 marks)

A 25.0 mL solution of 0.050 mol L^{-1} potassium hydroxide solution is added to a 25.0 mL solution of 0.050 mol L^{-1} sulfuric acid solution. Calculate the pH of the resulting solution.

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Question 28 (5 marks)

There are many different ways of analysing acids and bases.

a) Discuss the use of indicators in determining acidity. **3**

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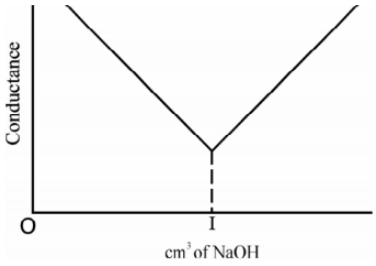
b) Another technique used to analyse acids and bases is conductometric titration. The graph below shows the conductance curve for a strong acid – strong base titration.



Conductometric titration of a strong acid (HCl) vs. a strong base (NaOH)

Explain the shape of this graph. **2**

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Question 29 (5 marks)

Polymers are very important for making many of the materials that we use every day.

a) An example of a polymer is polystyrene. Draw the polymer notation for polystyrene. **1**

b) Another polymer is PVC. Outline a use of PVC linking its use to its properties. **1**

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c) Compare addition and condensation polymers. **3**

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Question 30 (6 marks)

The tables below show the boiling points of some alkanes and carboxylic acids.

Fig 1: Boiling Points of some alkanes and carboxylic acids

Alkane	Relative molecular mass ($g.mol^{-1}$)	Boiling Point (^oC)
Methane	16	-164
Ethane	30.1	-87
Propane	44.1	-42
Butane	58.1	-0.5
Pentane	72.1	36.1
Hexane	86.2	68.7

Carboxylic Acid	Relative molecular mass ($g.mol^{-1}$)	Boiling Point (^oC)
Methanoic acid	46	101
Ethanoic acid	60.1	118
Propanoic acid	74.1	141
Butanoic acid	88.1	164
Pentanoic acid	102.1	186
Hexanoic acid	116.2	202

a) Use the grid below to graph this data (draw two separate lines on the same graph, one for each homologous series, clearly labelling each line) **3**

Question 30 continues on the next page

b) Explain the boiling point trends within and between these two homologous series. **3**

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Question 31 (3 marks)

Explain how soaps and detergents clean dirt off surfaces such as plates and clothes.

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Question 32 (6 marks)

Esterification is an important chemical reaction.

a) Write a balanced equation for the reaction of ethanol with propanoic acid. **2**

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b) Name the ester that is formed in this reaction. **1**

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c) Justify the use of refluxing in esterification. **3**

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Question 33 (10 marks)

a) How are ions present in the environment identified and measured? **7**

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Question 33 continues on the next page

b) For a named ion, explain why it is important to monitor for its presence in the environment. **3**

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Question 34 (10 marks)

An organic compound '**X'** is 68.11 % carbon, 13.74 % hydrogen and 18.15 % oxygen by mass.

a) Show that the empirical formula of the compound 'X' is $C_5H_{12}O$. **2**

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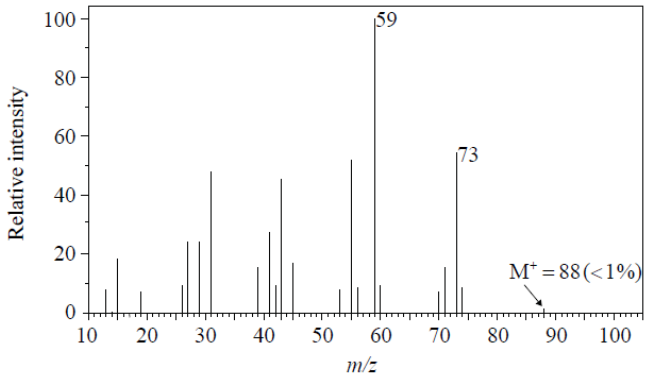
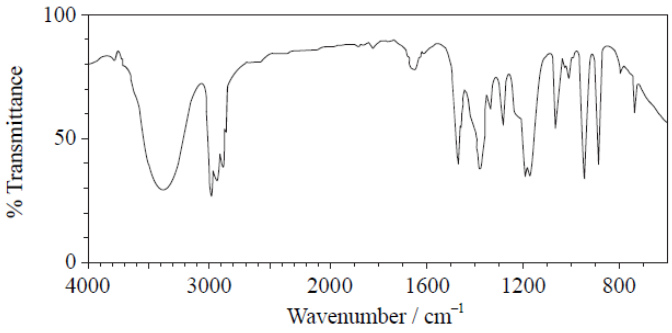
The mass spectrum, infrared spectrum, ^{13}C NMR spectrum and ^{1}H NMR spectrum for compound 'X' are given below.

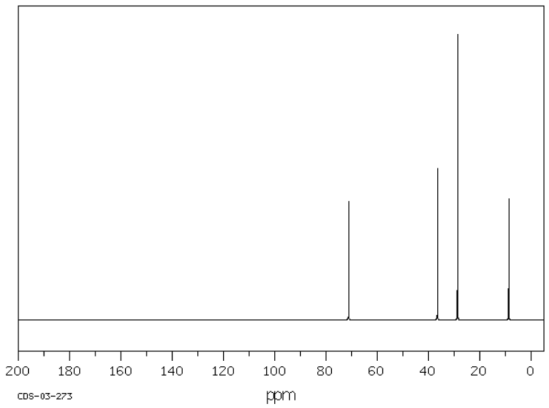
Mass spectrum



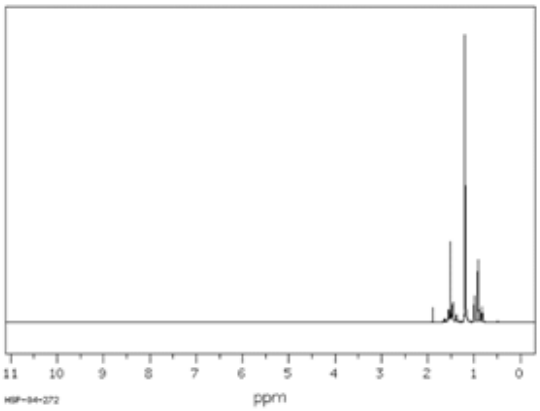
Infrared spectrum



^{13}C NMR Spectrum



^{1}H NMR Spectrum



This shows, from right to left, a quartet, singlet, triplet & singlet on the ^{1}H NMR

b) Analyse these four spectra and referring to the information in <u>each</u> of these spectra deduce the identity of this compound 'X'. **8**

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End of Trial Examination

Extra writing space for Section II

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2020 Chemistry Trial Exam Marking Guidelines

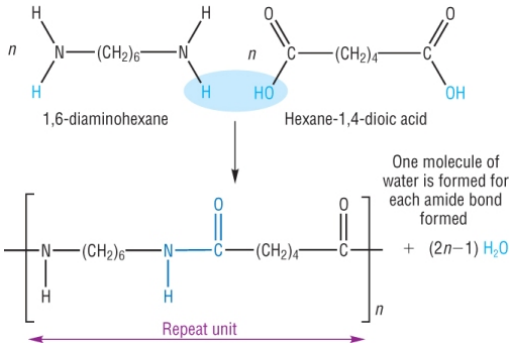
Test Section	Question	Marks	Outcomes	Targeted Performance Bands	Answer
Section I: Multiple Choice	1	1	CH12-12	3-4	D
	2	1	CH12-15	3-4	A
	3	1	CH12-14	3-4	A
	4	1	CH12-14	3-4	B
	5	1	CH12-12	3-5	A
	6	1	CH12-12	3-5	D
	7	1	CH12-15	3-5	C
	8	1	CH12-13	4-5	C
	9	1	CH12-14	3-5	D
	10	1	CH12-13	3-5	B
	11	1	CH12-13	4-5	D
	12	1	CH12-13	4-5	C
	13	1	CH12-13	4-5	C
	14	1	CH12-13	4-5	A
	15	1	CH12-14	3-5	B
	16	1	CH12-15	4-6	A
	17	1	CH12-12	4-6	C
	18	1	CH12-14	4-6	B
	19	1	CH12-15	5-6	A
	20	1	CH12-15	5-6	C
Section II	21	3	CH12-4, CH12-12	4-6	
	22a	3	CH12-12	3-5	
	22b	3	CH12-12	3-4	
	23a	2	CH12-4, CH12-12	4-5	
	23b	2	CH12-4, CH12-12	4-5	
	23c	3	CH12-12	4-6	
	24a	1	CH12-5, CH12-12	3-4	
	24b	2	CH12-5, CH12-12	3-4	
	24c	2	CH12-4, CH12-12	3-5	
	25	4	CH12-4, CH12-13	5-6	
	26a	1	CH12-13	3-4	
	26bi	2	CH12-13	4-5	
	26bii	2	CH12-13	4-5	
	26c	2	CH12-13	3-4	
	27	3	CH12-4, CH12-13	4-6	
	28a	3	CH12-2, CH12-13	3-5	
	28b	2	CH12-5, CH12-13	4-5	
	29a	1	CH12-7, CH12-14	2-4	
	29b	1	CH12-14	2-4	
	29c	3	CH12-14	3-5	
	30a	3	CH12-7, CH12-14	3-4	
	30b	3	CH12-5, CH12-14	4-5	
	31	3	CH12-14	4-5	
	32a	2	CH12-14	3-4	
	32b	1	CH12-14	3-4	
	32c	3	CH12-2, CH12-14	4-5	
	33a	7	CH12-15	3-6	
	33b	3	CH12-15	3-4	
	34a	2	CH12-4, CH12-15	3-4	
	34b	8	CH12-5, CH12-6, CH12-15	4-6	

Section I – Multiple Choice

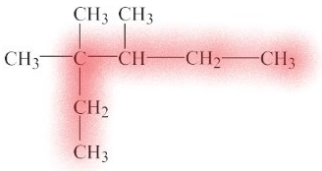
Question 1 - D
At equilibrium the reactions do not stop. The forward and reverse reactions occur at the same rate so nothing appears to be changing. Concentrations of reactants and products do not need to be the same, as the equilibrium position (quantified as K) can be to the left or right.

Question 2 - A
NMR uses the magnetic properties of certain nuclei such as ^{1}H and ^{13}C to study their absorption of radio waves. Colourimetry uses absorption of red, green or blue visible light by coloured species. IR spectroscopy uses absorption of infrared by vibrating bonds.

Question 3 - A
An amide linkage (shown in blue in the polymer) is formed between the diamine (that loses a H) and the dicarboxylic acid (that loses the OH) to make a polyamide and water is released (condensation reaction)



Question 4 - B
The longest chain can go around a corner. Numbering is always done to give the smallest sum. Side branches are placed in the name in alphabetical order.



Question 5 - A
Decreasing the temperature of the surroundings favours the reaction that increases temperature of surroundings which is an exothermic reaction. This is the forward reaction in this equation.

Question 6 - D
This is an ICE problem

	P	Q	R	S
I	6.0	6.0	0	0
C	-4.0	-4.0	+4.0	+4.0
E	2.0	2.0	4.0	4.0

$$K = \frac{[R]\,[S]}{[P]\,[Q]}$$

$$= (4 \times 4) / (2 \times 2)$$
$$= 4.0$$

Question 7 - C

Addition of HCl caused no reaction, so cannot be lead, which would precipitate. Addition of H_2SO_4 caused a white precipitate, so cannot be iron which is soluble. These leaves calcium and barium as the only possible answers: the orange seen in flame means it is calcium (an orange-red colour called brick red) as barium is a yellow-greenish colour.
Some of the most common flame colours are shown.
Remember you have a table of solubility constants – if a substance is on the list you can consider it insoluble for the ion tests.

Question 8 - C

The lower the pKa, the higher the Ka, the stronger the acid

Question 9 - D

The C in the CO_2 and the H in the H_2O come from the hydrocarbon. If there is 1.5 mol of CO_2 there is 1.5 mol of C in CO_2 and therefore 1.5 mol in the hydrocarbon. If there is 2 mol of water there is 4 mol of H (there are two H for every H_2O), so 4 mol in the hydrocarbon. Therefore, in the hydrocarbon the ratio of C:H is 1.5:4. Written as whole numbers this is C_3H_8.

Question 10 - B

$m(CaCO_3) = 10.0g$

$M(CaCO_3) = 40.08 + 12.01 + (3 \times 16.00)$

$= 100.09 \text{ g mol}^{-1}$

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

$= \frac{10.0}{100.09}$

$= 0.0999 \text{ mol}$

ratio $CaCO_3 : H_2SO_4$ is 1:1

$n(H_2SO_4) = 0.0999 \text{ mol}$

$c(H_2SO_4) = 0.500 \text{ mol L}^{-1}$

$c = \frac{n}{v}$

$v = \frac{n}{c}$

$= \frac{0.0999}{0.500}$

$= 0.200 \text{ L}$

Question 11 - D

The acid strength (hydrochloric is strong and ethanoic is weak) does not affect the stoichiometry. Therefore, the same volume of CO_2 is formed because there is the same concentration of the acids. Cannot be A – CH_3COOH has a higher pH than HCl.

Question 12 - C

To write the base dissociation expression for ammonia (NH_3) you need to write it for the reverse reaction (the reactants are on the right and the products on the left). Only substances with concentrations go in the expression, so liquid water is not included.

Question 13 - C

$c_1v_1 = c_2v_2$

$0.01 \times 0.010 = c_2 \times 0.100$ (note v_2 is 100 mL – 10 + 90)

$c_2 = (0.01 \times 0.010)/0.100$

$= 1.0 \times 10^{-3}$

As nitric acid is a strong acid this is also the concentration of the H_3O^+

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

$= -\log 10^{-3}$

$= 3$

Question 14 - A
You are looking for the combination that produces a basic salt. This is the titration of a weak acid with a strong base, which is NaOH and CH_3COOH

Question 15 - B
Working backwards, compound Y reacted with a carbonate to form CO_2, so Y must be an acid. To get an acid from oxidation using acidified dichromate, the starting reactant X must have been a primary alcohol, which oxidises to an aldehyde and then is further oxidised to a carboxylic acid. Answer A would be compound Y and answers C and D are secondary and tertiary alcohols respectively. Secondary alcohols oxidise to ketones and tertiary alcohols cannot be oxidised.

Question 16 - A

$n(BaSO_4) = 5.02 \times 10^{-3}$ mol
The sulfate ions can only come from the $Fe(NH_4)_2(SO_4)_2$, and the mass must be the same before and after, so there must be 2 barium sulfate produced for every one ammonium iron sulfate reacted as there are 2 sulfates per mole of this reactant.

If ratio of $BaSO_4$: $Fe(NH_4)_2(SO_4)_2$ is 2:1 and there is one Fe^{2+} per mole, there is 2.51×10^{-3} mol iron.

Question 17 - C
$Cr(OH)_{2\,(s)} \rightleftharpoons Cr^{2+}_{(aq)} + 2OH^-_{(aq)}$

$K_{sp} = [Cr^{2+}]\,[OH^-]^2$
$2.00 \times 10^{-16} = s \times (2s)^2$
$= s \times 4s^2$
$= 4s^3$

$s^3 = 2.00 \times 10^{-16} / 4$
$= 5.00 \times 10^{-17}$

$s = \sqrt[3]{5.00}\ e - 17$
$= 3.38 \times 10^{-6}$

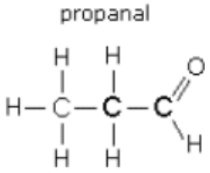
Question 18 - B
$m(CO_2)$ produced = 515.67-503.12
= 12.55g
$M(CO_2) = 12.01 + (2 \times 16.00)$
$= 44.01$ g mol^{-1}
$n = \frac{m}{M}$
$= \frac{12.55}{44.01}$
= 0.2852 mol

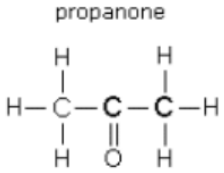
ratio CO_2:C_2H_5OH is 1:1

$n(C_2H_5OH) = 0.2852$ mol
$M(C_2H_5OH) = (2 \times 12.01) + (6 \times 1.008) + 16.00$
$= 46.068$ g mol^{-1}
$n = \frac{m}{M}$
$m = nM$
$= 0.2852 \times 46.068$
= 13.14g

Question 19 - A

This compound could be an aldehyde or a ketone. Both molecules can produce fragments of 15, 43 and the parent molecule of 58. Only propanal, written in condensed structural formula as CH_3CH_2CHO can produce the 29 fragment from the COH on the end.





Question 20 - C

The first hydrogen environment has 2 hydrogens on the neighbouring carbon, so using the n+1 rule, it will be a 3H triplet.
The second hydrogen environment has 3 hydrogens on the neighbouring carbon, so using the n+1 rule it will be a 2H quartet.
The third hydrogen environment has no neighbouring hydrogens, so using the n+1 rule it will be a 3H singlet.
The singlet will be furthest downfield due to its proximity to the electronegative oxygen. The quartet is closer to the oxygen than the triplet so the triplet will be the least downfield.

Section II – 80 marks

Question 21 (3 marks)

Criteria	Marks
Correct answer with full working	3
Mostly correct working with minor mistake	2
Some correct calculation	1

Sample answer

From solubility rules prediction of lead chloride precipitate:

$Pb(NO_3)_{2\,(aq)} + 2NaCl_{\,(aq)} \rightarrow 2NaNO_{3\,(aq)} + PbCl_{2\,(s)}$

v_2 is the new volume after mixing the two solutions (150.0 mL + 100.0 mL = 250.0 mL = 0.2500 L)

$[Pb(NO_3)_2]$	[NaCl]
$c_1v_1=c_2v_2$	$c_1v_1=c_2v_2$
$0.100 \times 0.1500 = c_2 \times 0.2500$	$0.200 \times 0.1000 = c_2 \times 0.2500$
$c_2 = (0.100 \times 0.1500) / 0.2500$	$c_2 = (0.200 \times 0.1000) / 0.2500$
$= 0.0600$ mol L-1	$= 0.0800$ mol L-1
$= [Pb^{2+}]$ (1:1 ratio)	$= [Cl^-]$ (1:1 ratio)

$PbCl_{2\,(s)} \rightleftharpoons Pb^{2+}_{\,(aq)} + 2Cl^-_{\,(aq)}$

$Q_{sp} = [Pb^{2+}][Cl^-]^2$

$= (0.0600)(0.0800)^2$

$= 3.84 \times 10^{-4}$

From data sheet $K_{sp} = 1.70 \times 10^{-5}$

$Q_{sp} > K_{sp}$, therefore a precipitate will form

Markers comment:

- Many students did not recognise $PbCl_{2\,(s)}$ as the precipitate. Students then treated the question like a moles/limiting reagent question and did not then use dilution formula to find correct concentrations.
- Students were able to successfully compare Q_{sp} to K_{sp}.

Question 22 (6 marks)

22 (a) (3 marks)

Criteria	Marks
Correctly explains in detail the processes involved in breaking an ionic compound apart and the role of water	3
Mostly correct	2
Some correct information	1

Sample answer

Ionic compounds are made up of a lattice of positive and negative ions. To dissolve the compound, the ions need to be separated. This is called lattice energy. Water is a polar molecule due to the electronegativity difference between oxygen and hydrogen. This creates a dipole in the water molecule with oxygen slightly negative and hydrogen slightly positive. When water is added to the ionic compound, the water molecules surround each ion forming an ion-dipole attraction between the ion and the polar ends of the water, separating the ions from each other causing the ionic compound to dissolve

Markers comments:

- Many students used a diagram to explain the dissolution process and this was done quite successfully.
- Many students missed labelling the new attractive force as a 'ion-dipole attraction'

22 (b) (3 marks)

Criteria	Marks
Gives in detail the main characteristics and features of the removal of toxins based on solubility equilibrium	3
Gives some characteristics and features of the removal of toxins based on solubility equilibrium	2
Some correct information	1

Sample answer

Cycads contain a fruit that is eaten by Indigenous Australians. This fruit contains a toxin. The toxin is water soluble. Through the process of leaching in running water the toxin is removed and washed away

A solubility equilibrium is set up between the solid and aqueous forms of the toxin

Cycasin $_{(s)} \rightleftharpoons$ cycasin $_{(aq)}$

When water is added, this reduces the concentration of cycasin $_{(aq)}$. According to Le Chatelier's Principle, this stress is opposed and favours the reaction that increases cycasin $_{(aq)}$ which is the forward reaction. Therefore, more of the solid toxin in the fruit is converted to soluble toxin which can then be washed away.

Markers comments:

- All students used “increasing the surface area by crushing the cycad seeds”- this isn’t the main link to equilibrium but it was most students first point in their answer.
- Most did not state that the toxin was soluble, but did put leaching in their answer.
- Very few students included an equilbrium equation, many attempted to say shift left/right but with no equation present in their answer.
- Very few students included LCP in their answer.
- Overall very poor links to equilibrium and most gave a general ATSI answer about the Cycad fruit and making it safe to eat.

Question 23 (7 marks)

23 (a) (2 mark)

Criteria	Marks
Correctly calculates molar solubility with working	2
Mostly correct	1

Sample answer

$CaCO_{3\,(s)} \rightleftharpoons Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$

$K_{sp} = [Ca^{2+}][CO_3^{2-}]$

$3.36 \times 10^{-9} = s^2$

$s = 5.80 \times 10^{-5} mol\ L^{-1}$

Markers comments:

- This question was done well.
- Units were not marked here but should be included.

23 (b) (2 marks)

Criteria	Marks
Correctly calculates solubility in calcium chloride with working	2
Mostly correct	1

Sample answer

$CaCO_{3\,(s)} \rightleftharpoons Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$

$[Ca^{2+}] = [CaCl_2] = 0.150\ mol\ L^{-1}$

$K_{sp} = [Ca^{2+}][CO_3^{2-}]$

$3.36 \times 10^{-9} = 0.150 \times s$

$s = 3.36 \times 10^{-9} / 0.150$

$= 2.24 \times 10^{-8} mol\ L^{-1}$

Markers comments:

- Some students confused Ksp with molar solubility. While Ksp is an indicator of solubility, when a question calls for you to "determine/calculate the solubility of x" this is always the molar solubility (the maximum number of moles of a substance that can be dissolved per litre of water).
- Another common error was to write an equilibrium/Ksp expression for the dissolution of calcium chloride. As per the question, the calcium chloride is already in solution (fully dissolved) so is only significant in its impact on the calcium concentration.

23 (c) (3 marks)

Criteria	Marks
Explains in detail the difference in solubilities in terms of the common ion effect and Le Chatelier's Principle	3
Explains the difference in solubilities in terms of the common ion effect	2
Some correct information	1

Sample answer
The solubility of calcium chloride in the calcium chloride solution is much less than in water. This is called the common ion effect.
$CaCO_{3\,(s)} \rightleftharpoons Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$
It is based on Le Chatelier's Principle. If you place $CaCO_3$ in a Ca^{2+} solution, this places a stress on the equilibrium above (Increasing $[Ca^{2+}]$). According to LCP, this stress is opposed, favouring the direction that minimises the stress and reduces the $[Ca^{2+}]$. This is the reverse direction, forming more solid calcium carbonate, therefore reducing its solubility.

Markers comments:
Many students did this well. It was clear however that many students had not recognised this question as a "common ion effect" problem. The difference in solubility cannot be explained in terms of intermolecular forces.

Question 24 (5 marks)
24 (a) (1 mark)

Criteria	Marks
Correct answer provided	1

Sample answer
At t=32s there was a temperature change

Markers comments:
This was done well. The most common error was misidentifying a change in pressure. Remember, a change in pressure could be caused by:
- Adding reactants/products (conc would change --> vertical lines on graph)
- Increasing or decreasing the volume of the reaction vessel (c=n/V so if volume changes so does concentration --> vertical lines)
- Adding an inert gas (no impact on equilibrium position --> no change in concentration)

24 (b) (2 marks)

Criteria	Marks
Correctly links the response of the system to the stress using Le Chatelier's Principle and referring to the lines on the graph	2
Some correct information	1

Sample answer

$CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$

At t=45 the concentration of $COCl_2$ was increased (more must have been added into the system). According to LCP, this stress is opposed, favouring the reaction that lowers the $[COCl_2]$. This is the reverse reaction above. This is shown on the graph where the concentrations of the reactants increase and the concentration of the product decreases.

Markers comments:
This question was done well. For LCP questions, if an equation is not given explicitly in the question you must write one in order to refer to a shift left or right.

24 (c) (2 marks)

Criteria	Marks
Correctly calculates K with working	2
Mostly correct	1

Sample answer

$CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$
From the graph at 15s: (some allowance for different values from reading graph)

$[CO] = 1.75 \text{ mol } L^{-1}$
$[Cl_2] = 0.60 \text{ mol } L^{-1}$
$[COCl_2] = 0.75 \text{ mol } L^{-1}$

$$K = \frac{[\text{products}]}{[\text{reactants}]}$$

$$= \frac{[COCl_2]}{[CO]\,[Cl_2]}$$

$= (0.75) / (0.60 \times 1.75)$
$= 0.71$

Markers comments:
This question was done well.

Question 25 (4 marks)

Criteria	Marks
Calculates moles NaOH, moles excess HCl titrated, total moles HCl originally added, moles HCl reacted with ammonia and ammonia concentration. Answer to 4sf.	4
4-5 out of the 6 components above	3
3-4 out of the 6 components above	2
1-2 of the 6 components above	1

Sample answer

1. Moles of NaOH needed to neutralise the excess HCl

$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

c(NaOH) = 0.1000 mol L-1
v(NaOH) = 21.50 mL
= 0.02150 L
$c = \frac{n}{v}$
n = cv
= 0.1000 x 0.02150
= 2.150×10^{-3} mol

2. Moles of excess acid titrated: ratio NaOH:HCl is 1:1 so n(HCl titrated) = 2.150×10^{-3} mol

3. Total moles HCl originally added

c(HCl total) = 0.1000 mol
v(HCl total) = 50.00 mL
= 0.05000 L
$c = \frac{n}{v}$
n = cv
= 0.1000 x 0.05000
= 5.000×10^{-3} mol

4. Moles of HCl that reacted with ammonia

n(HCl titrated) + n(HCl reacted) = n(HCl total)
n(HCl reacted) = n(HCl total) = n(HCl titrated)
= $5.000 \times 10^{-3} - 2.150 \times 10^{-3}$
= 2.850×10^{-3} mol

5. Concentration of ammonia

$NH_{3(aq)} + HCl_{(aq)} \rightarrow NH_4Cl_{(aq)}$

Ratio HCl: NH_3 is 1:1

$n(NH_3) = 2.850 \times 10^{-3}$
$v(NH_3)$ = 25.00 mL
= 0.02500 L

$c = \frac{n}{v}$

$c = \frac{2.850\ e{-}3}{0.02500}$

= 0.1140 mol L^{-1}

6. 4sf

Question 26 (6 marks)

26 (a) (1 mark)

Criteria	Marks
Correct definition	1

Sample answer

A buffer is a solution (of a weak acid/base and its conjugate base/acid salt in equal moles) that resists a change in pH when small amounts of a strong acid or strong base are added

26 (bi) (2 marks)

Criteria	Marks
Correct explanation based on Le Chatelier's Principle	2
Partially correct	1

Sample answer

$A^-_{(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + HA_{(aq)}$

If you add a strong base this increases the $[OH^-]$. According to Le Chatelier's Principle, this stress is opposed, favouring the reaction that decreases the $[OH^-]$. This is the reverse reaction, so this means the $[OH^-]$ will remain fairly constant and the pH will not change dramatically.

26 (bii) (2 marks)

Criteria	Marks
Correct explanation based on Le Chatelier's Principle	2
Partially correct	1

Sample answer

$A^-_{(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + HA_{(aq)}$

If you add a strong acid, this adds H_3O^+ ions into the solution. These ions react with the OH- ions in a neutralisation reaction. This decreases the $[OH^-]$. According to Le Chatelier's Principle, this stress is opposed, favouring the reaction that increases the $[OH^-]$. This is the forward reaction, so this means the $[OH^-]$ will remain fairly constant and the pH will not change dramatically.

26 (c) (2 marks)

Criteria	Marks
Sketches in general terms how a named, real buffer example is important in a natural system	2
Names a natural buffer system	1

Sample answer

One important buffer system is the human carbonic acid/bicarbonate ion blood buffer. It helps to regulate the pH in our bodies so that our cells don't get damaged from acidosis or alkanoisis. The human blood must stay in a narrow pH range close to 7. Anything outside of this range is considered detrimental to cell function. Thus, the buffer ensures the health of humans and correct metabolic functioning.

Question 27 (3 marks)

Criteria	Mark
Correct answer with full working	3
Mostly correct with minor mistake	2
Some correct calculations	1

Sample answer

$2KOH_{(aq)} + H_2SO_{4\,(aq)} \rightarrow K_2SO_{4\,(aq)} + 2H_2O_{(l)}$

Moles of both reactants are the same

c = 0.050 mol L^{-1}

v = 25.0 mL

= 0.0250 L

$c = \frac{n}{v}$

n = cv

= 0.050 x 0.0250

= 1.25 x 10^{-3} mol

Ratio KOH : H_2SO_4 is 2:1

Therefore H_2SO_4 is in excess by 1.25 x 10^{-3} / 2

= 6.25 x 10^{-4} mol

This will determine the pH

v is the two solutions combined = 50.0 mL

= 0.0500 L

$c(H_2SO_4)$ in excess = $\frac{n}{v}$

$= \frac{6.25\,e{-4}}{0.0500}$

= 0.0125 mol L^{-1}

$H_2SO_{4\,(aq)} + 2H_2O_{(l)} \rightarrow 2H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

Therefore $[H_3O^+]$ = 2 x 0.0125

= 0.0250 mol L^{-1}

pH = -log $[H_3O^+]$

= -log (0.0250)

= 1.60 (2sf)

Question 28 (5 marks)

Question 28 (a) (3 marks)

Criteria	Marks
Identifies the issues regarding using indicators to determine acidity and provides multiple points for and against their use	3
Identifies the issues regarding using indicators to determine acidity and provides multiple points for or against their use	2
Describes/Outlines/Explains how indicators measure acidity	1

Sample answer
Main issues: Indicators change colour, rely upon human judgement to match colour produced to a colour chart, have a limited range of pH, give an approximate value, easy to use

Points for using indicators	Points against using indicators
Very simple to use – just need to add a few drops and observe colour Good to give a general idea of whether the substance being tested is acidic, neutral or basic Good to use if an accurate numerical value is not required	Matching a colour change to a colour chart can be difficult, especially if the original solution being tested is coloured. It has a degree of subjectivity Indicators act across a limited range, they usually cannot distinguish between the stronger acids or stronger bases Indicators are not very accurate or precise – they only give an approximate pH value

Markers comments
This question was poorly done. Many students missed the verb "discuss" and instead gave detailed explanations for how indicators work. Discuss means "identify issues and provide points for and/or against"

Question 28 (b) (2 marks)

Criteria	Marks
Correctly explains the shape of the graph	2
Some correct information	1

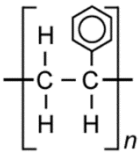
Sample answer
Before NaOH is added, the conductance is high due to the presence of highly mobile hydronium ions from the HCl solution. When the base is added, the hydroxide ions react with the hydronium ions. This forms nonconductive water and the less mobile salt ions (Na^+ and Cl^-) so the conductance falls. This decrease in the conductance continues until the equivalence point where there are no mobile hydronium ions left and no excess hydroxide ions. At the equivalence point, the solution contains the less mobile Na^+ and Cl^- ions. After the equivalence point, the conductance increases due to the large conductivity of the excess mobile OH^- ions

Question 29 (5 marks)

Question 29 (a) (1 mark)

Criteria	Marks
Correctly written	1

Sample answer



Markers comments

- Any of the 3 common representations of a benzene ring are fine to use in the HSC chemistry exam.
- Polymer notation should always be given for the shortest repeating section (ie students who drew 4 or 6 carbons inside the brackets have not used polymer notation correctly).
- Remember also to include the "n" and make sure the styrene ring is bonded from a vertex, not the middle of a side.

Question 29 (b) (1 mark)

Criteria	Marks
Correct use linked to properties	1

Sample answer

PVC is used in water pipes because it is waterproof and rigid.

Markers comments

- This question was well done. The most common error was to overlook the plural in the word properties in the question.
- Note also, "brittle" means hard and liable to smash/shatter/break. While some polymers are brittle (eg polystyrene) PVC is not. Brittleness is not usually a desirable property and should not be used when linking properties to uses.

Question 29 (c) (3 marks)

Criteria	Marks
Provides three correct similarities and differences between addition and condensation polymerisation	3
Provides three correct similarities or differences between addition and condensation polymerisation OR Provides a similarity and a difference between addition and condensation polymerisation	2
Provides a similarity or a difference between addition and condensation polymerisation	1

Sample answer

Criteria	Addition Polymerisation	Condensation polymerisation
Number of products	1	2
Number of monomers	1 only	1 or 2
Repeating pattern	Yes	Yes
Reaction mechanism	Breaking of double C=C bond and adding next monomer to free electron	Two functional groups join with the loss of a small molecule
Chain length	Often very long	Often very long

Markers comments

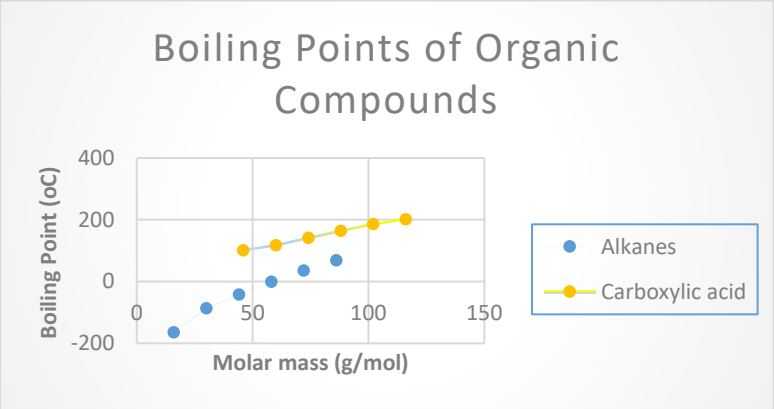
- Using a table is the best way to answer a "compare" question and avoid missing one half the comparison for a particular criterion. For example, many students who wrote in paragraph form identified that the formation of a condensation polymer also produces a small molecule as a byproduct without explicitly clarifying that there is only a single product formed (no byproduct) during addition polymerisation.
- Students naturally gravitate towards "differences" when comparing things. "similarities" are equally valid.
- "Examples" was not considered a valid criterion for comparison as it tells you nothing about the nature of addition vs condensation polymers.
- "Properties" and "Uses" were also not considered valid criteria for comparison as there is so much variety in both categories of polymers.

Question 30 (6 marks)

Question 30 (a) (3 marks)

Criteria	Marks
Graph drawn completely correctly (bp on Y axis, all labels and units, title, correct points plotted and 2 lines of best fit)	3
Graph drawn correctly with minor error/emission	2
Multiple errors	1

Sample answer



Question 30 (b) (3 marks)

Criteria	Marks
Correctly links in detail the structure of the molecules to their boiling points within and between the homologous series	3
Mostly correct	2
Partially correct	1

Sample answer

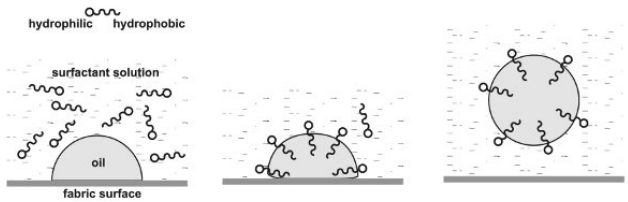
In both the alkanes and the carboxylic acids, the boiling point increases with increasing relative molecular mass. This is because as the mass increases there are more electrons and therefore more chance of weak dispersion forces occurring. This increases the attraction between the molecules so more heat is required to separate and boil them.
The boiling points of alkanes are lower than corresponding carboxylic acids of similar mass. This is because the alkanes are non-polar molecules, so the only intermolecular force between alkane molecules is the weak dispersion forces which require the least heat energy to overcome. In carboxylic acids the polar C=O and O-H covalent bonds create permanent dipoles and this gives rise to the strongest of the intermolecular forces; hydrogen bonds. More heat energy is required to overcome hydrogen bonds so carboxylic acids have higher boiling points that alkanes

Question 31 (3 marks)

Criteria	Mark
Links the structure of soaps and detergents to how they clean using detailed chemistry (a well annotated diagram is appropriate here)	3
Links the structure of soaps and detergents to how they clean briefly	2
Some correct information	1

Sample answer

The structure of soaps and detergents enable them to clean surfaces. Dirt molecules are generally non-polar. They are attracted to other non-polar molecules. The long hydrocarbon tail chain of soap/detergent is non-polar and hydrophobic. It is attracted to dirt or oil which is also non-polar. The negatively charged head of soap is polar and hydrophilic, so it is attracted to other polar molecules. Water is polar, so the head part of soap is attracted to water. Anionic, cationic and non-ionic detergents also have polar head regions.
Soap forms micelles around the dirt, with the polar heads pointing out. Agitation will wash these micelles away.



Markers comments
This question was moderately well done. Key areas for improvement include:

- precise use of vocabulary (micelle, hydrophobic, hydrophilic, non-polar, ion-dipole, dispersion) especially around the intermolecular forces.
- Inclusion of a clear labelled diagram for questions where structural arrangement of atoms/molecules is a key concept. While a diagram was not required for full marks, it was easier to achieve full marks if included.

Question 32 (6 marks)

32 (a) (2 marks)

Criteria	Mark
Correct balanced equation with states, reversible arrow and acid catalyst	2
Correct balanced equation	1

Sample answer

$$C_2H_5OH_{(aq)} + C_2H_5COOH_{(aq)} \overset{\text{Conc } H^+/\text{heat reflux}}{\rightleftharpoons} C_2H_5COOC_2H_{5\,(aq)} + H_2O_{(l)}$$

32 (b) (1 mark)

Criteria	Mark
Correct answer	1

Sample answer

Ethyl propanoate

32 (c) (3 marks)

Criteria	Mark
Supports the need for refluxing in esterification with detailed explanation	3
Supports the need for refluxing in esterification with brief explanation	2
Some correct information	1

Sample answer

Esterification will not successfully occur without reflux. Esterification requires heat for the reaction to start and to drive the reaction forward but heating causes the volatile reactants to boil and they would be lost. Refluxing involves using a condenser surrounded by cool water to cause the reactants to change back to a liquid and fall back into the reaction vessel. This makes sure that the reactants can combine to form the ester.

Markers comments:

- Most students did very poorly in this question. Students did not link to esterification being a slow process. Many didn't link to collisions or actually forming the ester.
- Students did not link to the specifics of reflux with heating and condensing. Most gave a general answer about the experiment and included the acid catalyst, bumping granules etc and didn't just focus on refluxing.

Question 33 (10 marks)

Question 33 (a) (7 marks)

Criteria	Marks
States all 6 methods in the syllabus used to identify and measure ions and describes how each technique identifies or measures ions	7
States 4-5 methods in the syllabus used to identify and measure ions and describes how each technique identifies or measures ions	5-6
States 2-3 methods in the syllabus used to identify and measure ions and describes how each technique identifies or measures ions	3-4
Identifies and describes a method used to identify and measure ions	1-2

Sample answer

There are many methods that can be used to identify and measure ions:

- Qualitative ion tests (precipitation, complexation, flame tests). These tests are only used to identify ions and not give concentrations. They require a higher concentration of the ion to be present than other tests to give a positive result.
- Gravimetric analysis. This involves weighing the precipitate formed in a reaction to measure a quantity of ion.
- Precipitation titrations. This uses a burette and indicator to measure the concentration of an ion in solution
- Colourimetry. This technique works on coloured solutions. The intensity of the colour of the coloured solution depends upon the concentration of the solution. By comparing to known standards, you can determine an unknown concentration based on Beer's Law
- UV-visible spectrophotometry. It uses a range of wavelengths across both the UV and visible spectra which are absorbed by the sample to determine the concentration based on Beer's Law
- Atomic absorption spectroscopy. This is a technique for determining the concentration of metal ions using the absorption of light specific to that metal ion, again based on Beer's Law

Markers comments:

- This is an inquiry question. These are written with question marks. A 'how' question is closest to the verb describe or outline.
- The qualitative ion tests were treated as one technique
- A number of students wrote a great answer to 'Explain how AAS works' but this was not the question.

Question 33 (b) (3 marks)

Criteria	Mark
Links a named ion (cause) with the harmful consequences of the ion in the environment (effect) to justify the need to monitor if it is in the environment	3
Outlines the harmful effects of a named ion on the environment	2
Some correct information	1

Sample answer

Certain metal and non-metal ions can cause significant environmental damage, even if present in small amounts. It is important to monitor for the presence and concentration of these ions to ensure ecosystems and human health are maintained. Phosphate and nitrate ions, originally in fertilizers, can enter waterways through runoff and may accumulate in these systems. These ions support algae growth. Once the algae dies, bacteria use up the oxygen in the water as part of their metabolic processes and oxygen depletion causes fish deaths as they suffocate. This has a significant impact of the water quality and wider food web of the particular ecosystem affected.

Question 34 (10 marks)

Question 34 (a) (2 marks)

Criteria	Mark
Calculates empirical formula correctly	2
Calculates with minor error	1

Sample answer

	C	H	O
% composition	68.11	13.74	18.15
Atomic mass	12.01	1.008	16.00
Mole ratio	$\frac{68.11}{12.01}$= 5.67	$\frac{13.74}{1.008}$= 13.63	$\frac{18.15}{16.00}$= 1.13
Divide by smallest	$\frac{5.67}{1.13}$= 5.0	$\frac{13.74}{1.13}$= 12.2	$\frac{1.13}{1.13}$= 1
Simplest whole number ratio	5	12	1

Markers comments

Many students did not know how to calculate the E.F and just attempted to prove the percentages made sense.

Question 34 (b) (8 marks)

Criteria	Marks
Draws correct detailed conclusions from all 4 spectra and then uses the information logically to determine the correct identity of the molecule	7-8
Draws correct detailed conclusions from 3 of the spectra and then uses the information logically to determine the correct identity of the molecule OR Draws correct detailed conclusions from all 4 spectra but does not identify the molecule correctly	5-6
Interprets the information correctly from 3 of the spectra but does not identify the molecule correctly	3-4
Interprets some of the spectra correctly	1-2

Sample answer

The empirical formula suggests that the molecule is an alcohol.

Mass spectrum

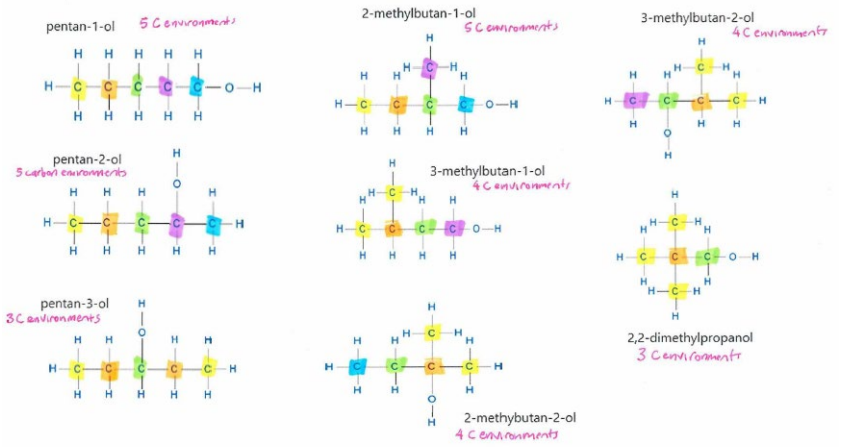
The parent ion (M^+) on the mass spectrum is at a m/z ratio of 88. This is also the mass of the empirical formula, so the molecular formula is also $C_5H_{12}O$. This means that the molecule is likely to be an isomer of pentanol. There is a peak at 73, suggesting that a CH_3 methyl group has fragmented off the molecule. There is a peak at 59, suggesting that a C_2H_5 ethyl group has fragmented off the molecule.

Infrared spectrum

There is a broad peak at a wavenumber of about 3200-3600. This suggests an O-H alcohol group in the molecule. The narrow peaks around 2800-3000 would correspond to the many C-H bonds. There is no C=O peak around 1680-1750, confirming that the O-H is not part of a carboxylic acid. This supports the molecule being an alcohol.

^{13}C NMR spectrum

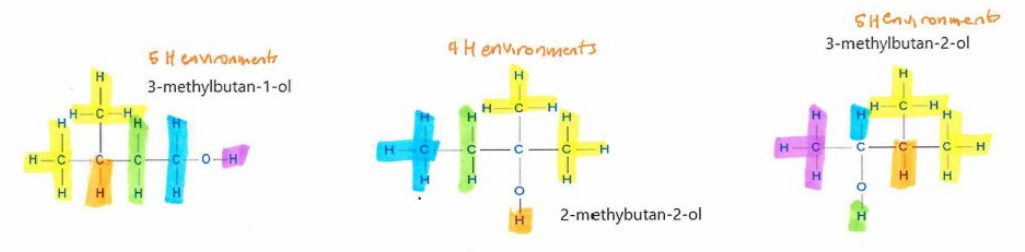
As there are 5 carbons but only 4 carbon environments there must be 2 equivalent carbon environments, suggesting a methyl side group. There are 8 structural isomers of pentanol as shown below with the carbon environments shown:



The ^{13}C NMR spectrum in the question shows 4 peaks, so this narrows down the possible molecules to: 3-methylbutan-1-ol, 2-methylbutan-2-ol or 3-methylbutan-2-ol. The C-O bond attached to an O-H has a chemical shift of 50-90, so this matches the peak most downfield, supporting the molecule being an alcohol

^{1}H NMR spectrum

There is only one of the three remaining isomers that matches the 4 peaks on the ^{1}H NMR spectrum. Reading the spectrum from the right to the left: The CH_2 group (green) forms a 2H quartet. The two CH_3 groups (yellow) form the tall 6H singlet. The CH_3 (blue) forms a 3H triplet. The H on the OH forms a 1H singlet, furthest downfield due to its attachment to the electronegative oxygen.



All the combined data shows that the molecule 'X' is 2-methylbutan-2-ol.

Markers comments:

- Analyse is probably the hardest verb. It means “Identify components and the relationships between them, draw out and relate implications”
- You need to carefully extract all the information in all the spectra and draw conclusions with supporting evidence from them.
- First step in these is to work out what the formula suggests it could be remembering the functional group isomers: carboxylic acids and esters or the aldehydes and ketones. Alcohols are functional group isomers with ethers but the ethers are not in the HSC course.