Name of Student:

Grade: **11**

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SUBJECT: **IB Chemistry HL: Topic 10.1/11.3 – Organic chemistry and spectroscopy**

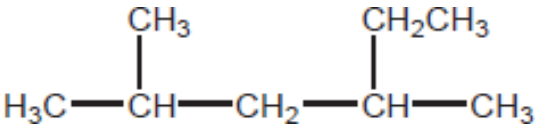
TIME: **Total 90 min**
Approximately 15 min Paper 1
Approximately 75 min Paper 2

INSTRUCTIONS TO STUDENTS:

- Do not open this test until instructed to do so.
- Write your name on the top of this sheet.
- Fill in the corresponding answer sheet with the correct letter
- Answer all questions.
- You may **not** use a calculator or the data booklet
- You may use a ruler.
- You will be provided with a copy of the periodic table.
- The maximum mark for the examination paper is **[10 marks]**

1.

What is the IUPAC name of the molecule shown?



A. 2,4-dimethylhexane

B. 3,5-dimethylhexane

C. 2-methyl-4-ethylpentane

D. 2-ethyl-4-methylpentane

2.

Which spectra would show the difference between propan-2-ol, $CH_3CH(OH)CH_3$, and propanal, CH_3CH_2CHO?

I. mass
II. infrared
III. ^1H NMR

A. I and II only

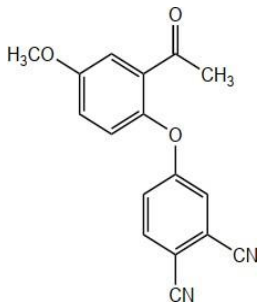
B. I and III only

C. II and III only

D. I, II and III

3.

Which functional groups are present in this molecule?



A. carbonyl, ether, nitrile

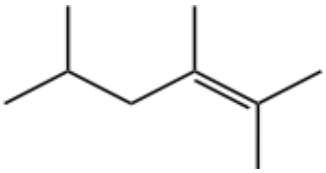
B. carbonyl, ester, nitrile

C. carboxyl, ether, amine

D. carboxyl, ester, amine

4.

What is the IUPAC name of this molecule?



A. 1,1,2,4-tetramethylpent-1-ene

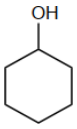
B. 2,4,5-trimethylhex-4-ene

C. 2,4,5,5-tetramethylpent-4-ene

D. 2,3,5-trimethylhex-2-ene

5.

What is the index of hydrogen deficiency (IHD) in cyclohexanol?



A. 0

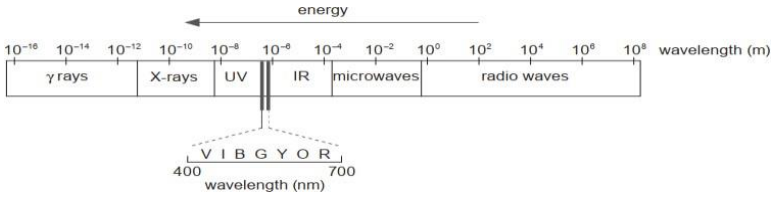
B. 1

C. 2

D. 3

6.

Which region of the electromagnetic spectrum is used to identify hydrogen environments in a molecule?



A. X-ray

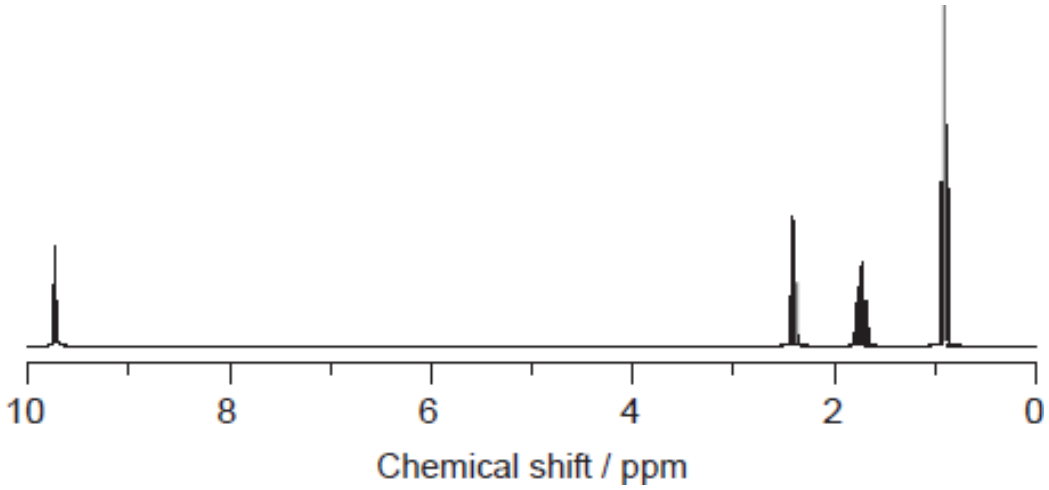
B. UV

C. IR

D. radio waves

7.

Which compound with the molecular formula C_4H_8O has this high resolution H1 NMR?



A. but-3-en-2-ol, $CH_2 = CHCH(OH)CH_3$

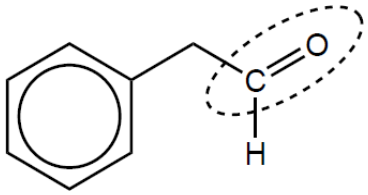
B. butanal, $CH_3CH_2CH_2CHO$

C. butanone, $CH_3COCH_2CH_3$

D. but-3-en-1-ol, $CH_2 = CHCH_2CH_2OH$

8.

Which functional group is surrounded in the molecule?



A. hydroxyl

B. carboxyl

C. carbonyl

D. ether

9. *[1 mark]*

Burette readings for a titration are shown.

Burette readings / $cm^3 \pm 0.05\,cm^3$	Trial 1	Trial 2	Trial 3
Final	11.35	24.60	11.70
Initial	0.20	13.50	0.50

What is the mean titre?

A. 11.1 cm^3 ± 0.1 cm^3

B. 11.15 cm^3 ± 0.05 cm^3

C. 11.2 cm^3 ± 0.05 cm^3

D. 11.2 cm^3 ± 0.1 cm^3

10.

How should a measurement of 5.00 g from a balance be recorded?

A. 5.00 ± 0.1 g

B. 5.00 ± 0.01 g

C. 5.00 ± 1 g

D. 5.00 ± 0.001 g

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- Do not open this test until instructed to do so.
- Write your name on the top of this sheet.
- Write in dark blue or black pen. You may use a soft pencil for any diagrams, graphs or multiple-choice questions. Do not use highlighters or correction fluid.
- Answer all questions.
- You may use a calculator, a copy of the data booklet, and a ruler.
- Answers written outside of given boxes will not be assessed.
- There are **5 questions**
- The maximum mark for the examination paper is **[50 marks]**

1. A mystery organic compound is known to contain only carbon, hydrogen, and oxygen.
    a. A 2.341 g sample of the compound is burned completely in oxygen to form 4.677 g of carbon dioxide and 1.915 g of water. Determine the empirical formula of the unknown compound. ***[3]***

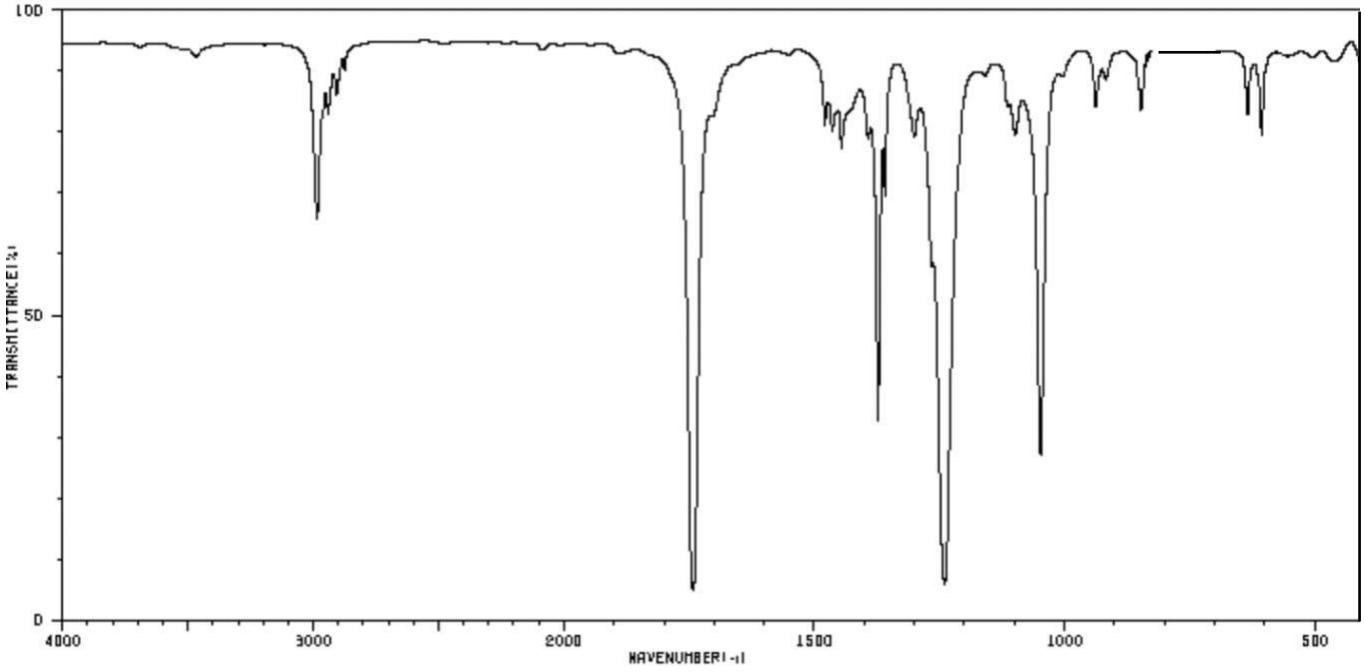
    b. A 1.150 g sample of the same compound is vaporized at 253 °C and 100.0 kPa of pressure. The volume occupied under these conditions is 570.4 cm^3. Determine the molar mass of the unknown compound. ***[3]***

    c. Using the information from parts a and b, determine the molecular formula. ***[1]***

Question 1 continues on the next page.

Question 1 continued.

d. The IR spectra for the compound is shown below.



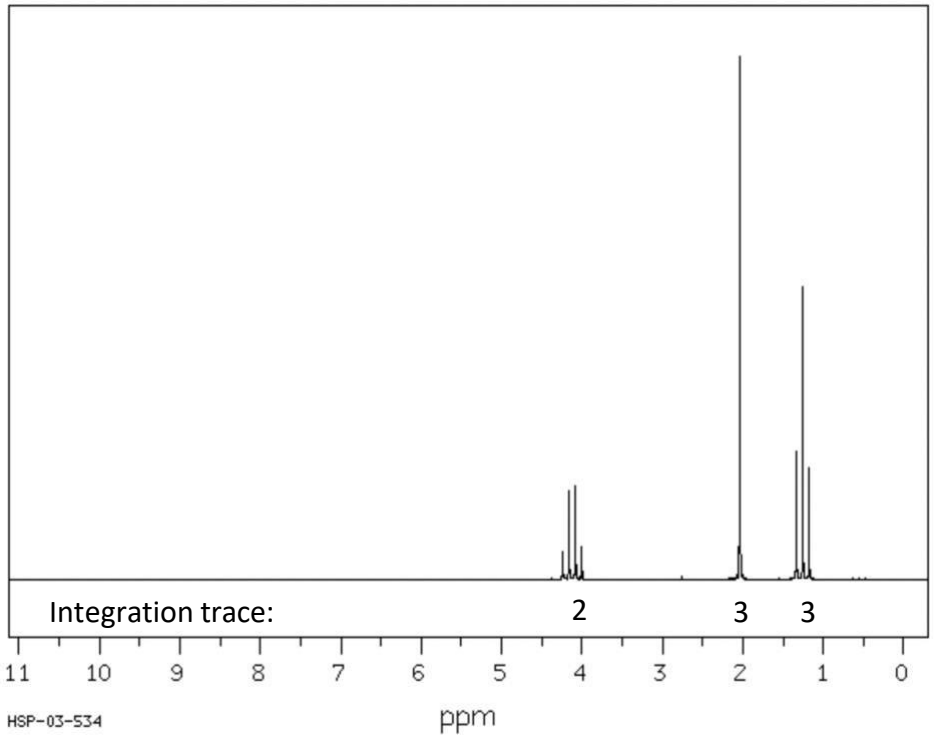
i. State the bond responsible for the absorption at 1720 cm^{-1}. ***[1]***

ii. State the bond responsible for the absorption at 1220 cm^{-1}. ***[1]***

Question 1 continued on the next page.

Question 1 continued.

e. The H-NMR spectrum for the compound is shown below.



i. State what information is given by the integration traces given in the H-NMR. ***[2]***

ii. State the type of hydrogen responsible for the shift at 4.1 ppm. ***[1]***

iii. State The type of hydrogen responsible for the shift at 2.0 ppm. ***[1]***

Question 1 continues on the next page.

Question 1 continued.

iv. State the information that can be deduced from the splitting pattern of the shift at 1.3 ppm. ***[1]***

v. Draw the full Lewis structure of the compound. ***[1]***

vi. State the correct IUPAC name for the compound. ***[1]***

2. Many organic compounds have isomers that present a different set of physical and chemical properties.

   a. Draw the full structural formula for butan-1-ol. ***[1]***

   b. State the correct IUPAC name for 4 structural isomers of butan-1-ol. ***[3]***

Question 2 continues on the next page.

Question 2 continued.

c. Isomers can have different physical properties, like boiling point.

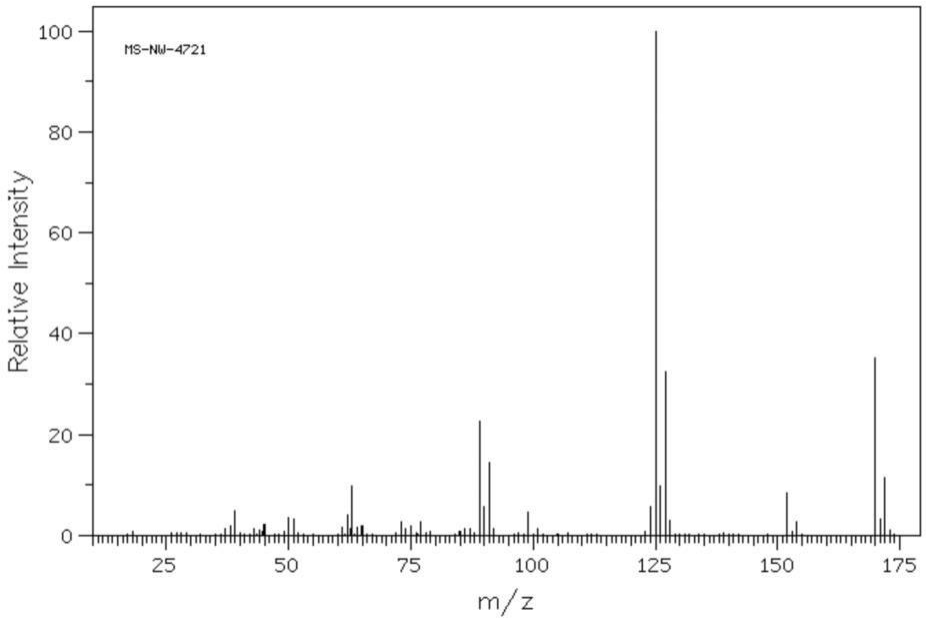
i. State which isomer for the compounds in part **a and b** has the highest boiling point.

[1]

ii. Explain why the boiling point of the compound in part i is higher than the other isomers.

[3]

3. Spectroscopic techniques can help to identify unknown organic compounds. This question is about compiling data from multiple techniques in order to identify a compound.
    a. Mass spectroscopy can be used to determine the molar mass, M_r, and other information about a variety of compounds. The mass spectrum of an unknown compound is shown below.



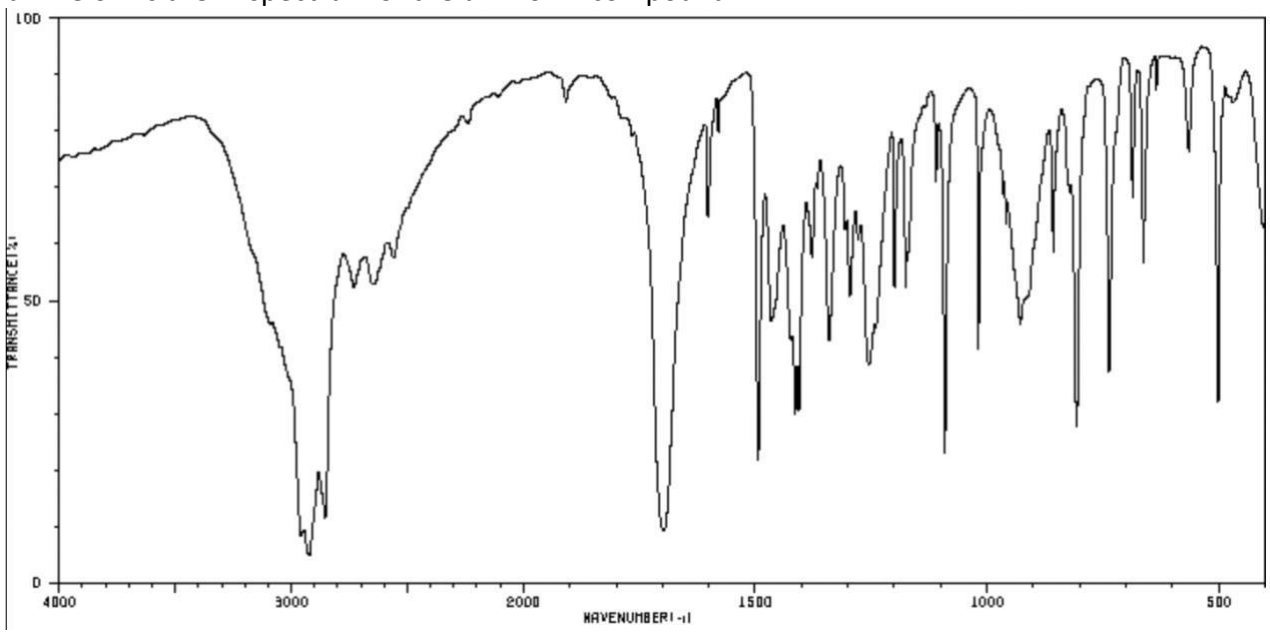
    i. State two pieces information can be determined from the peaks at m/z 170 and 172.

[2]

Question 3 continued on the next page.

Question 3 continued.

b. Below is the IR spectrum of the unknown compound.



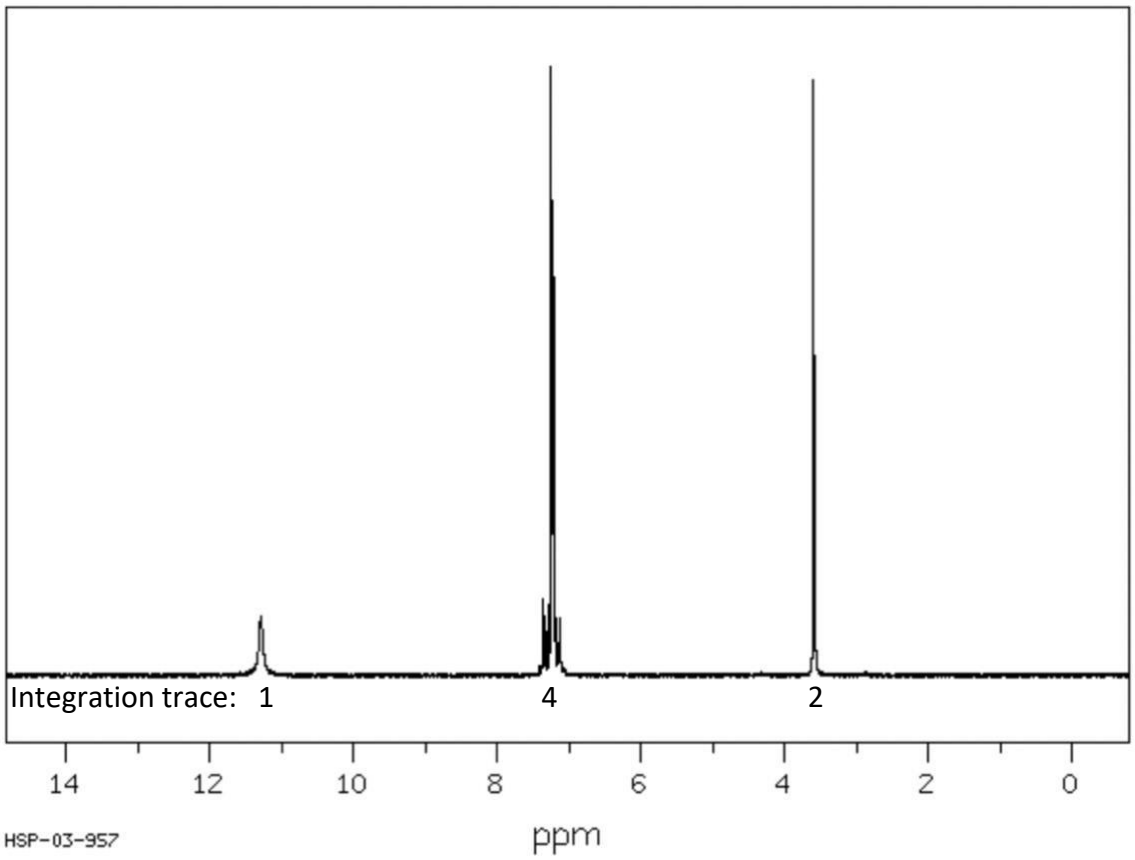
i. State the bond responsible for the absorption between 2500 and 3000 cm^{-1}. ***[1]***

ii. State the bond responsible for the absorption at 1700 cm^{-1} ***[1]***

Question 3 continues on the next page.

Question 3 continued.

c. Below is the H NMR spectra of the unknown compound.



i. State the type of proton responsible for the shift at 11.2 ppm. ***[1]***

ii. State the type of proton responsible for the shift at 7.1 ppm. ***[1]***

iii. State what information can be deduced about the unknown compound from the relative integration traces, ***[1]***

iv. State what information can be deduced about the unknown compound from the lack of splitting in the shifts at 12.2 and 3.7 ppm. ***[1]***

Question 3 continues on the next page.

Question 3 continued.

d. Draw the full structural formula of the unknown compound. ***[1]***

4. Propyl ethanoate is an organic compound both useful as a solvent and as a fragrance or food additive due to its characteristic smell of pears.
   a. Propyl ethanoate is prepared by reacting liquid propan-1-ol with liquid ethanoic acid.
      i. State a balanced equation for the reaction between propan-1-ol and ethanoic acid to form liquid propyl ethanoate and liquid water. ***[1]***

      ii. Draw the condensed structural formula of propyl ethanoate. ***[1]***

      iii. 22.3 kg of propan-1-ol is reacted with 24.0 kg of ethanoic acid.
         1. Determine the limiting reactant, showing all work. ***[2]***

         2. Determine the theoretical yield of propyl ethanoate in kilograms. ***[2]***

5. Hydrogen is a very important resource for the future, including its use as a fuel, and use in organic synthesis.
    a. One important application of hydrogen is the conversion of alkenes into alkanes. State a balanced equation for the reaction between buta-1,3-diene and hydrogen to form butane. ***[1]***

    b. Hydrogen is produced on an industrial scale by reacting methane with water vapor to form carbon monoxide, CO, and hydrogen.
        i. State the balanced equation for the reaction of methane with water vapor to form hydrogen and carbon monoxide. ***[1]***

        ii. Determine the yield of hydrogen in m^3 when 100.0 m^3 of methane is reacted with 75.0 m^3 of water vapor at 750 K and 100.0 kPa. Assume there is no change in pressure and temperature. ***[2]***

    c. Modern atomic theory is based largely on the hydrogen emission/absorption spectra.
        i. Explain the convergence of lines in the emission spectra. ***[1]***

        ii. State what can be determined from frequency of the convergence limit. ***[1]***

        iii. State one electron transition responsible for the absorption of UV light in the hydrogen atom. ***[1]***

6. The periodic table is organized in order of atomic number. There are many patterns and trends that can be found in the periodic table.
    a. Outline the acid base nature of the period three oxides from sodium to chlorine. ***[3]***

    b. State the equation showing the acid base nature of magnesium oxide. ***[1]***