CSSA

2021

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

DO NOT REMOVE PAPER FROM EXAM ROOM

Centre Number

Student Number

Chemistry

Morning Session
Friday, 30 July 2021

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- NESA-approved calculators may be used
- Use the Multiple-Choice Answer Sheet provided
- Draw diagrams using pencil
- A data sheet and Periodic Table are provided SEPARATELY
- Write your Centre Number and Student Number on the top of this page

Total marks – 100

Section I Pages 2-9

20 marks

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

Section II Pages 10-25

80 marks

- 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 part

Use the Multiple-Choice Answer Sheet for Questions 1–20.

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1 Which of the following solutions would cause a precipitate with a solution of sodium sulfate?

A. Copper chloride

B. Barium acetate (barium ethanoate)

C. Potassium nitrate

D. Sodium carbonate

2 Which of the equations below is correct for the reaction of sulfuric acid and aluminium carbonate solid?

A. $Al_2CO_3\,(s) + 3H_2SO_4\,(aq) \rightarrow Al_2(SO_4)_3\,(aq) + H_2O\,(l) + CO_2\,(g)$

B. $Al_2(CO_3)_3\,(aq) + 3H_2SO_4\,(aq) \rightarrow Al_2(SO_4)_3\,(aq) + 6H_2O\,(l) + 3CO_2\,(g)$

C. $2Al_2CO_3\,(s) + 3H_2SO_4\,(aq) \rightarrow 2Al_2(SO_4)_3\,(aq) + 6H_2O\,(l) + 3CO_2\,(g)$

D. $Al_2(CO_2)_3\,(s) + 3H_2SO_4\,(aq) \rightarrow Al_2(SO_4)_3\,(aq) + 3H_2O\,(l) + 3CO_2\,(g)$

3 Phenolphthalein is a common indicator. It contains (by mass) 75.46% carbon, 4.43% hydrogen and 20.10% oxygen. It contains four oxygen atoms in each molecule, two of which are connected to hydrogen atoms.

The molecular formula for phenolphthalein is

A. $C_{10}H_7O_2$

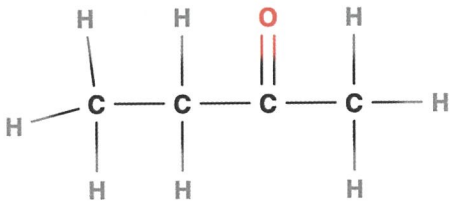
B. $C_{10}H_7O_4$

C. $C_{20}H_{12}O_4$

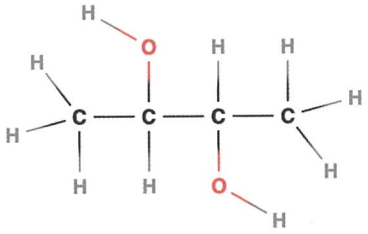
D. $C_{20}H_{14}O_4$

4 Which of the molecules below is a functional group isomer of butanoic acid?

A.



B.



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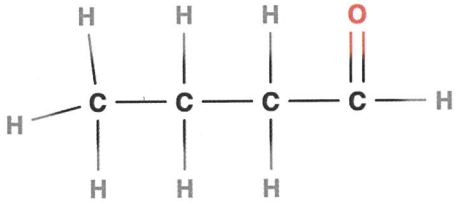
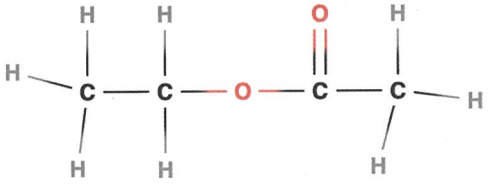


D.



5 In a sealed vessel, gaseous nitrogen monoxide, oxygen and nitrogen dioxide form the following equilibrium:

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

$$\Delta H = -114 kJmol^{-1}$$

Which one of the following sets of conditions is likely to lead to the highest yield of nitrogen dioxide gas?

A. 150°C and 100 kPa pressure

B. 150°C and 200 kPa pressure

C. 350°C and 100 kPa pressure

D. 350°C and 200 kPa pressure

6 What is the correct K_{eq} expression for the reaction below?

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

A. $K_{eq} = \frac{[NO_2]^2}{[N_2O_4]}$

B. $K_{eq} = \frac{[N_2O_4]}{[NO_2]^2}$

C. $K_{eq} = \frac{[NO_2]^4}{[N_2O_4]^2}$

D. $K_{eq} = \frac{[NO_2]}{[N_2O_4]^{\frac{1}{2}}}$

7 Drops of 0.1 M copper (II) sulfate are added to a beaker of 2 M ammonia. Initially a blue precipitate forms. When stirred, the solid dissolves to form a dark blue solution.

The dark blue solution is caused by the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ion. This is an example of which type of reaction?

A. Complexation

B. Precipitation

C. Oxidation

D. Addition

8 Determine the pH of a 0.0015 mol L^{-1} solution of calcium (II) hydroxide.

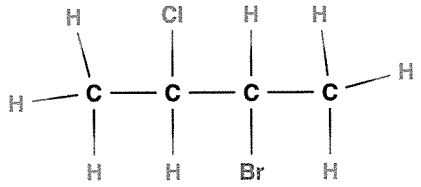
A. 1.52

B. 2.52

C. 2.80

D. 11.48

9 What is the correct name for the molecule below?



A. 2-chloro-3-bromo-butane

B. 3-bromo-2-chloro-butane

C. 2-bromo-3-chloro-butane

D. 3-chloro-2-bromo-butane

10 Which of the statements below correctly defines a closed system?

A. Closed systems are always reversible reactions

B. Both energy and matter can be transferred between the system and the surrounding environment

C. Matter can be transferred between the system and the surrounding environment but energy cannot

D. Energy can be transferred between the system and the surrounding environment, but matter cannot

11 What is the effect of adding a catalyst to an equilibrium system?

A. The rate of the forward reaction and the rate of the backward reaction increase equally; equilibrium is reached faster

B. The rate of the forward reactions is reached faster and equilibrium shifts to the right

C. The rate of the backward reactions is reached faster and equilibrium shifts to the left

D. The activation energy is increased, equilibrium is reached faster

12 Which of the following is a conjugate acid/base pair?

A. NO_2/NO_3^-

B. HNO_3/NO^-

C. $H_2CO_3^-/HCO_3^-$

D. CH_3COOH/CH_3COO^-

13 Which statement best describes how Bioethanol is produced?

A. Bioethanol is produced from the fermentation of carbohydrates, commonly sourced from crops such as sugar cane

B. Bioethanol is a gas released in the breakdown of organic waste by anaerobic bacteria

C. Bioethanol is a fossil fuel found in deposits of the Earth's crust

D. Bioethanol is formed from a chemical reaction of vegetable oils or animal fats with small chained alcohols

14 Which statement is correct for a solution of 0.01 mol L^{-1} hypobromous acid (HOBr), which has pH 4.4?

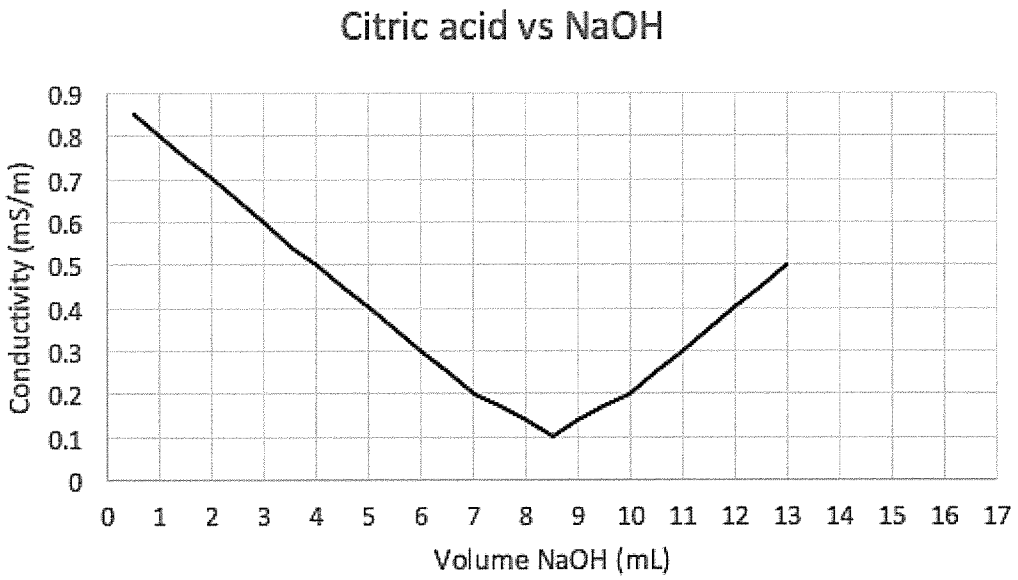
A. $[H_3O^+] > 0.01M$

B. $[OBr^-] = [HOBr]$

C. $[HOBr] > [OBr^-]$

D. $[OBr^-] < [H_3O^+]$

15 A student used a conductivity meter to determine the concentration of a 15 mL solution of citric acid, a triprotic acid ($C_6H_8O_7$). A 0.010 mol L^{-1} solution of NaOH was used to neutralise the acid. The results are recorded in the graph below.



What is the concentration, in mol L^{-1}, of the citric acid?

A. 0.000059

B. 0.0019

C. 0.0057

D. 0.0059

16 Which statement below is correct when referring to the reaction of alcohols with hydrogen halides?

A. Tertiary alcohols react quicker than primary alcohols

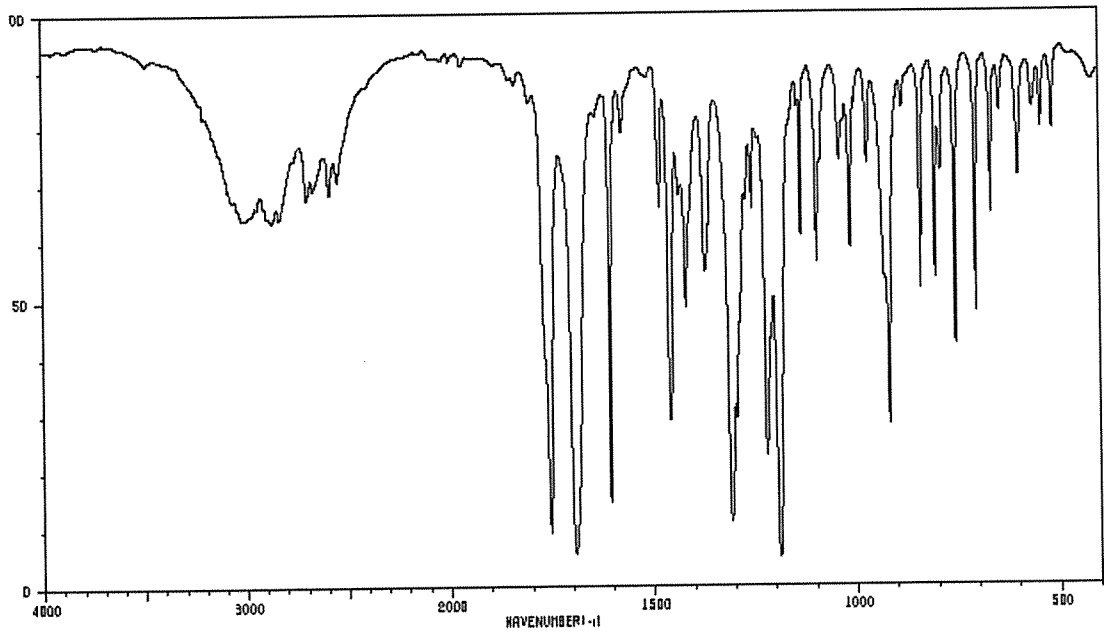
B. Primary alcohols react quicker than tertiary alcohols

C. Primary alcohols react at the same rate as tertiary alcohols

D. Hydrogen halide reactivity decreases down the halogen group

17 The following two questions relate to aspirin.

The chemical formula of aspirin is $C_9H_8O_4$. The infrared spectrum for aspirin is:



Based on the spectrum, which of the following bond types does aspirin probably **NOT** have?

A. O-H (alcohol)

B. O-H (acid)

C. C=O

D. C-C

18 Aspirin is an ester that can be produced by the reaction of acetic acid and salicylic acid, in the presence of an acid catalyst.
The chemical formula for salicylic acid is:

A. $C_2H_4O_2$

B. $C_7H_4O_2$

C. $C_7H_6O_3$

D. $C_7H_8O_4$

19 Which row in the table below gives correct information about the 2 types of polymers?

	Addition polymers	Condensation polymers
A.	Small molecules are often produced as a by-product	No by-products are produced during the reaction
B.	One example is Polyester	One example is Polystyrene
C.	Monomers are unsaturated and contain a double or triple bond	Monomers contain two functional groups that can react with neighbouring molecules
D.	The polymer backbone contains various functional group	The polymer backbone is a long Carbon-Carbon chain

20 A student wishes to determine the concentration of a lead solution, using a precipitation titration. The student takes a 25.00 mL aliquot of the lead solution and titrates against a 0.0978 M solution of hydrochloric acid. The average titre before a faint lead(II) chloride precipitate is detected is 36.75 mL.

The concentration of lead in the aliquot (in mol L^{-1}) is

A. 0.000125

B. 0.000292

C. 0.00502

D. 0.0712

Section II

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 Extra writing space is provided on page 27. If you use this space, clearly indicate which question you are answering.

Question 21 (4 marks)

Determine if a precipitate will form if 10.0 mL of a 0.0150 mol L^{-1} $Cu(NO_3)_2$ is mixed with 20.0 mL of 0.0300 mol L^{-1} of NaOH. **4**
Show all working out.

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Question 22 (5 marks)

(a) Naturally occurring esters are used in the production of soaps and detergents. Write an equation using structural formulae to describe ester hydrolysis. Use methyl propanoate as one of the reactants. **2**

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(b) Explain how soap acts as a cleaning agent. **3**

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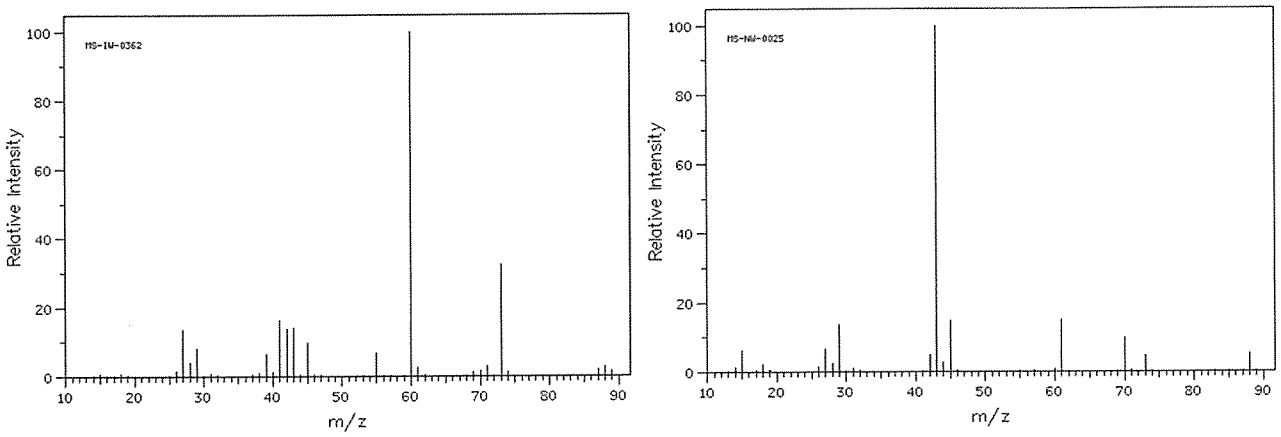
Question 23 (7 marks)

Two mass spectra are shown below, one for butanoic acid and one for ethyl acetate.
(Source: AIST:Spectral Database for Organic Compounds, SDBS).



(a) Identify why both spectra would have a peak at m/z = 88.1. **1**

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(b) With reference to their structure, explain why both spectra have a peak at m/z = 45. **3**

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(c) Outline a method for a chemical test to distinguish between the two compounds. **3**

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Question 24 (4 marks)

A student heated 250g of water by combusting 1.8g of butanol. The starting temperature of the water was 23°C. Calculate the final temperature of the water if there is 20% heat loss to the surroundings. **4**

The molar heat of combustion of butanol, $-\Delta H_c$, is 2871 kJ mol^{-1}.

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Question 25 (6 marks)

The solubility product (Ksp) of $Ca(OH)_2$ is 6.4×10^{-6} at 298K.

(a) Calculate the solubility (in g L^{-1}) of calcium hydroxide in pure water at 298K. **3**

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(b) Using the information below, explain the effect a temperature increase would have on the quoted Ksp. **3**

Thermodynamic data (at 25 °C, 100 kPa)

	$\triangle H^\circ_f$ /kJ mol^{-1}
Ca^{2+} (aq)	-543
OH^- (aq)	-230
$Ca(OH)_2$ (s)	-986

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Question 26 (7 marks)

Four test tubes contain four different solids: calcium carbonate, barium chloride, sodium chloride and potassium sulfate. None of the test tubes are labelled.

(a) Describe how flame tests could be used to identify some or all of the four solids. **2**

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(b) Your teacher says that you cannot use flame tests to identify the solids but gives you a dropper bottle of 1.0 M HCl, a dropper bottle of 0.1 M H_2SO_4 and a bottle of distilled water. **5**

Outline a method to identify the solids. Clearly detail the expected results in a table.

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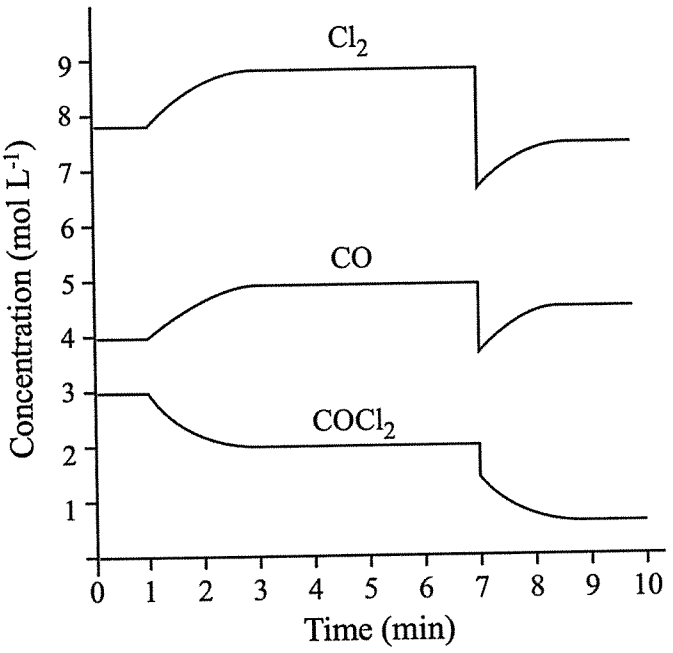
Question 27 (6 marks)

The reaction between chlorine gas Cl_2 (g) and carbon monoxide gas CO (g) is shown in the equation below. **6**

Cl_2 (g) + CO (g) $\rightleftharpoons$ $COCl_2$ (g) $\Delta H = -108$ kJ mol^{-1}

The graph below shows the changes to the system.



Using collision theory and the information above, explain the changes in the concentration of reactants and products over time.

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Question 28 (4 marks)

The boiling points and molar masses of three compounds are shown in the table. **4**

Compound	**Boiling Point (°C)**	**Molar Mass (g mol^{-1})**
Butane	-89	58
Ethanoic acid	118	60
Ethanamide	221	59

Butane, ethanoic acid and ethanamide have similar molar masses but very different boiling points. Explain why, in terms of the structure and bonding of the three compounds.

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Question 29 (4 marks)

Explain the importance of a buffer in a named natural system. **4**

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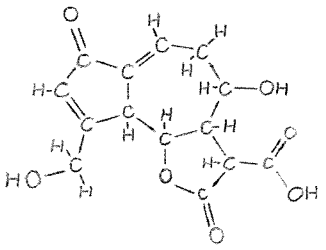
Question 30 (7 marks)

Spiky lettuce has been commonly used by many indigenous tribes of Australia. Lactucin, ($C_{14}H_{12}O_7$), is commonly found in the seeds of the spikey lettuce. Lactucin is a weak monoprotic acid. Lactucin is an analgesic, which is has been used to treat tooth ache and other bodily pains. Lactucin has similar analgesic properties to ibuprofen, a synthetic analgesic.



Lactucin

1.20g of spiky lettuce seeds was collected and crushed into a fine powder. This dried sample was then added to 50.0 mL of distilled water, stirred and filtered to make a Lactucin solution. A 10.0 mL aliquot of this solution was added to 15.0 mL of 0.00100 $molL^{-1}$ NaOH. This reaction is very slow. The remaining NaOH was titrated against 0.000150 $molL^{-1}$ oxalic acid ($H_2C_2O_4$, which is diprotic) requiring 14.3 mL to neutralise the solution.

(a) Determine the concentration of Lactucin in the filtered sample. Give your answer to three significant figures. **5**

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(b) What is the percent composition of Lactucin in the original seeds? **2**

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Question 31 (7 marks)

In 2017, scientists found heavy metal contamination seeping from the disused coal mine in Berrima. For example, zinc contamination was about 120 times more than normal baseline measurements. **7**

With reference to heavy metal contamination and one other example, evaluate the role of at least TWO different types of spectroscopy in monitoring the environment.

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Question 31 continued on page 21

Question 31 continued

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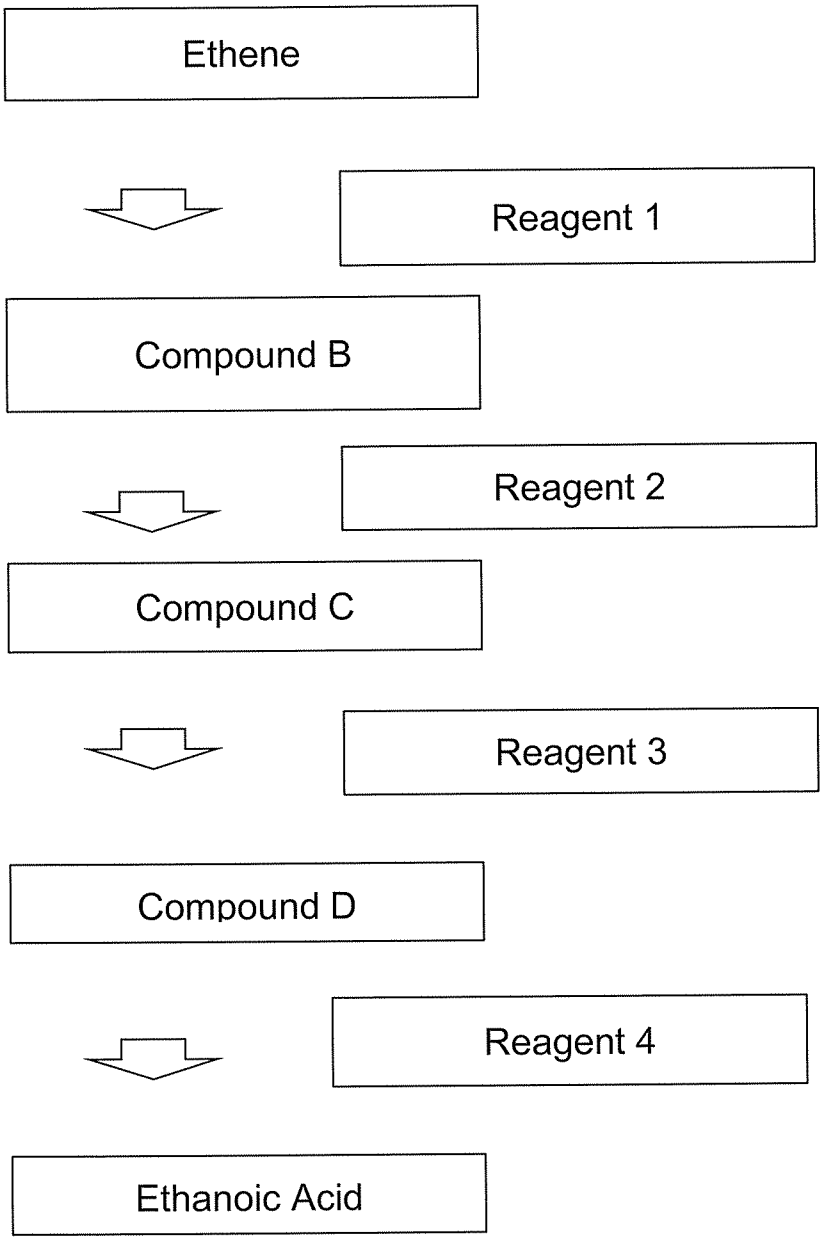
Question 32 (7 marks)

The flow chart below shows an organic reaction pathway. 7
Identify compounds B, C, D and the reagents 1,2,3,4. Write the names next to each relevant box.



Question 33 (6 marks)

(a) Two position isomers have the formula C_4H_8O. **1**
Define the term *position isomer*.

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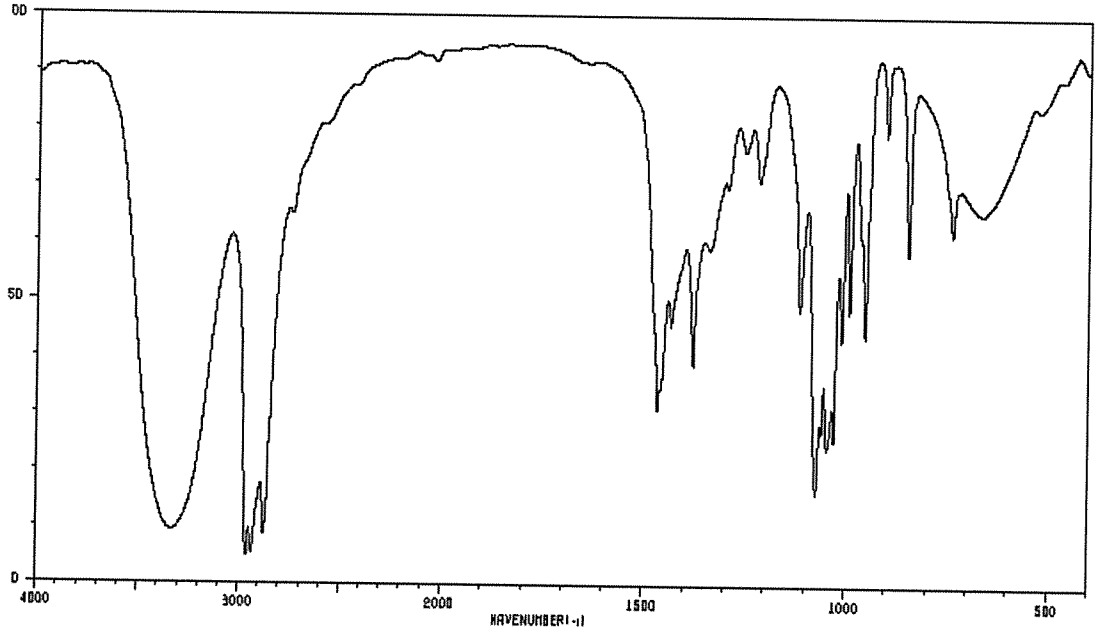
(b) (i) One of the isomers has the following infrared (IR) spectrum. **2**



What functional group is on the isomers, based on the spectrum?

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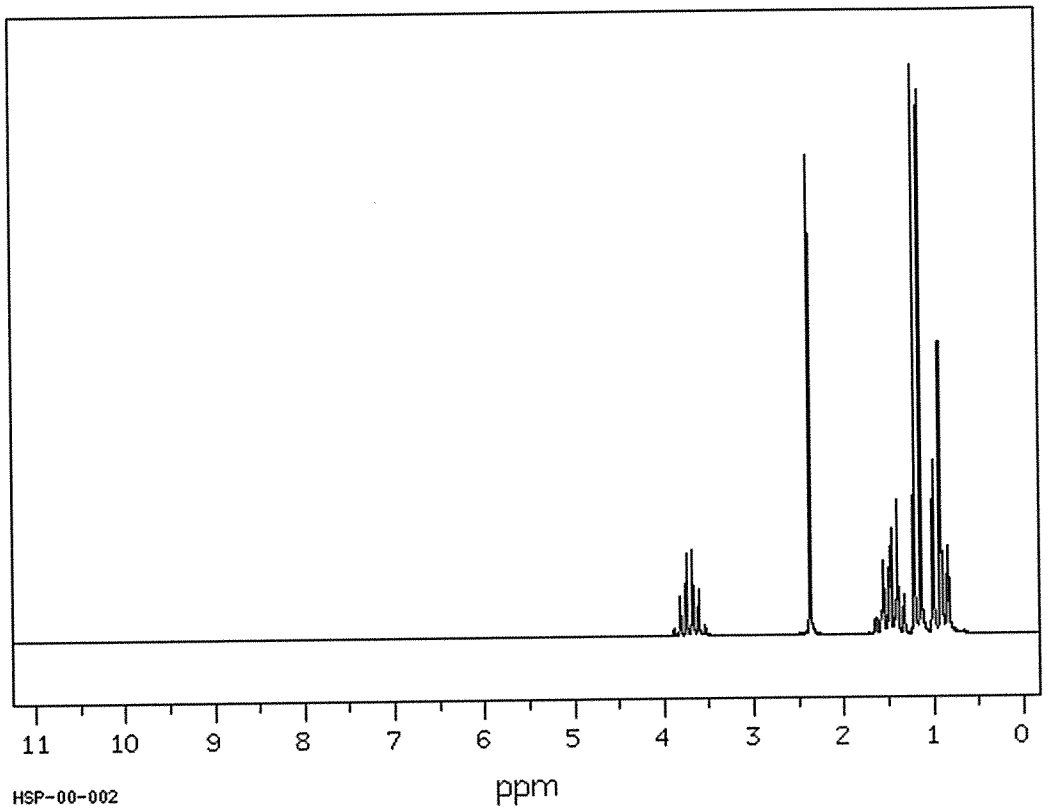
(ii) One of the isomers has the following hydrogen NMR spectrum. **3**



Hydrogen NMR

The table below lists the relative areas under the five peaks. The peak at 0.93 is a triplet and peak at 1.173 is a doublet.

Shift	0.93	1.173	1.46	2.37	3.709
Relative area	3	3	2	1	1

Can the structural formula of the isomer be determined? Explain your answer, referring to each piece of information.

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Question 34 (6 marks)

Sodium fluoride forms a solution with a pH around 8.6 when added to water, whereas amphiprotic sodium hydrogen carbonate forms a solution with a pH of 1. Compare and contrast how each of these salts affects the pH of water. **6**

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End of examination

Section II extra writing space

If you use this space, clearly indicate which question you are answering by writing the question number before beginning the response.

Section II extra writing space

If you use this space, clearly indicate which question you are answering by writing the question number before beginning the response.

CSSA

2021

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

MARKING GUIDELINES

Chemistry

Section I
20 marks

Questions 1-20 (1 mark each)

Question	Answer	Outcomes Assessed	Targeted Performance Band
1	B	CH11/12-6, CH12-15	2-3
2	D	CH11/12-5	2-3
3	D	CH11/12-5, CH12-14	3-4
4	D	CH12-14	3-4
5	B	CH12-12	2-3
6	B	CH12-12	2-3
7	A	CH11/12-6, CH12-15	3-5
8	D	CH11/12-4	3-4
9	C	CH12-14	3-4
10	D	CH12-12	3-4
11	A	CH12-12	3-4
12	D	CH11/12-5	3-4
13	A	CH12-14	3-4
14	C	CH11/12-4	4-5
15	B	CH11/12-4	4-5
16	A	CH12-14	4-5
17	A	CH11/12-6, CH12-14	4-5
18	C	CH11/12-6, CH12-14	5-6
19	C	CH12-14	5-6
20	C	CH11/12-6, CH12-15	5-6

Section II
80 marks

Question 21 (4 marks)
Outcomes Assessed: CH12-4, CH12-12
Targeted Performance Bands: 4-5

Criteria	Marks
• Correct half equation AND • All calculations AND • Justified if the solution will precipitate based on calculations and data	4
• Correct calculations with one minor mistake	3
• Correct half equation written, with the equilibrium sign. AND • Some relevant working out	2
• Some relevant information	1

Sample answer:

$Cu(OH)_2\ (s) \rightleftharpoons Cu^{2+}(aq) + 2OH^-(aq)$

$n Cu^{2+} = 0.0150\ M \times 0.01L = 1.5 \times 10^{-4}$ moles

$[Cu^{2+}]$ initial $= 1.5 \times 10^{-4} / 0.01L + 0.02\ L = 0.005$ mol L^{-1} Cu^{2+}

$n OH^- = 0.0300\ M \times 0.02L = 6.00 \times 10^{-4}$ moles

$[OH^-]$ initial $= 6.00 \times 10^{-4} / 0.01L + 0.02\ L = 0.02$ mol L OH^-

$Q_{sp} = [Cu^{2+}][OH^-]^2 = (0.005)(0.02)^2 = 2.00 \times 10^{-6}$

K_{sp} of $Cu(OH)_2 = 2.2 \times 10^{-20}$, since Q_{sp} is more than K_{sp}, $Cu(OH)_2$ will precipitate

Question 22 (5 marks)

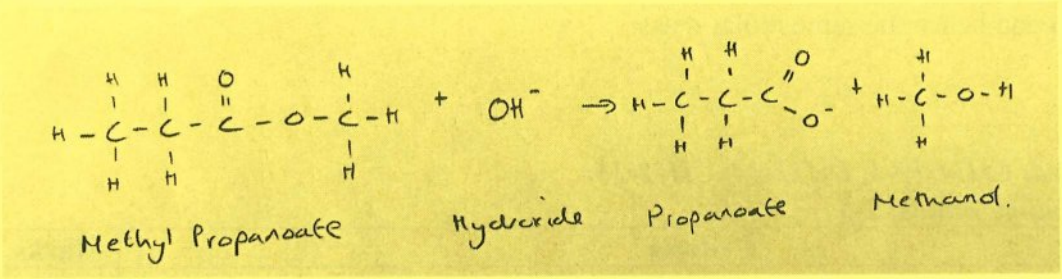
(a) (2 marks)

Outcomes Assessed: CH12-14

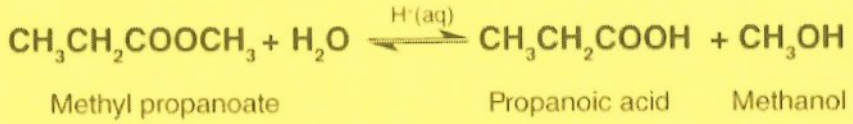
Targeted Performance Bands: 2-4

Criteria	Marks
• Provides a correct equation using structural formulae	2
• Shows some relevant understanding	1

Sample answer:



OR



(b) 3 marks

Outcomes Assessed:CH11/12-7, CH12-14

Targeted Performance Bands: 2-4

Criteria	Marks
• Explains the cleaning action of soap	3
• Describes the cleaning action of soap	2
• Shows some relevant understanding	1

Sample answer:

The non-polar end of the molecule dissolves in the oil (non-polar) via dispersion forces. The polar end of the molecule interacts with water molecules (polar) via hydrogen bonding. This produces a micelle. Agitation causes the oil to be lifted from the surface and remain suspended within the water as an emulsion.

Question 23 (5 marks)

(a) 1 mark

Outcomes Assessed: CH11/12-6, CH12-15

Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly identifies the reason for the peak	1

Sample answer:

Both have a peak at about 88, which is the peak for their molecular ion. They both have the same molecular formula and hence the same molar mass.

(b) 3 marks

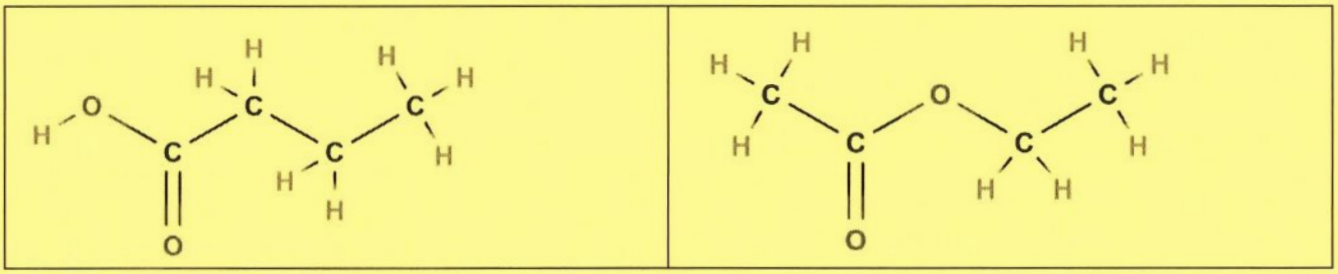
Outcomes Assessed: CH11/12-6, CH12-14, CH12-15

Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly identifies the fragments for BOTH molecules	3
• Correctly identifies the fragment for ONE molecule	2
• Correctly describes the structure of ONE compound	1

Sample answer:

Butanoic acid and ethyl acetate have the following structures (created with Molview):



For butanoic acid, the –COOH fragment would correspond to the m/z = 45 peak. For ethyl acetate, the CH3CH2O- fragment would correspond to the m/z = 45 peak.

(c) 3 marks

Outcomes Assessed: CH11/12-2, CH11/12-3, CH11/12-5, CH11/12-6, CH12-14, CH12-15

Targeted Performance Bands: 3-5

Criteria	Marks
• Outlines a suitable method, with approximate quantities • Identifies the expected results	3
• Outlines a suitable method, with approximate quantities OR • Outlines a suitable method and identifies the expected results	2
• Identifies some relevant feature	1

Sample answer:

A simple chemical method to distinguish between butanoic acid and ethyl acetate is a reaction with sodium bicarbonate (bicarb soda):

1. Conduct the experiment in a fumehood, with appropriate PPE.
2. Pour 1 cm of bicarb soda into two test tubes.
3. Add about 1 cm of one compound into one test tube, and 1 cm of the other compound into the other test tube.
4. The test tube with the butanoic acid should fizz/produce gas.
5. Dispose of both solutions in an appropriate container for organic waste.

Question 24 (4 marks)
Outcomes Assessed: **CH12-4**

Targeted Performance Bands: 2-6

Criteria	Marks
• Correctly calculates moles of butanol AND • Correctly calculates heat transferred AND • Correctly calculates 20% heat loss AND • Correctly calculate final temperature, including units	4
• As above with one error	3
• As above with two errors	2
• Demonstrates some relevant understanding	1

Sample answer:

n (butanol) = m/M = 1.8/74.121 = 0.024 mol

$\Delta H_c = q/n$, so $q = \Delta H_c \times n$

$q = 2871 \times 0.024 = 69.7$ kJ

20% is lost to the environment, so available q is $69.7 \times 80/100 = 55.8$ kJ

$\Delta T = q/mC$ where m is the mass of water and C is its specific heat capacity.

$= 55\ 800/(0.250 \times 4.18 \times 10^{23}) = 53.4\ ^0C$

$T_{final} = 53.4 + 23 = 76\ ^0C$

Question 25 (6 marks)

(a) 3 marks

Outcomes Assessed: **CH12-12**

Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculated solubility, with the correct sig fig	3
• Calculated solubility with one error	2
• Some relevant information	1

Sample answer:

Ksp = $6.4 \times 10^{-6} = [Ca^{2+}][OH^-]^2 = x(2x)^2$, where x = solubility

$x(4x^2) = 6.4 \times 10^{-6}$

$4x^3 = 6.4 \times 10^{-6}$

$x^3 = 6.4 \times 10^{-6}/4$

$x = \sqrt[3]{\frac{6.4 \times 10^{-6}}{4}}$

$x = 1.17 \times 10^{-2}$ mol L^{-1}

Molar mass is $40.08 + 2(16.00 + 1.008) = 74.096$ $gmol^{-1}$

To convert mol L^{-1} to g L^{-1}

$1.7 \times 10^{-2} \times 74.096 = 8.7$

Therefore, the solubility of calcium hydroxide is 8.7 g L^{-1}

(b) 3 marks

Outcomes Assessed: CH11/12-7, CH12-12

Targeted Performance Bands: 3-6 **Criteria**	Marks
• Correctly calculated $\triangle H^o_f$ and explained the effect on quoted Ksp when temperature is increased	3
• Correctly calculated $\triangle H^o_f$	2
• Some relevant information	1

Sample answer:

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

$\triangle H^o_f = \Sigma \triangle H^o_f$ products - $\Sigma \triangle H^o_f$ reactants

$= [(-543) + 2(-230)] - (-986)$

$= -17$ kJ mol^{-1}

According to LCP, when $\triangle H^o$ is less than 0 and temperature is increased, the equilibrium will shift to counteract the change in temperature, therefore Ksp will decrease.

Question 26 (7 marks)
Outcomes Assessed: CH11/12-6, CH12-14, CH12-15
Targeted Performance Bands: 2-3
(a) 1 mark

Criteria	Marks
• Describes that different cations can have different colours and gives one example	2
• Provides some relevant information	1

Sample answer:
Different metal ions (cations) can be identified using a flame test, as they give different colours. For example, barium gives a yellowy-green flame and calcium gives a reddish flame.

(b) 5 marks
Outcomes Assessed: CH11/12-2, CH11/12-4, CH11/12-5, CH11/12-6, CH12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Outlines a clear method to correctly identify each of the solids • Presents correct expected results in a neat table	5
• Outlines a method to correctly identify TWO or more of the solids AND • Describes TWO or more correct expected results	4
• Outlines a method to correctly identify ONE or more of the solids OR • Describes ONE or more correct expected results	2-3
• Provides some relevant information	1

Sample answer:

Method

1. Place half a spatula of each solid onto four separate watchglasses.
2. Add a drop of hydrochloric acid to the solid on each watchglass (to identify the carbonate - fizzes).
3. Take a half a spatula of each of the remaining three solids and put them in three new test tubes. Dissolve each in a third of a test tube of distilled water.
4. Add 3 drops of sulfuric acid to each test tube (identifies the barium chloride).
5. Repeat Step 3. Add half of the barium chloride solution to the unknown test tubes. The potassium sulfate will react.

Results

Unknown	1.0 M HCl	0.1 M H_2SO_4	Barium chloride solution
Calcium carbonate	Fizzes		
Barium chloride	No reaction	White precipitate	
Potassium sulfate	No reaction	No reaction	White precipitate
Sodium chloride	No reaction	No reaction	No reaction

Question 27 (6 marks)
Outcomes Assessed: CH12-12
Targeted Performance Bands: 3-6

Criteria	Marks
• Thoroughly explains, using the information provided and collision theory, the changes occurring within this closed system when the system was disturbed at both 1 and 7 minutes	5-6
• Explains, using the information provided and collision theory, one of the changes occurred within this closed system when the system was disturbed	3-4
• Describes the changes of the concentration of reactants and products over time in terms of Le Chatelier's Principle	2
• Describes one of the changes	1

Sample answer:

$Cl_2\,(g) + CO\,(g) \rightleftharpoons COCl_2\,(g) \qquad \Delta H = -108\ kJ\ mol^{-1}$

At 1 minute, it is evident that the concentration of $COCl_2$ gradually decreases from 3 mol L^{-1} to 2 mol L^{-1} at 2.5 minutes, whereas the concentrations of CO and Cl_2 increase by1 mol L^{-1} in the same time interval. This is consistent with an increase in temperature within this closed system. Adding heat favours the backward, endothermic reaction rate in terms of collisions more than the forward rate, so the equilibrium shifts to the left, producing more CO and Cl_2. This then results in more collisions between these until eventually the forward and reverse rates are equal and concentrations remain constant. A new equilibrium position has been achieved.

At 7 minutes, the sudden proportional decrease in the concentrations of product and reactants is evident. Cl_2 concentration dropped from 8.8 mol L^{-1} to 6.5 mol L^{-1}, CO decreased from 5 mol L^{-1} to 4 mol L^{-1} and $COCl_2$ decreased from 2 mol L^{-1} to 1.5 mol8L^{-1}. The decrease in volume of the system reduces the chances of collision between CO and Cl_2, favouring the rate of decomposition of $COCl_2$ molecules. Gradually, more CO and Cl_2 forms, resulting in more frequent collisions until the rate of the forward and reverse reactions become equal and concentrations remain constant. Equilibrium is re-established.

Question 28 (4 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 2-6

Criteria	Marks
• Clearly explains why the three compounds have very different boiling points but similar molar masses in terms of their structure and bonding	4
• Outlines why the three compounds have very different boiling points but similar molar masses in terms of their structure and/or bonding	3
• Shows some understanding of the structure and/or bonding of the three compounds	2
• Shows some relevant understanding	1

Sample answer:

Butane – molar mass is 58 g mol^{-1}

Butane is an alkane and alkanes are nonpolar molecules. The forces of attraction between the molecules are only weak dispersion forces, resulting in a low boiling point as not much energy is required to overcome the forces.

Ethanoic acid – molar mass is 60 g mol^{-1}

Hydrogen bonding can occur between two carboxylic acid molecules resulting in the formation of a dimer. This increase in size also increases the strength of the dispersion forces between the neighbouring dimers. The stronger dispersion forces and the hydrogen bonds between molecules result in the higher boiling point observed for carboxylic acids.

Ethanamide – molar mass is 59 g mol^{-1}

The higher boiling point observed with amides occurs as they have more atoms that can donate or accept hydrogen bonds. As a result, hydrogen bonds form between the non-bonding electron pairs on the oxygen atom of one molecule and the partially positive hydrogen atom bonded to N on a neighbouring molecule. As this can happen at two sites, there is greater hydrogen bonding between ethanamide molecules than ethanoic acid, resulting in a higher boiling point.

The range of boiling points in these three compounds is due to the differences in intermolecular forces and cannot be linked to their molar masses.

Question 29 (4 marks)
Outcomes Assessed: 12-13
Targeted Performance Bands: 3-5

Criteria	Marks
• Defines a buffer AND • Clearly links the buffer to a named natural system AND • Describes what happens when conditions are changed (Addition of acid/base) AND • Equations include states.	4
• Defines a buffer AND • Clearly links the buffer to a named natural system AND • Describes what happens when conditions are changed (Addition of acid/base)	3
• Defines a buffer. • Clearly links the buffer to a named natural system OR • Describes what happens when conditions are changed (Addition of acid/base)	2
• Defines a buffer.	1

Sample answer:

A buffer is a solution that contains significant amounts of a weak acid and its conjugate base and which will resist a change in pH when small amounts of strong acid or base are added to it.

For example, blood contains carbonic acid and hydrogen carbonate ion in equilibrium in approximately equal concentrations and must maintain an approximately constant pH of 7.4.

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

In acidic conditions, (when acid is added), the equilibrium shifts to consume the added acid:

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

In basic conditions, (when some strong base is added), the equilibrium shifts to consume the added base:

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

A buffer does resist the change in pH but there is a limit to a buffer's capabilities. If excess acid is added using up all the available HCO_3^- (aq), the resulting increase in H_3O^+ (aq) causes the pH to lower. The same is also applicable if excess OH^- (aq) is added; the carbonic acid will be consumed, resulting in an increase in pH. As a result, the body will be placed under stress as many cell processes are pH dependent.

Question 30 (7 marks)
Outcomes Assessed: CH11/12-5, 12-13
Targeted Performance Bands: 3-6
(a) 5 marks

Criteria	Marks
• Correctly calculates concentration to three significant figures, showing all relevant working	5
• As above, with one processing error	4
• As above, with two errors	3
• Calculates mol of oxalic acid added and finds total volume of NaOH added	2
• Finds total volume of NaOH added	1

Sample answer:
[lactucin] = mol lactucin in aliquot / volume of aliquot in L
mol lactucin = total mol of NaOH added – mol NaOH reacted with oxalic acid
Total NaOH added = $0.0150 \times 0.00100 = 1.50 \times 10^{-5}$ mole of OH^-
Reaction of NaOH with oxalic acid:

$$H_2C_2O_4\ (aq) + 2NaOH\ (aq) \rightarrow Na_2C_2O_4\ (aq) + 2H_2O\ (l)$$

Ratio is 2:1.

	NaOH	Oxalic Acid
c		$0.000150\ molL^{-1}$
V		0.0143 L
n	0.00000429 mol	0.000002145 mol

Mole of OH^- reacted with oxalic acid = 0.00000429 mol = 4.29×10^{-5} mol
Moles of OH reacted with lactucin = $1.5 \times 10^{-5} - 4.29 \times 10^{-5} = 0.00001071$
$= 1.071 \times 10^{-5}$ mol
Concentration of lactucin.
$c = 1.071 \times 10^{-5} / 0.0100 = 1.071 \times 10^{-3}\ mol\ L^{-1} = 1.07 \times 10^{-3}\ mol\ L^{-1}$

(b) ***Outcomes Assessed: CH11/12-5***
Targeted Performance Bands: 3-6
2 marks

Criteria	Marks
• Calculates mass of lactucin and percent composition	2
• Finds molar mass of lactucin	1

Sample answer:
Concentration lactucin $= 1.07 \times 10^{-3}\ mol\ L^{-1}$
Mol lactucin $= 1.07 \times 10^{-3} \times 0.0500 = 5.35 \times 10^{-5}$ mol
Lactucin MM = $292.24\ g\ mol^{-1}$
Mass $= 5.35 \times 10^{-5} \times (12.01 \times 14 + 12 \times 1.008 + 16 \times 7) = 0.0156g$
Percent composition $= (1.56 \times 10^{-2} / 1.2) \times 100 = 1.3\%$

Question 31 (7 marks)
Outcomes Assessed: CH11/12-5, CH11/12-7, CH12-15
Targeted Performance Bands: 2-6

Criteria	Marks
• Identifies at least TWO different types of spectroscopy, including AAS, for monitoring the environment • Describes an example of monitoring the environment for each type of spectroscopy • Evaluates the role of each type of spectroscopy in monitoring the environment	6-7
• Identifies TWO different types of spectroscopy for monitoring the environment • Describes an example of monitoring the environment for each type of spectroscopy	4-5
• Identifies a type of spectroscopy for monitoring the environment • Describes an example of monitoring the environment for the identified type of spectroscopy	2-3
• Correctly identifies ONE relevant type of spectroscopy OR • Describes an example of monitoring the environment other than heavy metal contamination	1

Sample answer:
Heavy metal monitoring can be done accurately with Atomic Absorption Spectroscopy (AAS). Unlike previous wet chemistry techniques, AAS can be used to detect and measure to ppm and ppb levels, thus making it an excellent method of monitoring waterways, such as those around the Berrima mine.
Infrared (IR) spectroscopy can be used to identify organic chemicals in gas discharges, such as from factories or from vehicles. The volume of gas discharge does not need to be large and the concentrations can be quite low, making IR spectroscopy an excellent tool in monitoring waste organic gases in the atmosphere.

Question 32 (7 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 2-6

Criteria	Marks
• Correctly identifies ALL compounds and reagents	7
• As above but lose one mark for each incorrect unknown	1-6

Sample answer:

Compound B = ethane

Compound C= chloroethane

Compound D = ethanol

Reagent 1 = H_2/Ni

Reagent 2 = Cl2/UV light

Reagent 3 = sodium hydroxide (aq)

Reagent 4 = $Cr_2O_7^{2-}$ /H^+

Question 33 (6 marks)
(a) 1 marks
Outcomes Assessed: CH12-15
Targeted Performance Bands: 2-3

Criteria	Marks
• Correctly defines the term position isomer	1

Sample answer:
Position isomers have the same chemical formula and the same functional group, but the functional group is located on a different part of the carbon skeleton.

(b) (i) (2 marks)
Outcomes Assessed: CH11/12-6, CH12-14, CH12-15
Targeted Performance Bands: 3-4

Criteria	Marks
• Correctly identifies the functional group with a specific band	2
• Identifies the functional group	1

Sample answer:
The spectrum shows the broad band near 3500 associated with an alcohol (-OH) group

(b)(ii) (3 marks)

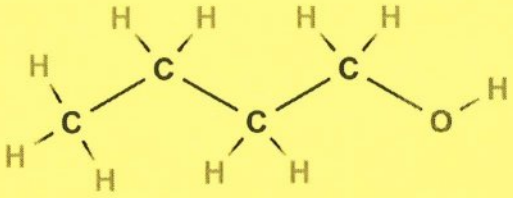
Outcomes Assessed: CH11/12-6, CH12-14, CH12-15

Targeted Performance Bands: 3-6

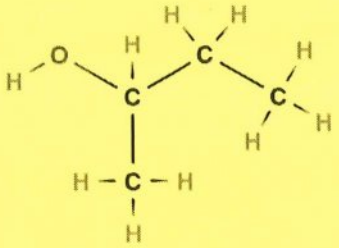
Criteria	Marks
• Identifies both possible isomers • Explains how splitting can be used to identify the isomer • Explains how relative area can be used to identify the isomer • Correctly identifies the isomer	3
• Identifies both isomers AND correctly explains ONE feature of the NMR spectrum OR • Shows a sound understanding of TWO features of NMR	2
• Identifies some relevant feature	1

Sample answer:

The two positional isomers are butan-1-ol and butan-2-ol (shown below).



butan-1-ol



butan-2-ol

butan-1-ol and butan-2-ol both have five different hydrogen environments, so their hydrogen NMR will have 5 peaks. This alone would not allow the isomers to be identified. However, the area and splitting of the peaks will be different. butan-1-ol cannot have a doublet but butan-2-ol can. The areas indicate the number of hydrogens in that environment. Only butan-2-ol has that pattern (eg two single hydrogens).

Question 34 (6 marks)
Outcomes Assessed: CH12-12, CH12-5
Targeted Performance Bands: 3-6

Criteria	Marks
• Identifies sodium fluoride as a basic salt AND • Identifies sodium hydrogen sulfate as amphiprotic AND • Provides relevant equations for both to clearly identify and explain similarity and differences.	5-6
• Identifies sodium fluoride as a basic salt AND • Identifies sodium hydrogen sulfate as amphiprotic AND • Explains similarity and differences. BUT • Missing relevant equations OR • Identifies basic and amphiprotic salt AND provides a relevant equation AND • Identifies similarities and differences between basic and amphiprotic salts.	3-4
• Identifies basic and amphiprotic salt AND provides a relevant equation. OR • Identifies salts, identifies a difference AND/OR a similarity.	2
• Identifies NaF as a basic salt OR identifies Hydrogen sulfate as amphiprotic.	1

Sample answer:

Sodium fluoride, a soluble salt, is the product of a strong base (NaOH) and a weak acid (HF). This means the fluoride, F^-, can act as a Bronsted – Lowry base, accepting a hydrogen ion from water and forming OH^- (aq) in solution, making it alkaline with a higher pH, as shown below. The sodium ion does not have the ability to accept hydrogen ions from water, so Na^+ has no pH effect on the water.

F^- (aq) + H_2O (aq) ⇌ HF (aq) + OH^- (aq)

Sodium hydrogen sulfate is soluble and is amphiprotic. It is able to donate and accept an H^+ ion.

In the presence of hydronium or hydroxide ion the following reactions occur:

(1) HSO_4^- (aq) + H_3O^+ (aq) ⇌ H_2SO_4 (aq) + H_2O (l) showing basic behaviour.
(2) HSO_4^- (aq) + OH^- (aq) ⇌ SO_4^{2-} (aq) + H_2O (l) showing acidic behavior.

In water the following reactions occur:

(1) HSO_4^- (aq) + H_2O (l) ⇌ H_2SO_4 (aq) + OH^- (l) showing basic behaviour.
(2) HSO_4^- (aq) + H_2O (l) ⇌ SO_4^{2-} (aq) + H_3O^+ (l) showing acidic behavior.

In water, reaction (2) is more likely, hence producing an acidic solution with a lower pH.

In summary, sodium fluoride, NaF is a basic salt, whereas sodium hydrogen sulfate is acidic. Both can accept hydrogen ions to produce some hydroxide ions in solution. However, hydrogen sulfate is able to donate hydrogen ions to water to produce H_3O^+. Hydrogen sulfate solutions are acidic.