
Student Number

ABBOTSLEIGH

2020 Trial HSC Examination

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 2–8)

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

Section II – 80 marks (pages 9–32)

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

	Knowledge and Understanding	Skills	Total
Section I	10	10	20
Section II	40	40	80
Total	50	50	100

Section I

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

Use the multiple-choice answer sheet at the back of this paper for Questions 1–20.

1 Which of the following lists contains only acidic substances?

(A) Ammonia, baking soda, blood

(B) Apple juice, aspirin, coffee

(C) Lemonade, bleach, urine

(D) Oven cleaner, milk, vinegar

2 Glow sticks are generally flexible plastic tubes in which a smaller glass tube inside is broken to initiate a chemical reaction. The reaction emits light for a period of time after initiation. Glow sticks are an example of:

(A) a dynamic equilibrium in a closed system

(B) a dynamic equilibrium in an open system

(C) a static equilibrium in a closed system

(D) a static equilibrium in an open system

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

(A) butanoic acid and butan-1-ol

(B) dimethylpropane and 2,3-dimethylbutane

(C) 1,1-dichloro-2-fluoropropane and 1,2-dichloro-1-fluoropropane

(D) cyclohexane and hexane

4 A chemist determined the equilibrium constants for several reactions. Which equilibrium constant indicates the products are favoured over the reactants?

(A) $K_{eq} = 5.8 \times 10^{-34}$

(B) $K_{eq} = 4.3 \times 10^{-10}$

(C) $K_{eq} = 2.9 \times 10^{-2}$

(D) $K_{eq} = 1.2 \times 10^{3}$

5 A colourless aqueous solution contains an unknown anion. Samples of this solution are tested with various reagents:

Reagent	*Observation*
$HNO_3(aq)$	no reaction
$Ba(NO_3)_2(aq)$	no reaction
$AgNO_3(aq)$	faint white precipitate
$Cu(NO_3)_2(aq)$	blue precipitate

The anion is most likely to be:

(A) Cl^-

(B) CO_3^{2-}

(C) OH^-

(D) SO_4^{2-}

6 Which acid/base pair could act as a buffer?

(A) H_2O / OH^-

(B) HCl / Cl^-

(C) HCO_3^- / CO_3^{2-}

(D) H_2SO_4 / SO_4^{2-}

7 Green Ni^{2+} reacts with ammonia to form blue $Ni(NH_3)_6^{2+}$ in the equilibrium reaction

$$Ni^{2+}_{(aq)} + 6NH_{3(aq)} \rightleftharpoons Ni(NH_3)_6^{2+}_{(aq)} \qquad \Delta H = -12.1 \text{ kJ mol}^{-1}$$

If a blue-green solution of Ni^{2+}/ $Ni(NH_3)_6^{2+}$ is heated, the solution will

(A) turn blue as the equilibrium shifts to form more $Ni(NH_3)_6^{2+}$

(B) turn green as the equilibrium shifts to form more $Ni(NH_3)_6^{2+}$

(C) turn blue as the equilibrium shifts to form more Ni^{2+}

(D) turn green as the equilibrium shifts to form more Ni^{2+}

8 Which of the following chemical equations correctly represents the complete combustion of pentane?

(A) $C_5H_{12}(l) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(l)$

(B) $C_5H_{12}(l) + 4O_2(g) \rightarrow 3C(s) + 2CO(g) + 6H_2O(l)$

(C) $C_3H_8(l) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

(D) $C_3H_8(l) + 3O_2(g) \rightarrow C(s) + 2CO\ (g) + 4H_2O(l)$

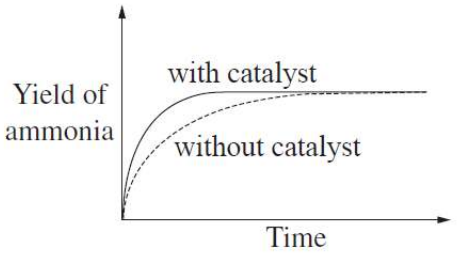
9 The Haber Process is an important industrial process used to manufacture ammonia in the following reaction:

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

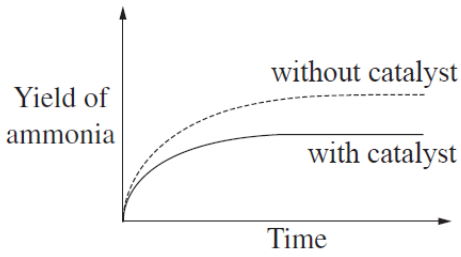
A chemist monitored the production of ammonia with and without a catalyst.

Which graph shows a correct comparison of the yield of ammonia produced with and without a catalyst?

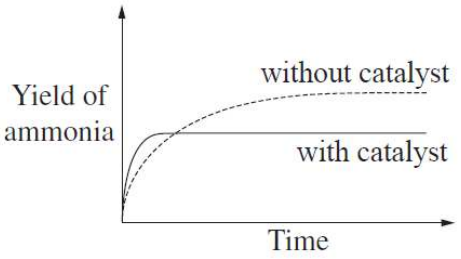
(A)



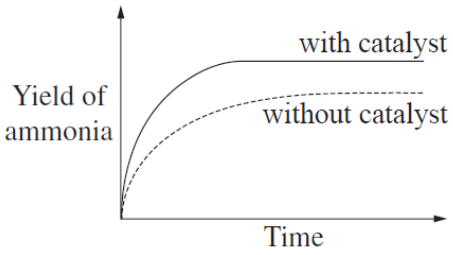
(C)



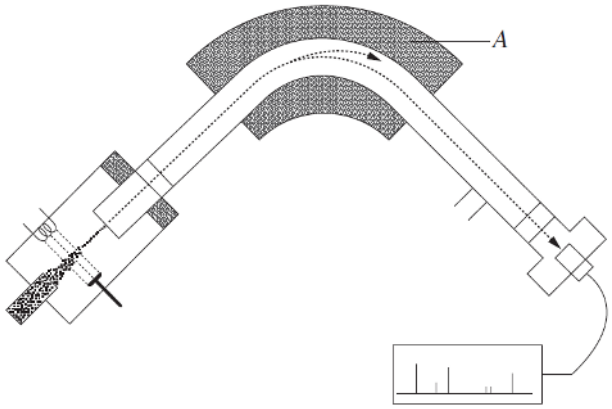
(B)



(D)



10 The diagram below is a schematic representation of a mass spectrometer.



The function of the part labelled A in the diagram is

(A) To accelerate the charged particles

(B) To bend the stream of charged particles

(C) To detect the mass to charge ratio of the particles

(D) To ionise the sample

11 Consider the following equilibrium equation:

$$2N_2H_4(g) + 2NO_2(g) \rightleftharpoons 3N_2(g) + 4H_2O(g)$$

What would be the equilibrium expressions, K_{eq}, for this reaction?

(A) $\dfrac{[N_2H_4]^2[NO_2]^2}{[N_2]^3[H_2O]^4}$

(B) $\dfrac{[N_2]^3[H_2O]^4}{[N_2H_4]^2[NO_2]^2}$

(C) $\dfrac{[2N_2H_4][2NO_2]}{[3N_2][4H_2O]}$

(D) $\dfrac{[H_2O]^4}{[N_2H_4]^2[NO_2]^2}$

12 The spice turmeric contains curcumin, a molecule that changes its chemical structure in solutions of different pH. A curcumin solution was tested with a range of solutions and the colour of each was noted.

Solution added	*Colour observed*
0.1 mol L^{-1} HCl(aq)	yellow
0.001 mol L^{-1} HCl(aq)	yellow
0.000001 mol L^{-1} HCl(aq)	yellow
Distilled water	yellow
0.000001 mol L^{-1} NaOH(aq)	orange
0.001 mol L^{-1} NaOH(aq)	red
0.1 mol L^{-1} NaOH(aq)	red

For which of the following titrations would it be appropriate to use this solution as an indicator?

(A) $H_2SO_4(aq) + NaHCO_3(aq)$

(B) $H_2SO_4(aq) + NH_3(aq)$

(C) $CH_3COOH(aq) + KOH(aq)$

(D) $CH_3COOH(aq) + NaHCO_3(aq)$

13 Identify the least soluble compound from the following:

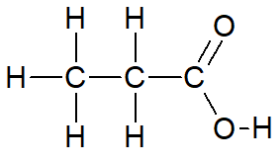
(A) Barium carbonate

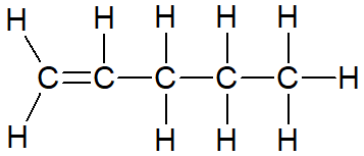
(B) Copper(II) carbonate

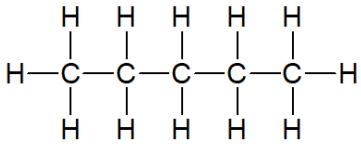
(C) Iron(II) carbonate

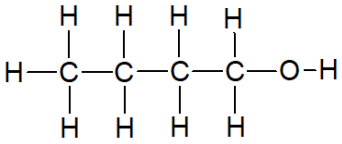
(D) Magnesium carbonate

14 Identify the compound with the highest boiling point.

(A) 

(C) 

(B) 

(D) 

15 A precipitation titration was conducted to determine the chloride ion concentration of a sample of sea water. Four 10.0 mL samples of sea water were titrated with a 0.300 mol L^{-1} silver nitrate solution. The average titration volume required to reach the end point was 17.1 mL. Calculate the concentration of chloride ions in the sea water.

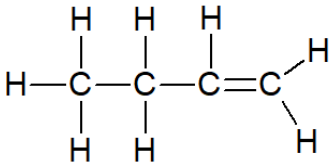
(A) 0.175 mol L^{-1}

(B) 0.205 mol L^{-1}

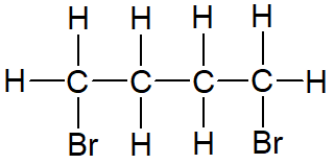
(C) 0.257 mol L^{-1}

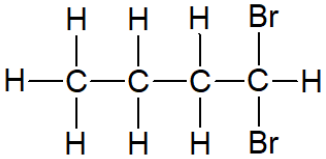
(D) 0.513 mol L^{-1}

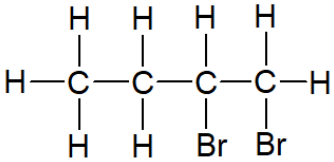
16 The molecule below is reacted with bromine water in an addition reaction:

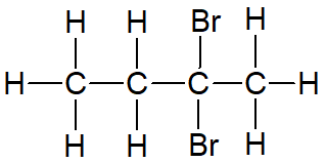


The most probable product of the reaction is:

(A) 

(C) 

(B) 

(D) 

17 A student makes a solution by combining 50.0 mL of 0.10 M magnesium chloride solution with 50.0 mL of 0.10 M sodium carbonate solution.

Which row of the table correctly identifies if a precipitate will form under these conditions and the reason?

	Will a precipitate form?	*Reason*
(A)	Yes	$Q > K_{sp}$
(B)	Yes	$Q < K_{sp}$
(C)	No	$Q > K_{sp}$
(D)	No	$Q < K_{sp}$

18 All the calcium ions present in a 50.0 mL solution were precipitated by reaction with excess sulfate ions. The mass of the dried precipitate was 0.344 g.

What was the concentration of calcium in the original solution in parts per million?

(A) 2.02 ppm

(B) 6.88 ppm

(C) 2020 ppm

(D) 6880 ppm

19 A neutralisation reaction takes place between 50 mL of 0.70 mol L^{-1} hydrochloric acid and 75 mL of 0.20 mol L^{-1} sodium carbonate.

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

(A) 0.8

(B) 1.4

(C) 1.7

(D) 2.3

20 A student wishes to determine the molar absorbivity (ε) of a copper(II) sulfate solution using colorimetry. The student first makes a standard solution using 2.00 g of anhydrous copper(II) sulfate in a 500 mL volumetric flask.

A colorimeter was set to a wavelength of 780 nm and calibrated to zero absorbance with a 1.00 cm cuvette of distilled water (the 'blank'). The blank was then replaced with a sample of the standard solution in a 1.00 cm cuvette and an absorbance of 0.24 was obtained.

The molar absorbivity of the copper(II) sulfate solution is:

(A) 0.10 L mol^{-1} cm^{-1}

(B) 0.12 L mol^{-1} cm^{-1}

(C) 4.8 L mol^{-1} cm^{-1}

(D) 9.6 L mol^{-1} cm^{-1}

Student Number

2020 Trial HSC Examination

Chemistry

Section II Answer Booklet

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

General Instructions

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

Please turn over

Question 21 (3 marks)

You performed a first hand investigation to investigate the amphiprotic nature of some salts.

(a) Identify an amphiprotic salt you used. **1**

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(b) Explain the amphiprotic nature of the salt, using equations to illustrate your response. **2**

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Question 22 (4 marks)

The following data summarises the solubility in water of a homologous series of carboxylic acids in water at 25°C.

Carboxylic acid	*Solubility in water (g/100 mL)*
methanoic acid	miscible
ethanoic acid	miscible
propanoic acid	miscible
butanoic acid	miscible
pentanoic acid	2.4
hexanoic acid	1.1
heptanoic acid	0.24
octanoic acid	0.068
nonanoic acid	0.0002
decanoic acid	practically insoluble

(a) Draw the structure of butanoic acid. **1**

(b) Explain the trend in the data for solubility of carboxylic acids in water. **3**

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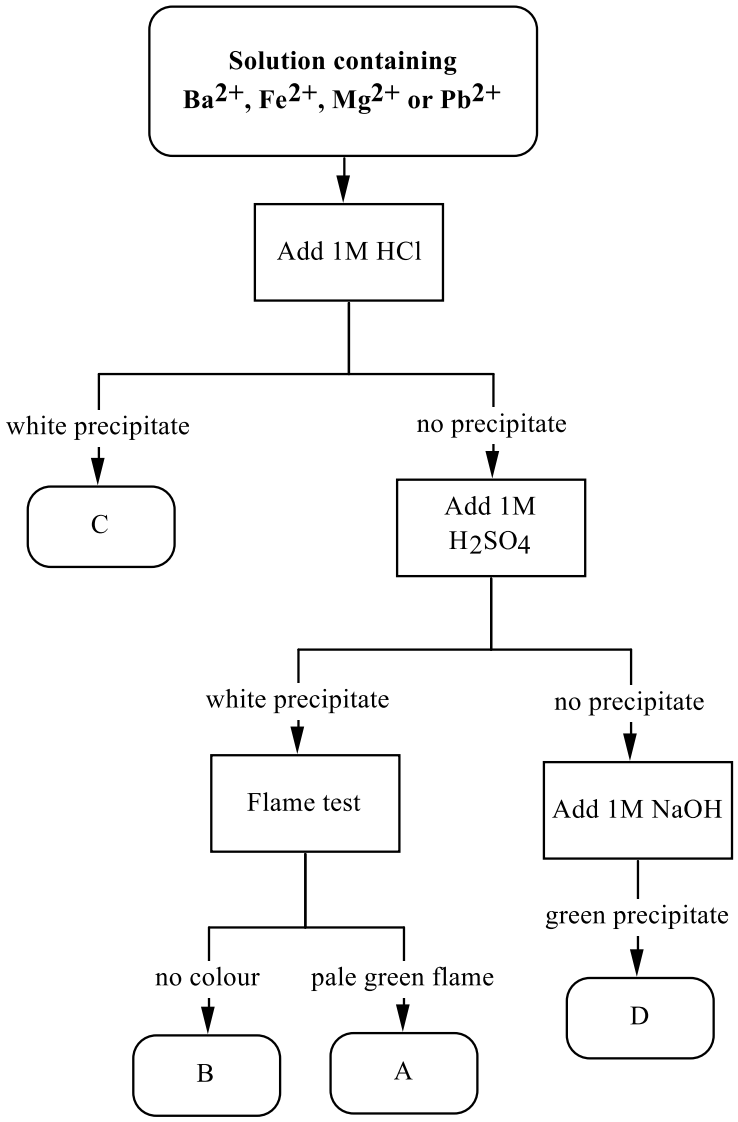
Question 23 (6 marks)

A student is given four unidentified solutions A–D, known to contain Ba^{2+}, Fe^{2+}, Mg^{2+} or Pb^{2+}. The flow chart below indicates the sequence of tests used to confirm the identity of the cation in each solution.



(a) Name the cation identified in each solution. **2**

Solution	*Cation identified*
A	
B	
C	
D	

Question 23 continues on page 13

Question 23 (continued)

(b) Justify why the tests are conducted in the order specified. Include equations in your response. **4**

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End of Question 23

Please turn over

Question 24 (3 marks)

Nitrosyl chloride decomposes into nitric oxide and chlorine according to the equation: **3**

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \qquad K_{eq} = 0.028 \text{ at } 298 \text{ K}$$

A quantity of nitrosyl chloride was introduced into a 2.00 L container at 298 K. A short time later the quantity of each substance was determined as follows:

Gas	*Quantity (mol)*
NOCl	0.74
NO	0.36
Cl_2	0.18

Determine if the system is at equilibrium.

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Question 25 (4 marks)

A student created the following models to demonstrate a chemical process.

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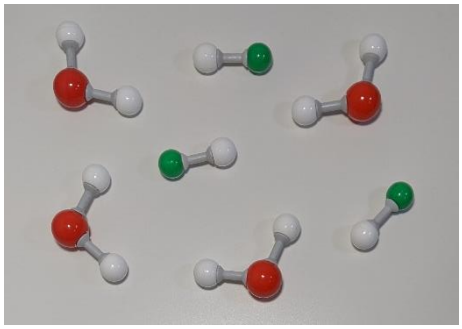
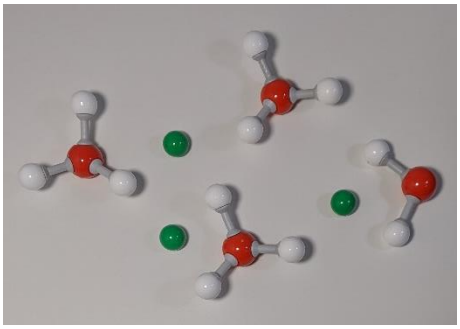


II



(a) Outline the process being modelled. **3**

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(b) Identify one limitation of the student's model. **1**

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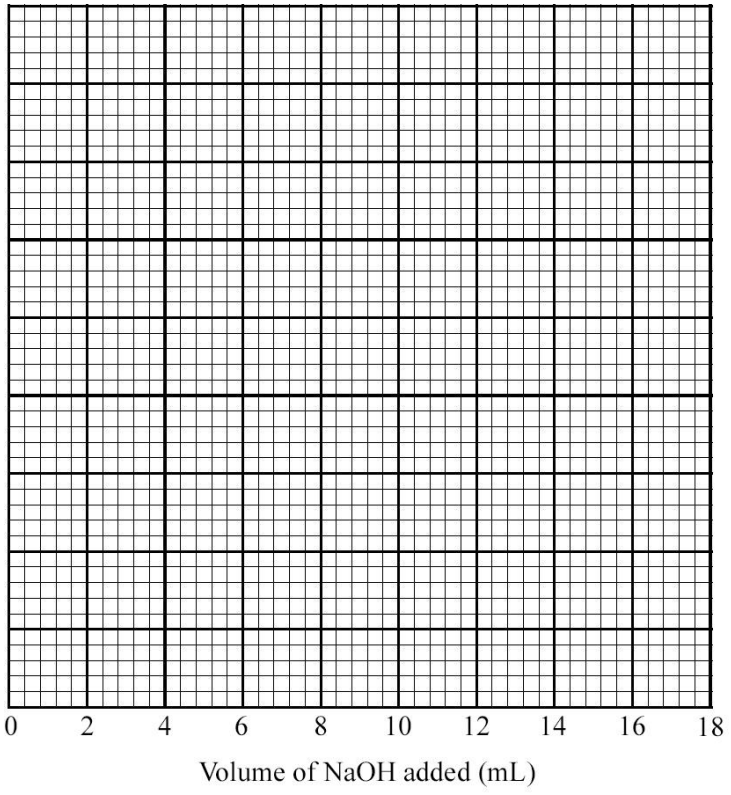
Question 26 (9 marks)

A student read on the internet that sour lollies can cause tongue burns and dental erosion in children due to the citric and malic acids in the sweets. She decided to determine the titratable acidity (TA) of the acids in Warheads Blue Raspberry Super Sour Spray candy.

20.0 mL of the candy solution was pipetted into a beaker containing a calibrated pH probe and enough distilled water was added to ensure the probe was immersed in solution.
A burette was used to dispense volumes of 0.0500 M sodium hydroxide solution. The student recorded the following pH data as the sodium hydroxide was added to the beaker.

Volume of NaOH (mL)	*pH*
0.0	4.5
3.0	5.4
6.0	5.9
9.0	6.5
9.5	6.9
10.0	7.6
10.5	8.4
11.0	9.0
11.5	9.6
12.0	10.2
15.0	10.7
18.0	11.1

(a) Construct a graph of the pH of the reaction mixture against the volume of sodium hydroxide added. Use your graph to calculate the titratable acidity (concentration of hydrogen ions) in the candy solution. **7**



Question 26 continues on page 17

Question 26 (continued)

(a) (continued)

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(b) Under acidic conditions (pH less than about 5.5), there is a net loss of calcium and phosphate ions from the tooth resulting in dental erosion. Evaluate the risk of dental erosion from consuming Warheads Sour Spray candy. **2**

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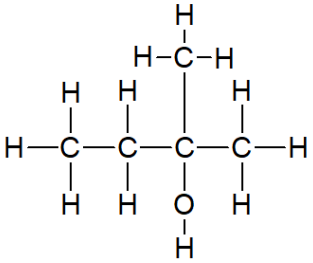
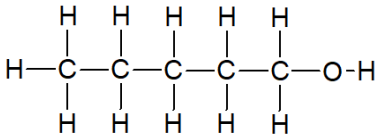
End of Question 26

Question 27 (5 marks)

The structural formulae for two compounds are shown below.



Compound A



Compound B

(a) Describe a qualitative test that could be carried out in the school laboratory to distinguish between the two compounds. Include the expected observations for each compound. **3**

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(b) Propose how the two compounds should be safely handled and disposed of following the experiment. **2**

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Question 28 (7 marks)

The Solvay Process is an industrial process used to produce sodium carbonate (Na_2CO_3) from limestone ($CaCO_3$) and brine (NaCl).

An early step in the process is to decompose limestone to produce carbon dioxide gas, then to dissolve this carbon dioxide gas in an ammoniated brine solution:

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \qquad \Delta H = -42 \text{ kJ mol}^{-1}$$

$$NH_3(aq) + H_2CO_3(aq) \rightleftharpoons NH_4^+(aq) + HCO_3^-(aq) \qquad \Delta H = -110 \text{ kJ mol}^{-1}$$

(a) State TWO reaction conditions that could be used to increase the yield of HCO_3^-. **2**

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(b) Using the Brønsted-Lowry definitions of an acid and base, identify an acid and a base from the above equations. **2**

	Chemical
Acid	
Base	

(c) Following the carbonation steps described above, a solution containing both NH_4Cl and $NaHCO_3$ is formed. **3**

Salt	K_{sp} *at 0°C*	K_{sp} *at 25°C*
NH_4Cl	30	51
$NaHCO_3$	0.67	1.5

Compare the solubility of the two salts.

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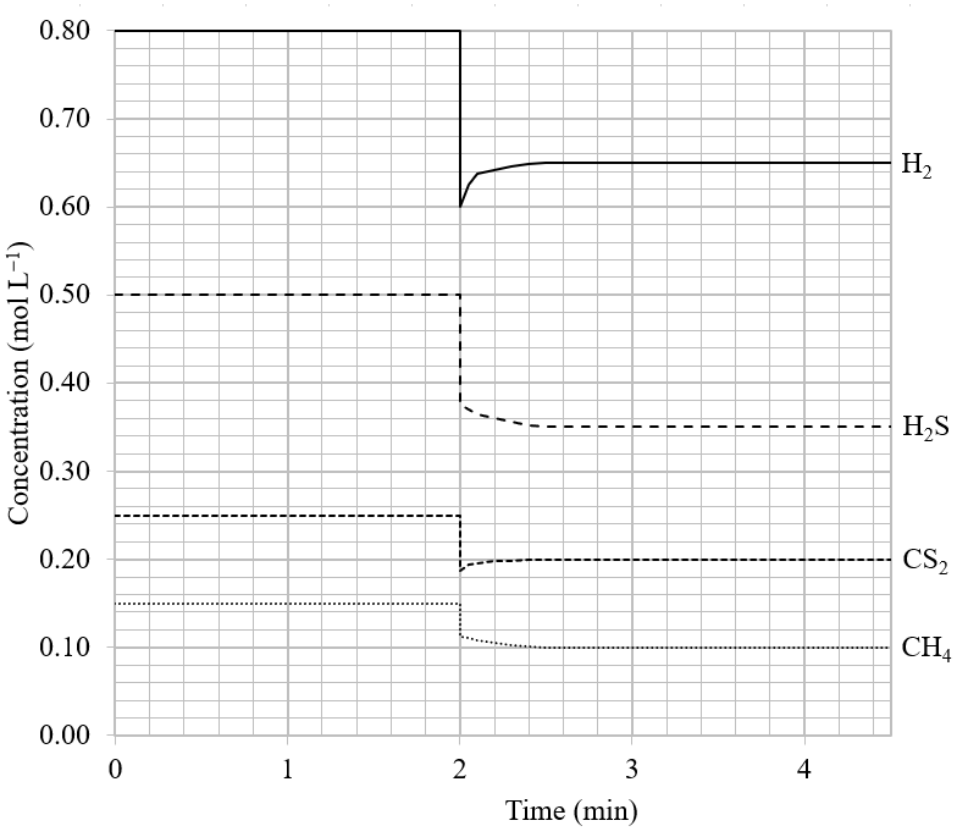
Question 29 (6 marks)

The concentrations of reactants and products as a function of time for the following system were determined.

$$2H_2S(g) + CH_4(g) \rightleftharpoons 4H_2(g) + CS_2(g)$$

At 2 minutes, a change was made to the system.



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

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(b) Calculate K_{eq} at 3 minutes. **2**

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Question 29 continues on page 21

(c) Using Le Chatelier's Principle, identify the change to the system at 2 minutes and explain the resultant changes in concentration of H_2 after 2 minutes. **3**

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End of Question 29

Please turn over

Question 30 (6 marks)

Hypochlorous acid is a weak monoprotic acid with the formula HOCl. The pH of a 0.100 M solution of hypochlorous acid was measured to be 4.27.

(a) Calculate the K_a of hypochlorous acid. **3**

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(b) Calculate the pK_a of hypochlorous acid. **1**

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(c) The pK_a of acetic acid is 4.76. Determine if hypochlorous acid is stronger or weaker than acetic acid. Justify your response. **2**

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Question 31 (5 marks)

The bitter yam or potato yam (*Discorea bulbifera*) is a food source in many parts of the world, including for the Tiwi people of the Tiwi Islands off the coast of the Northern Territory. The yams are leached in running water before consumption to remove oxalates that would be toxic if consumed.

The oxalate in the yams is assumed to be mostly calcium oxalate (CaC_2O_4).

$$CaC_2O_4(s) \rightleftharpoons Ca^{2+}(aq) + C_2O_4^{2-}(aq) \qquad K_{sp} = 2.7 \times 10^{-9}$$

(a) Calculate the solubility of oxalate ions **in mg L^{-1}**. **3**

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(b) The concentration of soluble oxalate in the yams has been measured to be 2.77 mg per 100 g. Determine the volume of water required to leach the oxalate from 1.0 kg of yams. **2**

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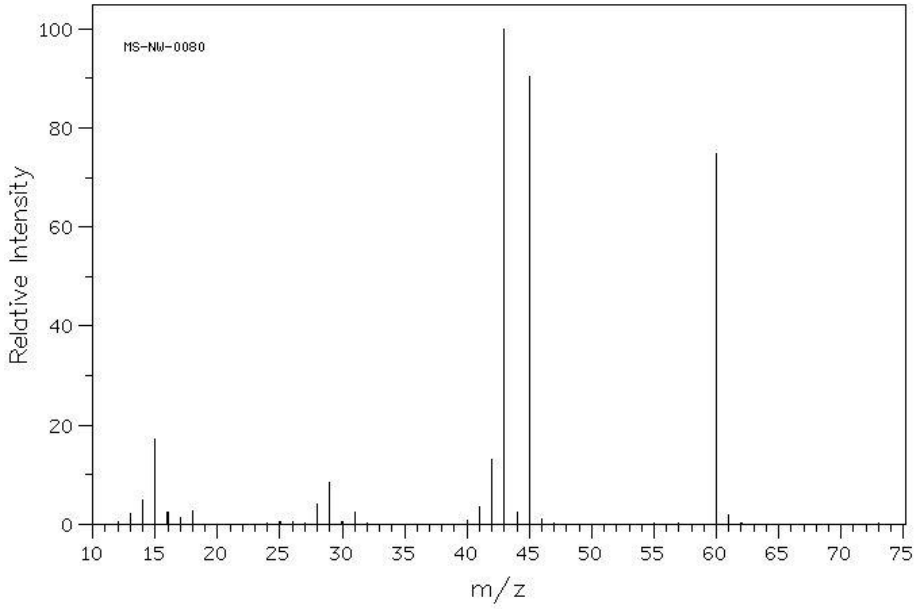
Question 32 (8 marks)

The following data were obtained for an organic compound containing carbon, hydrogen and oxygen.

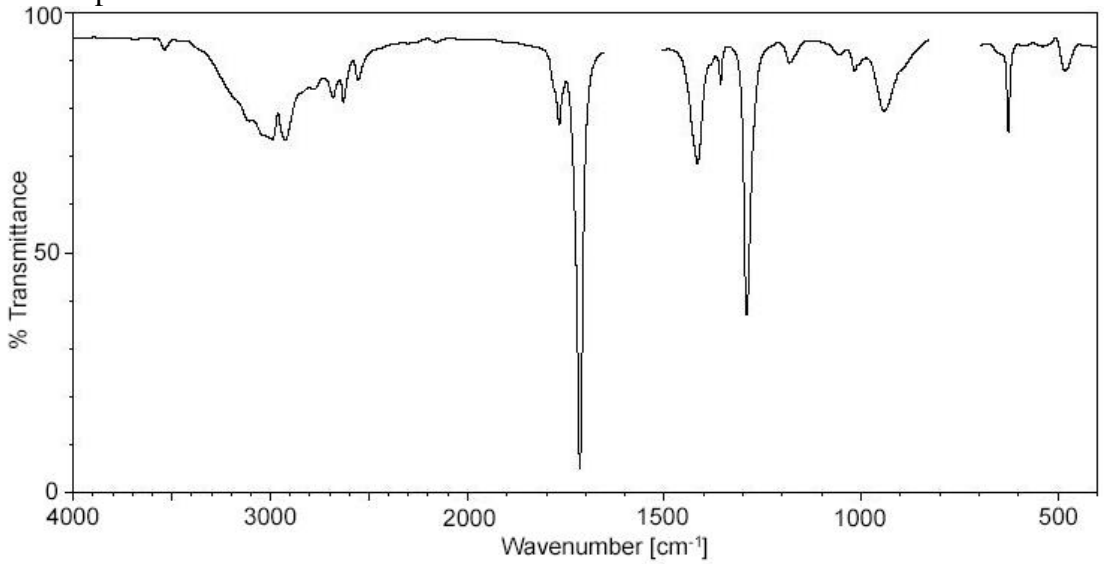
Chemical tests:

Test	*Result*
Addition of sodium metal	Bubbles of a gas produced
Addition of acidified $KMnO_4$	No reaction
Addition of solid $NaHCO_3$	Bubbles of a gas produced

Mass Spectrum:



Infrared Spectrum:



Question 32 continues on page 25

Question 32 (continued)

(a) On the mass spectrum on the previous page, **circle ONE of the peaks** (other than the parent molecular ion peak). Draw the structure of the species responsible for the chosen peak in the box below. **2**

(b) On the infrared spectrum on the previous page, identify the wavenumber of the peak of maximum absorbance AND identify the type of bond responsible for this peak. **2**

Wavenumber (cm^{-1})	*Bond*

(c) Identify the name and structure of the compound. Justify your answer with reference to the information given on its reactivity and at least TWO features of the provided spectra. **4**

Structure:
Name:

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End of Question 32

Question 33 (7 marks)

The procedure of a first-hand investigation conducted in a school laboratory to determine the molar heat of combustion of methanol is shown.

- 100.0 g of water was placed in a conical flask and clamped to a retort stand.
- A digital thermometer was placed in the conical flask and the initial temperature of the water measured and found to be 21.4°C.
- A spirit burner of known mass was placed under the conical flask and lit. After five minutes, the spirit burner was extinguished. Its mass was measured with an electronic balance and the change in mass was determined to be 0.92 g.
- The final temperature of the water was measured with the digital thermometer and found to be 37.2°C.

(a) Suggest TWO modifications that could be made to the procedure to improve the results of this investigation. Justify your suggestions. **4**

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Question 33 continues on page 27

Question 33 (continued)

(b) Calculate the molar enthalpy of combustion of methanol in kJ mol^{-1} from the results of the procedure followed. **3**

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End of Question 33

Please turn over

Question 34 (7 marks)

Ethanol is produced on an industrial scale using two methods in Australia: by fermentation of molasses from sugar cane, or by hydration of ethene obtained from catalytic cracking of hydrocarbons from crude oil. **7**

Contrast the environmental implications of these two methods of obtaining and producing ethanol. Include chemical equations in your response.

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End of paper

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Section II extra writing space

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

Section II extra writing space

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

Section II extra writing space

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

Student Number

Multiple-choice answer sheet

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 =(A) 2 (B) 6 (C) 8 (D) 9

A ○ B ○ C ● D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ○ B ● C ⊗ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word ***correct*** and drawing an arrow as follows.

correct ↙

A ○ B ⊗ C ⊗ D ○

Section I

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

Task 4 2020
Marking Guidelines

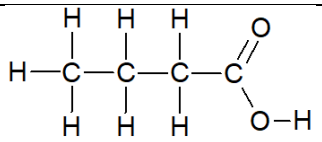
Section I

1	B
2	C
3	C
4	D
5	C
6	C
7	D
8	A
9	A
10	B

11	B
12	C
13	C
14	A
15	D
16	B
17	A
18	C
19	B
20	D

10 - Knowledge & Understanding; 10 - Skills

Section II

Question	Criteria	Mark
21a S	Names an amphiprotic salt (name or formula) $NaHCO_3$ or $NaHSO_4$ or Na_2HPO_4 or NaH_2PO_4 (Prac 6.4) Very poorly done. Most students did not read the 'salt' in the question and named only the anion. No mark given if this was the case.	1
21b K	Relates amphiprotism to both gain and loss of a proton Writes equations demonstrating the anion from part (a) acting as an acid and acting as a base $NaHCO_3$ is amphiprotic as the HCO_3^- ion can both act as an acid and donate a proton: $HCO_3^-(aq) + OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$ or act as a base and accept a proton: $HCO_3^-(aq) + H_3O^+(aq) \rightarrow H_2CO_3(aq) + H_2O(l)$ Generally, well done. Some students did not 'explain' amphiprotic nature of salts and only provided equations, so lost a mark.	1 1
22a K	 Very well done.	1

<table>
<tr><th>Question</th><th>Criteria</th><th>Mark</th></tr>
<tr><td>22b
K</td><td>Correctly states the trend
Relates the smaller acid's solubility to the presence of the polar carboxylic acid group and hydrogen bonding to water/solubility in polar water
Relates the larger acid's insolubility to the dominance of the non-polar hydrocarbon chain

Generally well done. Students were able to correctly identify the trend and explain the solubility of the shorter chain molecule and the insolubility of the longer chain molecules.

Teaching point: Students need to explicitly state trend. A large number of students did not. But if they referred to it in their explanation marks were given this time.

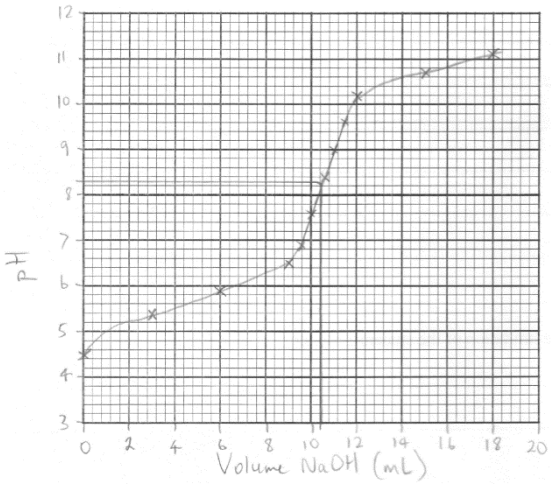
Students who lost marks only related solubility to either short or long chain not to both OR did not relate the solubility to the polar COOH group/non-polar HC chain</td><td>1
1

1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>23a
K</td><td>Correctly identifies all four cations
Correctly identifies two or three cations

<table><tr><th>Solution</th><th>Cation identified</th></tr><tr><td>A</td><td>Ba^{2+}</td></tr><tr><td>B</td><td>Mg^{2+}</td></tr><tr><td>C</td><td>Pb^{2+}</td></tr><tr><td>D</td><td>Fe^{2+}</td></tr></table>
Mostly well done.</td><td>2
1</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Question	Criteria	Mark
23b K	Provides specific reasons to show that if the tests are done out of order, they will not identify each of the four ions; 2 justifications which includes at least two relevant equations **with states** Makes one error or omission Gives ONE justification- an example where if the tests are completed in a different order two of the ions would not be distinguished; includes an equation Provides a relevant piece of information This question was very poorly answered. Question asks to 'justify' but most students 'described' the tests in the order that they were presented in Q23. A good response had to show why the order of tests to identify the 4 ions had to be carried out in the order specified/shown in the flow chart. Sample answer: *If sulfuric acid was added to the unknowns first, both Ba and Pb ions will precipitate OR if NaOH is added first, all except Ba will precipitate OR flame test cannot be done with the ions first as burning Pb is dangerous/not safe. So, Pb had to be first eliminated by adding HCl as only Pb ions are precipitated.* The justifications also had to include equations -net ionic equations - **balanced** and with the correct **"states'.** **Some examples :** $Mg^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Mg(OH)_{2(s)}$ $Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$ **Common mistakes:** • Quite a few students had the wrong arrow (reversible) or forgot states. Some students used Ksp data to explain solubility and justify order- no marks given Quite a few students had the wrong arrow (reversible) or forgot states. Some students used Ksp data to explain solubility and justify order- no marks given	4 3 2 1

Question	Criteria	Mark
24 S	Correctly calculates Q and compares Q to K_{eq} to determine the system is not at equilibrium Makes one error (eg. does not calculate the concentrations) One correct step $K_{eq} = \frac{[NO]^2[Cl_2]}{[NOCl]^2} = 0.028$ $[NO] = n/V = 0.36/2 = 0.18$ M $[Cl_2] = n/V = 0.18/2 = 0.090$ M $[NOCl] = n/V = 0.74/2 = 0.37$ M $Q = \frac{0.18^2 \times 0.090}{0.37^2} = 0.021$ $Q \neq K_{eq}$ thus the system is not at equilibrium Done well. Important that all steps are shown in calculations especially how concentration is calculated.	3 2 1
25a K	Outlines in detail the process of complete ionisation of a strong acid (1) by donation of a proton from the acid to the water ions to produce hydronium ions and a conjugate base anion(2) includes an equation (3) $HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$ Outlines in brief/less detail the process of ionisation of an acid Identifies the process or provides one relevant piece of information Many students did not identify the chemical process being modelled- the ionisation of a strong acid correctly. Some answers lacked detail and did not provide an equation	3 2 1
25b K	Provides a valid limitation The model does not show hydration shells around the ions The ions/atoms are not of the correct relative sizes Well done. All relevant limitations were accepted Some examples cannot see IMF, cannot see bonds breaking or forming, cannot see movements/dissociation etc- were all accepted.	1

Question	Criteria	Mark
26a S	Correctly labelled y-axis (with a sensible scale eg 3-12) Points correctly plotted line of best fit  Graph generally well done. There were some squishy graphs- students to be reminded to spread the scale. Make sure plotting is accurate and that the origin is correctly labelled for both x and y axes.	1 1 1
26a S	Determines the equivalence point from the graph; Calculates moles OH^-; shows H^+:OH^- or equal moles; calculates $[H^+]$ to 3 **significant figures** Calculates the $[H^+]$ with one error At least two correct steps of the calculation One correct step of the calculation Equivalence point (from graph) = 10.4 mL $n(OH^-) = c\,V = 0.0500 \times 0.0104 = 5.20 \times 10^{-4}$ mol H^+:OH^- = 1:1 $\therefore$ $n(H^+) = 5.20 \times 10^{-4}$ mol $[H^+] = n/V = 5.20 \times 10^{-4} \div 0.0200 = 0.0260$ mol L^{-1} The calculation part of the question was not done well. Most students got 1 mark just by determining the equivalence point from the graph. Unfortunately, students then went down the wrong path by using pH from the graph to try to work out the H+ concentration in the candy solution instead of calculating n(NaOH) and working out concentration of H+. Other errors included using a 3:1 mole ratio (for citric acid but the chemical formula was not provided in the question) instead of assuming equal moles of H+ and OH- and not **calculating to correct sig fig.**	4 3 2 1
26b S	Either calculates pH from result in (b) OR reads initial pH from table/graph Provides judgement that pH<5.5 thus high risk of dental erosion Done very well.	1 1

<table>
<tr><th>Question</th><th>Criteria</th><th>Mark</th></tr>
<tr><td>27a
S</td><td>Correctly outlines the procedure with some indication of volume/s; identifies an appropriate reagent (acidified $KMnO_4$); result for A (no reaction) and B (from purple to brown/colourless)
Two of the above features
Identifies one correct aspect of the procedure
Done poorly in terms of quantities. Most identified that there is a tertiary alcohol (A) and primary alcohol (B). Need to name reagent accurately. Lot of students referred to solutions which is not the case as the test is for the compounds.</td><td>3

2
1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>27b
K</td><td>Identifies an appropriate handling procedure
Identifies an appropriate disposal procedure

Handling: no open flames; small quantities; wear gloves (toxicity); wash hands; wear safety glasses
Disposal: into a flammable waste bottle/organic waste bottle
Part b done very well – be wary of being specific with disposal. Not good enough to simply say waste container as we use more than one type.</td><td>1
1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>28a
K</td><td>Provides two appropriate reaction conditions
Provides one appropriate reaction condition

Decrease the temperature; increase the pressure; increase $[CO_2]$ or $[NH_3]$
Well done, except that a few responses were closer to explain than state</td><td>2
1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>28b
K</td><td>Correctly identifies both an acid and a base
Identifies either an acid or a base
Really well done

<table><tr><th></th><th>Chemical</th></tr><tr><td>Acid</td><td>H_2CO_3 or NH_4^+</td></tr><tr><td>Base</td><td>NH_3 or HCO_3^-</td></tr></table></td><td>2
1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>28c
K</td><td>Provides both a similarity and difference in the solubility of the two salts
Provides a similarity and difference in the K_{sp} values given
Provides either similarities OR differences in solubility or K_{sp}

Similarities: The solubility of both salts is high (large K_{sp} values); the solubility of both salts increases as temperature increases.
Differences: NH_4Cl is more soluble than $NaHCO_3$; $NaHCO_3$ is much more likely to precipitate at 0°C than NH_4Cl due to a lower solubility than NH_4Cl (or due to $K_{sp}<1$).

Very good responses. We had anticipated a lot of use of Ksp rather than solubility but we were wrong and responses were clearly linked to solubility.</td><td>3
2
1</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

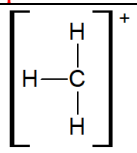
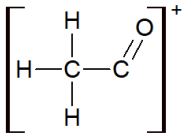
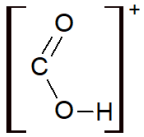
Question	Criteria	Mark
29a S	Writes the correct equilibrium expression $K_{eq} = \frac{[H_2]^4[CS_2]}{[H_2S]^2[CH_4]}$ Excellent	1
29b K	Determines the concentrations of each species from the graph and correctly substitutes the values into the equilibrium expression to calculate K_{eq} One correct step From the graph $[H_2] = 0.65$ M; $[CS_2] = 0.20$ M; $[H_2S] = 0.35$ M and $[CH_4] = 0.10$ M $K_{eq} = \frac{[0.65]^4[0.20]}{[0.35]^2[0.10]} = 2.9$ This Q was done well – a few minor mathematical errors – double check the data, especially when raising to a power.	2 1
29c S	Identifies the change as an increase in volume; Uses LCP to explain the effect of the increase in volume causing a decrease of pressure as shifting the equilibrium to the right to increase the pressure. This is the side with the greater number of moles and thus more hydrogen so increased concentration. Includes the ratio of moles of gas; Relates the increasing volume to the initial fall in $[H_2]$ and the equilibrium shift to increase $[H_2]$ Most of the above (missing one point such as the ratio or not identifying that the change is increase in volume or stating due to LCP with no detail around it) One relevant point This question has the verb explain – thus requiring a cause and effect relationship. Unfortunately, there were a lot of good descriptions but missing the relationships for cause and effect. Lots of responses not referring to the mole ratio and a significant number stating a decrease in pressure with no reference to volume. Concentration is in mol/L so to decrease the concentration a change in volume is required. The resultant increase in pressure will produce a decrease in pressure and this then leads to LCP coming into effect.	3 2 1

Question	Criteria	Mark
30a S	Correctly calculates K_a including the equation, expression and substitution. The [HOCl] to be calculated and not left as 0.100 Provides the main steps of the calculation Provides some relevant information Teaching point that the arrow should be equilibrium arrow. Significant ecf was applied if Ka was wrongly calculated. Overall this question was done well. There are a couple of things to watch out for including the calculation of [HOCl]. $HOCl_{(aq)} \rightleftharpoons OCl^-_{(aq)} + H^+_{(aq)}$ $K_a = \frac{[OCl^-][H^+]}{[HOCl]}$ $[H^+] = 10^{-pH} = 10^{-4.27} = 5.37 \times 10^{-5} = [OCl^-]$ $[HOCl] = 0.100 - 5.37 \times 10^{-5} = 0.0999$ mol L^{-1} $K_a = \frac{(5.37\times10^{-5})^2}{0.0999} = 2.89 \times 10^{-8}$	3 2 1
30b S	Correctly calculates pK_a pK_a = – log K_a = – log 2.89×10^{-8} = 7.54 ecf from part a – done well	1
30c K	Compares the pK_a values Concludes acetic acid is stronger than hypochlorous acid Error carried forward from a to b to c. This was done well.	1 1
31a S	Correctly calculates the solubility of calcium oxalate in the correct units Provides the main steps of the calculation (one error or omissions) Provides some relevant information (two errors or omissions) Let $[C_2O_4^{2-}] = x$ ∴ $[Ca^{2+}] = x$ $K_{sp} = [Ca^{2+}][C_2O_4^{2-}] = 2.7 \times 10^{-9}$ $x^2 = 2.7 \times 10^{-9}$ $x = \sqrt{2.7 \times 10^{-9}} = 5.2 \times 10^{-5}$ mol L^{-1} ∴ $[C_2O_4^{2-}] = 5.2 \times 10^{-5}$ mol L^{-1} $MM(C_2O_4^{2-}) = 2 \times 12.01 + 4 \times 16.00 = 88.02$ g mol^{-1} (must show working of MM) $m = n \times MM = 5.2 \times 10^{-5} \times 88.02 = 0.0046$ g = 4.6 mg ∴ $[C_2O_4^{2-}] = 4.6$ mg L^{-1} Overall, this was well done. Some students tried to find calcium oxalte $[Ca_2C_2O_4]$ rather than oxalate ions $[C_2O_4^{2-}]$ so make sure you read the question carefully. (This question was not marked for significant figures but take care- this was only to 2 sf)	3 2 1

<table>
<tr><th>Question</th><th>Criteria</th><th>Mark</th></tr>
<tr><td>31b
S</td><td>Correctly determines the volume of water required with units stated
Calculates the mass of oxalate in 1.0 kg of yams

10 × 2.77 = 27.7 mg in 1.0 kg
$V = m/c = 27.7 \div 4.6 = 6.0$ L

A bit of confusion here. Students who correctly used part a and divided this number into 27.7 mg were awarded two marks.</td><td>2
1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>32a
S</td><td>Draws the structure of an ion fragment that matches the size of the peak circled
Makes one error (fragment not shown with positive charge or does not match chosen peak)

<table>
<tr><th>peak = 15</th><th>peak = 43</th><th>peak = 45</th></tr>
<tr><td>  </td><td>  </td><td>  </td></tr>
</table>

Very few full marks with this one! Most common error was to forget that the fragment is positively charged.</td><td>2

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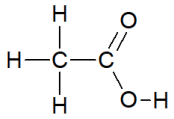
<tr><td></td><td></td><td></td></tr>
<tr><td>32b
S</td><td>Identifies the wavenumber of the peak in the range 1700–1750 cm^{-1}
Identifies the carbonyl bond C=O

Well done!</td><td>1
1</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Question	Criteria	Mark
32c K	Identifies the name and structure of acetic acid; justifies the structure referring to at least one chemical test result and two features of the spectra provided Provides most of the information above, but incomplete in some aspect Provides at least two aspects of above Identifies the structure and name OR one relevant piece of information not already given in (a) or (b).  acetic (or ethanoic) acid Justifications from reactivity: • possibly an alcohol or acid as does react with Na • possibly a 3° alcohol or acid as not oxidised • is a carboxylic acid and not an alcohol as does react with $NaHCO_3$ Justifications from spectra [at least one not from (a) & (b)]: • mass spectrum molecular fragment at 60 m/z ($2 \times 12 + 4 \times 1 + 2 \times 16 = 60$) so formula $C_2H_4O_2$ • [one of which identified in (a)] major fragments CH_3^+, CH_3CO^+ and $COOH^+$ • IR spectrum has a very broad peak at 2500–3000 so O–H (acid) present • [identified in (b)] peak at 1730 indicates C=O This was well done on the whole. Remember that carboxylic acid AND alcohol can react with Na so this does not automatically prove the unknown was carboxylic acid. Better to use this fact in combination with the fact that the unknown reacted with $NaHCO_3$ which confirms that it is a carboxylic acid. Also, make sure you use at least one difference piece of information that was given in (a) and (b) – this shows a deeper understanding of the spectra provided.	4 3 2 1

<table>
<tr><th>Question</th><th>Criteria</th><th>Mark</th></tr>
<tr><td>33a
S</td><td>
Provides at least two possible modifications that would improve the results and justifies each one
Provides most of the information above, but incomplete in some aspect
Provides one possible modification with justification OR suggests two possible modifications
Suggests a possible modification
<table>
<tr><th>Modification</th><th>Justification</th></tr>
<tr><td>Increase the time the spirit burner is used to heat the water OR allow the water to be heated until there has been a greater increase in the temperature</td><td>Increases the mass used so that the change in mass contains less error/greater accuracy/significant figures</td></tr>
<tr><td>Ensure the spirit burner is not too close to the conical flask</td><td>If too close, insufficient oxygen may be available and incomplete combustion will be more probable, reducing the heating of the water</td></tr>
<tr><td>Ensure the spirit burner is not too far from the conical flask</td><td>If too far, there will be greater heat loss from the flame to the surroundings/less heat will be absorbed by the water in the flask</td></tr>
<tr><td>Trim the wick of the spirit burner</td><td>Reduces the likelihood of incomplete combustion, reducing the heating of the water</td></tr>
<tr><td>Use a copper calorimeter instead of the conical flask.</td><td>Copper is a better conductor of heat than laboratory glass so more heat would reach the water</td></tr>
<tr><td>Put a lid on the conical flask</td><td>To reduce heat loss from the water to the surroundings</td></tr>
</table>
Well done.
A few points to remember:

“Copper calorimeter” was accepted, but not “metal calorimeter”, not “styrofoam calorimeter”, not “calorimeter” without qualifying that it is copper. If these phrases were used but the justification was correct then = 1 mark
Using an electronic balance with more decimal places was not accepted as a modification. This is because this is a school laboratory setting and more sophisticated balances are not available. Also, there are better ways of increasing sig figs, namely increasing time that the fuel is burnt for leading to greater mass loss and temp increase. The justification was accepted if it was sensible. = 1 mark. Same goes for digital thermometers.
Clamping the thermometer to a retort stand was not accepted as a modification. This is because clamping thermometers will mean the water may not be mixed adequately leading to areas that are hotter than others.

</td><td>4

3
2

1</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Question	Criteria	Mark
33b S	Correctly calculates the molar enthalpy of combustion of methanol Calculates the enthalpy with one error One correct step of the calculation $\Delta T = 37.2 - 21.4 = 15.8$ °C $q = m\ c\ \Delta T = 100.0 \times 4.18 \times 15.8 = 6604.4$ J = 6.6044 kJ $MM(CH_3OH) = 12.01 + 4 \times 1.008 + 16.00 = 32.042$ g mol^{-1} $n(CH_3OH) = m / MM = 0.92 \div 32.042 = 0.02871$ mol $\Delta H_c = q / n = -6.6044 \div 0.02871 = -230$ kJ mol^{-1} (should be negative – this is a teaching point) Big improvement in this type of question from previous assessments- well done. Remember that combustion is an exothermic reaction therefore the final answer must be negative.	3 2 1

34 K	The following marking rubric was used:	7

Demonstrates an extensive knowledge of the two methods of production of ethanol by outlining each method. Includes at least two relevant and correct chemical equations in the response. Contrasts the environmental implications of the two methods both for the obtaining of the raw materials and the method of production. Provides at least two well explained environmental implication for each method of production. (states were ignored this time!)	7
One error or omission in above. Must have at least one correct equation.	6
No outline of each method, at least one correct equation AND four correctly explained environmental implications. OR Outline of each method, at least one correct equation AND three correctly explained environmental implications.	5
No outline of each method, no equations or errors with equations provided AND four correctly explained environmental implications. OR Outline of each method, no equations or errors with equations provided AND three correctly explained environmental implications.	4
No outline of each method, no equations or errors with equations provided AND three correctly explained environmental implications. OR Outline of each method, no equations or errors with equations provided AND two correctly explained environmental implications.	3
One correctly explained environmental implication OR two pieces of relevant information	2
One piece of relevant information	1

Here is a summary of the features of a response demonstrating extensive knowledge:

Q34 continued:

Here is a summary of the features of a response demonstrating extensive knowledge:
Note that for each environmental issue, the implication of the issue had to be clearly explained. This is where most students did not take their explanation far enough. Remember to show your depth of understanding and clearly step out the implication of the issue you are describing.

Method of production	**Environmental issue**	**Environmental implications of the issue**
Producing ethanol by fermentation: **Outlines method** of producing ethanol from industrial fermentation of glucose from molasses- yeast needed, warm, anaerobic and acidic conditions needed. **Equation** of fermentation $C_6H_{12}O_{6(aq)}$ -> $2C_2H_5OH_{(aq)} + 2CO_{2(g)}$	Source of raw materials is molasses from sugar cane	Renewable- can be replanted therefore more sustainable
	Source is molasses from sugar cane	Land needed to grow the sugar cane could be used to grow food. Is this the best use of the land.
	Land use in growing sugar cane for ethanol production	Often involves the use of fertilisers which can lead to run off and algal blooms in waterways OR monoculture of sugar cane can lead to loss of biodiversity of the ecosystem.
	Source is molasses from sugar cane- land needed for growth of the sugar cane.	Deforestation and land clearing, exacerbating climate change.
	Potential to be carbon neutral but probably not, due to the CO_2 produced during fermentation AND	CO_2 taken up in plants in process of photosynthesis

Question	Criteria			Mark
		the combustion of fossil fuels used in the machinery used in farming, etc.		
		Method of production: Fermentation needs warm conditions.	While fermentation is an exothermic process, on an industrial scale there is still a need for a source of heat-Fossil fuels needed to keep warm conditions- greenhouse gases (CO_2) produced in the process, leading to climate change.	
		Method of production: To purify the ethanol, distillation is needed. Heat is needed which often requires combustion of fossil fuels.	Fossil fuels needed to heat mixture during distillation- greenhouse gases such as CO_2 produced, leading to climate change.	
	Producing ethanol from the hydration of ethene obtained from catalytic cracking of hydrocarbons from crude oil: **Equation**: either Hydration of ethene (dilute H_2SO_4 as catalyst and heat) $C_2H_{4(g)} + H_2O_{(l)} \rightarrow C_2H_5OH_{(l)}$ Catalytic cracking of larger crude oil fractions to produce the ethene. $C_{10}H_{22(l)} \rightarrow C_8H_{18(l)} + C_2H_{4(g)}$ **Outlines method** of obtaining ethanol through hydration of ethene that has been obtained from catalytic cracking of fractions from crude oil.	Source of raw materials- crude oil	Crude oil is non-renewable. It takes millions of years to form so once it is used up it cannot be replaced.	
		Method of production: catalytic cracking needs heat which requires combustion of fossil fuels	Fossil fuels needed to heat reaction- greenhouse gases such as CO_2 produced, leading to climate change.	
		Method of production: hydration conditions need heat which requires fossil fuels.	Fossil fuels needed to heat reaction- greenhouse gases such as CO_2 produced, leading to climate change.	
		Method of obtaining crude oil: mining	Mining- oil wells and drilling on land and under the sea damages environment, leading to habitat changes and species loss.	
		Method of obtaining crude oil: transport of crude oil	Oil spills during transport or obtaining crude oil from wells, leading to damage to aquatic environments and species loss.	
	40 - Knowledge & Understanding; 40 - Skills			

40 - Knowledge & Understanding; 40 - Skills