CSSA

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.

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) → $Al_2(SO_4)_3$ (aq) + H_2O (l) + CO_2 (g)

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

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

    D. $Al_2(CO_2)_3$ (s) + $3H_2SO_4$ (aq) → $Al_2(SO_4)_3$ (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.
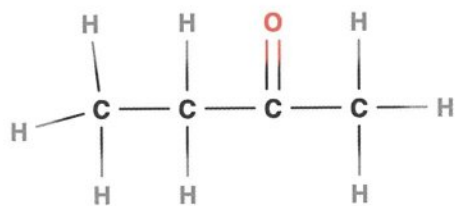
B.
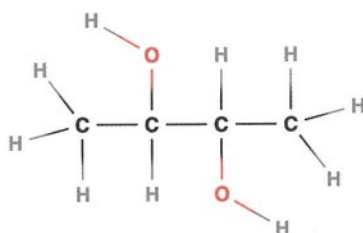
C.
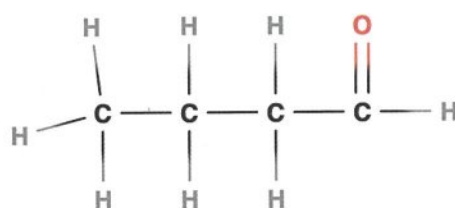
D.
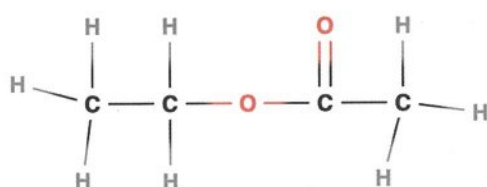
5 In a sealed vessel, gaseous nitrogen monoxide, oxygen and nitrogen dioxide form the following equilibrium:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$
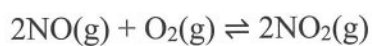
$$\Delta H = -114 kJmol^{-1}$$

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?

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$
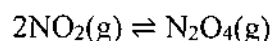
A. $K_{eq} = \dfrac{[NO_2]^2}{[N_2O_4]}$

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

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

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

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

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9 What is the correct name for the molecule below?
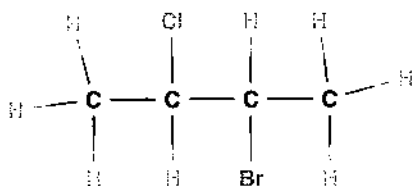
A. 2-chloro-3-bromo-butane

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.

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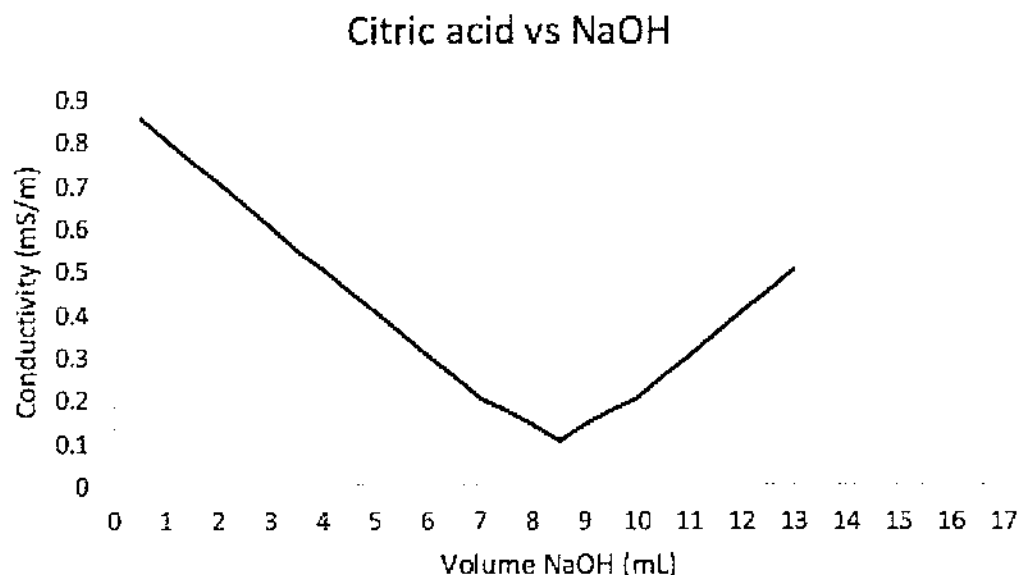
What is the concentration, in mol L^{-1}, of the citric acid?

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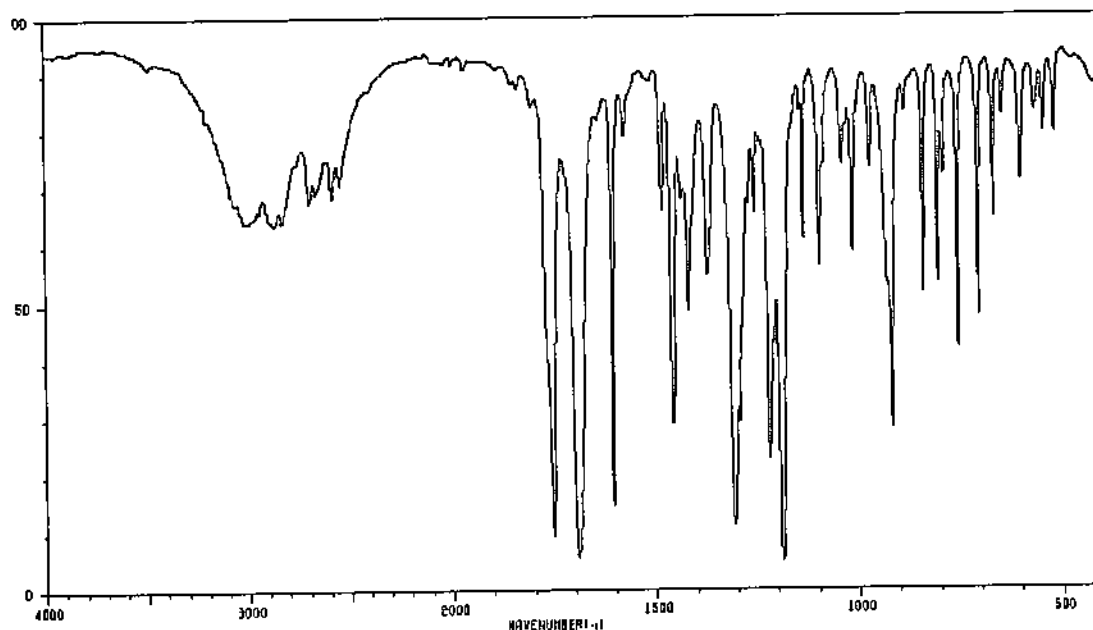
Based on the spectrum, which of the following bond types does aspirin probably **NOT** have?

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

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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   **2**
equation using structural formulae to describe ester hydrolysis.
Use methyl propanoate as one of the reactants.

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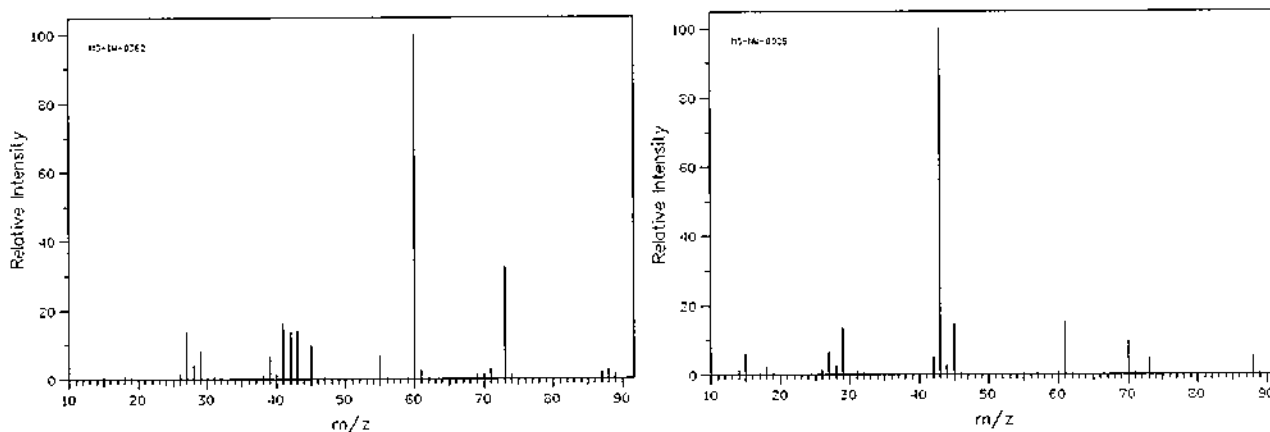
(a)   Identify why both spectra would have a peak at m/z = 88.1.   **1**

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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.
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   **3**
the quoted Ksp.

Thermodynamic data (at 25 °C, 100 kPa)

	$\Delta H°_f$ /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   **5**
        dropper bottle of 1.0 M HCl, a dropper bottle of 0.1 M H_2SO_4 and a bottle of distilled
        water.

        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   6
equation below.

$$Cl_2 \text{ (g)} + CO \text{ (g)} \rightleftharpoons COCl_2 \text{ (g)} \quad \Delta H = -108 \text{ kJ mol}^{-1}$$
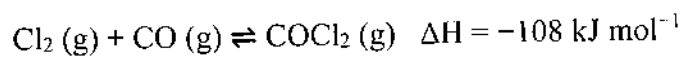
The graph below shows the changes to the system.
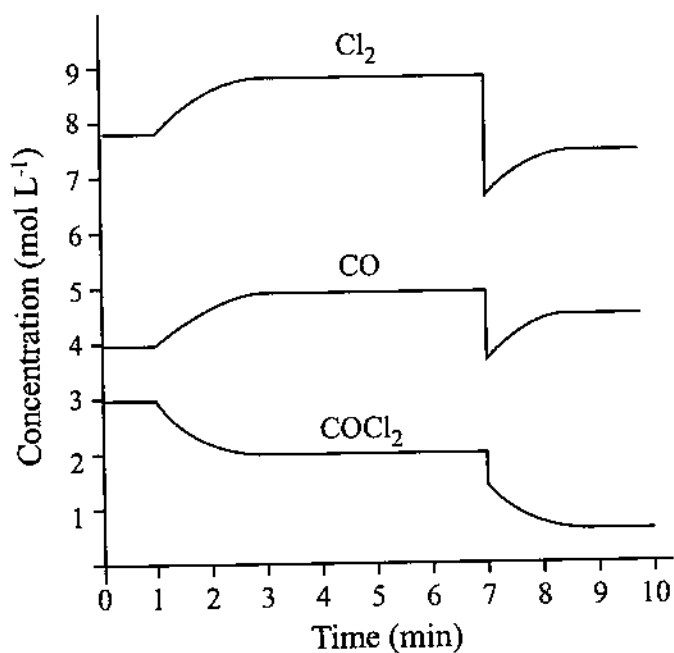
Using collision theory and the information above, explain the changes in the concentration
of reactants and products over time.

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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.
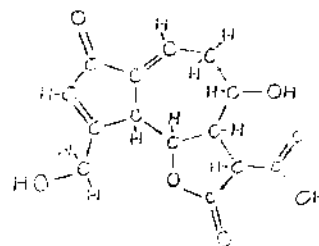
Lactucin

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   **7**
Berrima. For example, zinc contamination was about 120 times more than normal baseline
measurements.
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

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.

Ethene

⬇ | Reagent 1 |

Compound B

⬇ | Reagent 2 |

Compound C

⬇ | Reagent 3 |

Compound D

⬇ | Reagent 4 |

Ethanoic Acid
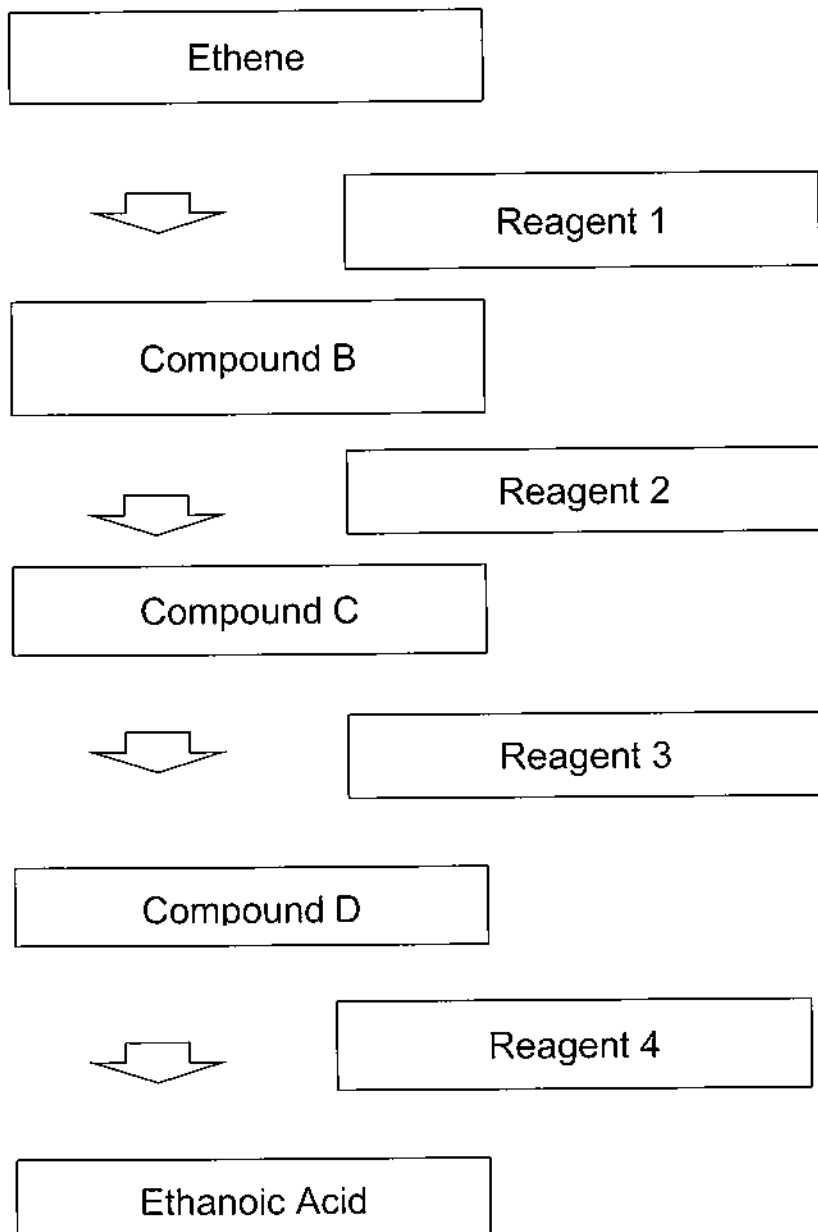
Question 33 (6 marks)

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

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

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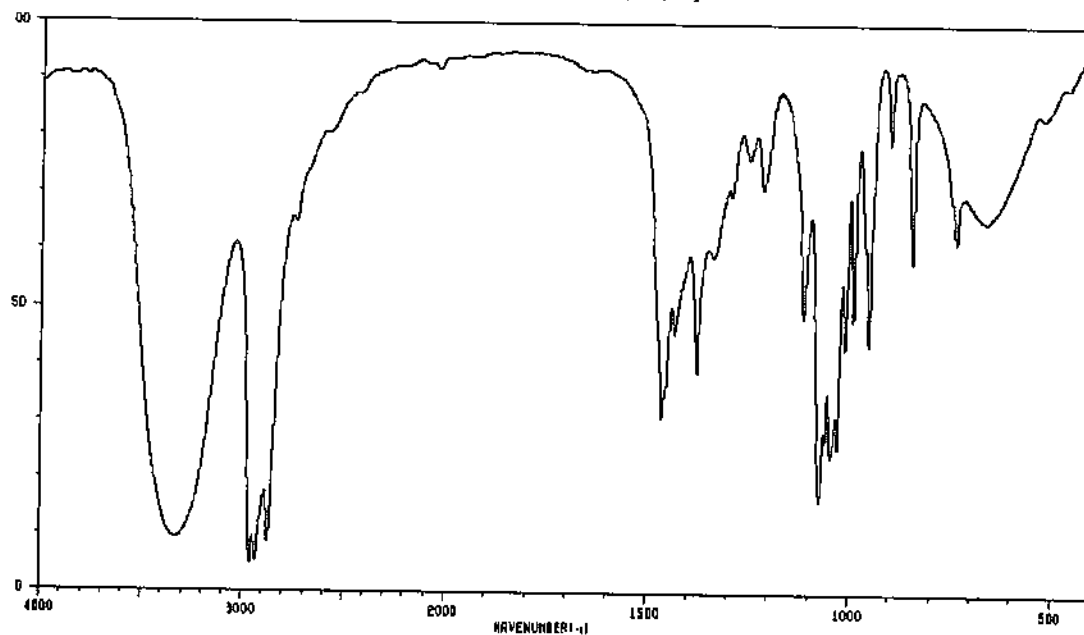
What functional group is on the isomers, based on the spectrum?

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

HSP-00-002

ppm
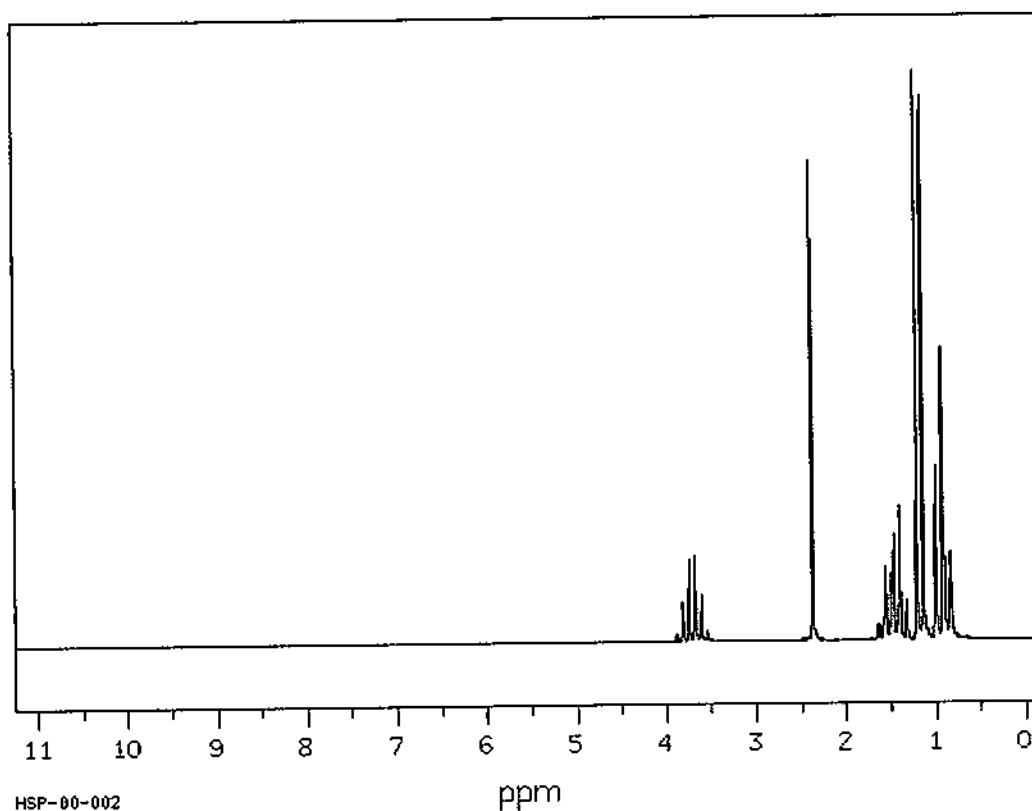
Hydrogen NMR

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.

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End of examination

Section 11 extra writing space

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

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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.

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