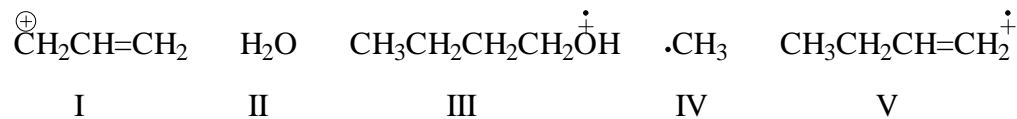


Part 1. (15 questions, 4 points each)

1. When 1-butanol is injected into a Mass Spectrometer, some of the species produced are listed below:



Which of the above species can be detected by a mass spectrometer?

- (A) I, II, and IV.
- (B) II, III, and V.
- (C) II, IV, and V.
- (D) I, III, and V.
- (E) All of the species can be detected.

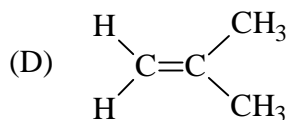
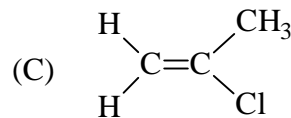
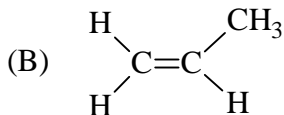
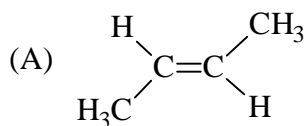
2. When a compound with a molecular formula of $\text{C}_6\text{H}_5\text{Cl}$ is analyzed in a mass spectrometer, a peak at $m/z=112$ is observed. Which of the following must also be observed:

- (A) a peak at $m/e=113$ with an intensity one-third of the peak at m/e 112.
- (B) a peak at $m/e=114$ with an intensity one-third of that at m/e 112.
- (C) a peak at $m/e=114$ with an intensity 6% of that at m/e 112.
- (D) a peak at $m/e=113$ with an intensity equal to that at m/e 112.
- (E) a peak at $m/e=114$ with an intensity equal to that at m/e 112.

3. In Mass Spectrometry, the term “base peak” is defined as:

- (A) The molecular ion peak in a spectrum.
- (B) The heaviest peak in a mass spectrum.
- (C) The lightest peak in a mass spectrum.
- (D) The most abundant peak in a spectrum.

4. In which of the following compounds is the $\text{C}=\text{C}$ stretching vibration infrared **inactive** ?



(E) All of them are infrared active

5. In an IR spectrum, the x axis represents wavenumber of the light being absorbed by bond vibrations. The wavenumber is

- (A) directly proportional to the wavelength.
- (B) directly proportional to the frequency.
- (C) inversely proportional to the energy of the wave.
- (D) None of the above.

6. For an alcohol molecule, the more the hydrogen bonding, the () the vibrational frequency of the OH stretching.

- (A) higher (B) lower (C) unchanged

7. An unknown compound's IR absorptions are listed below. Deduce its structure.

C_3H_3Br : 3300, 2950, 2100 cm^{-1}



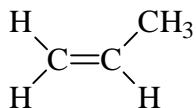
8. The energy difference between the α and β spin states for an 1H nucleus is _____ the strength of the external magnetic field in which the nucleus is placed.

- (A) inversely proportional to
(B) independent
(C) directly proportional to
(D) equal to

9. Consider the ethyl iodide molecule, CH_3CH_2I , which of the statements below is correct?

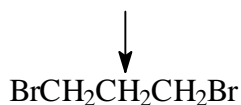
- (A) CH_3 protons are more deshielded.
(B) The energy gap between α and β spin states of CH_2 protons is smaller than the counterpart of CH_3 protons.
(C) The electronegative element I shields the CH_2 protons.
(D) None of the above.

10. How many types of chemically non-equivalent protons are there in the following compound?



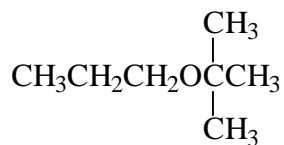
- (A) 2 (B) 3 (C) 4 (D) 5 (E) 6

11. The splitting pattern for the proton designated by the arrow below would appear in 1H -NMR as



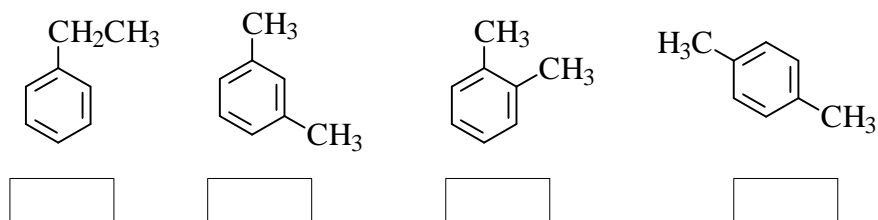
- (A) singlet (B) sextet (C) quintet (D) triplet

12. How many types of chemically non-equivalent protons exist in the following molecule?



- (A) 4 (B) 5 (C) 6 (D) 16

13. In the boxes below each structure, fill in the number of carbon signals expected in each compound's ^{13}C NMR spectrum (no protons are allowed to split the signal, i.e. noise-decoupled)



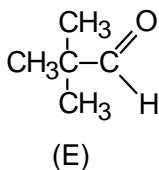
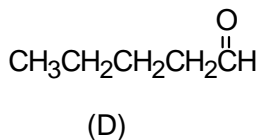
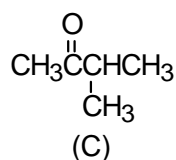
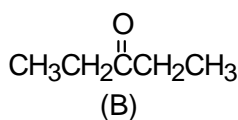
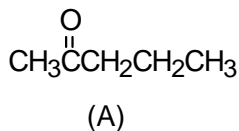
14. In Nuclear Magnetic Resonance spectroscopy, the frequency of electromagnetic radiation needed to bring about a "spin-flip" (α to β) falls in the:

- (A) Radiowave region (B) X-ray region. (C) UV-Visible region
(D) microwave region

15. A compound $\text{C}_5\text{H}_{10}\text{O}$ gave the following spectral data:

^1H NMR: δ 1.1 (doublet); δ 2.1 (singlet); δ 2.5 (septet)
IR: a strong peak near 1720 cm^{-1} .

Which is a reasonable structure for the compound?



End of Part 1

Part 2: (40 points)

1. (10 points) Unknown X has a molecular formula of $C_4H_{10}O$. Its 1H NMR is shown on page 6. Integrals are shown to indicate the area under each set of peaks. Deduce its structure. Credits will be given for any relevant parts of the structure.

2. (10 points) The mass spectrum of Unknown Y has its molecular ion peak at $m/z=122$. It also shows a peak at $m/z=124$ that is as tall as the 122 peak. ^{13}C NMR shows two carbon signals. 1H NMR is shown on the following page. Deduce its structure.

3. (20 points) Spectral data for Unknown Z are listed below. Deduce its structure.

MS: m/z 134 (Molecular Ion)

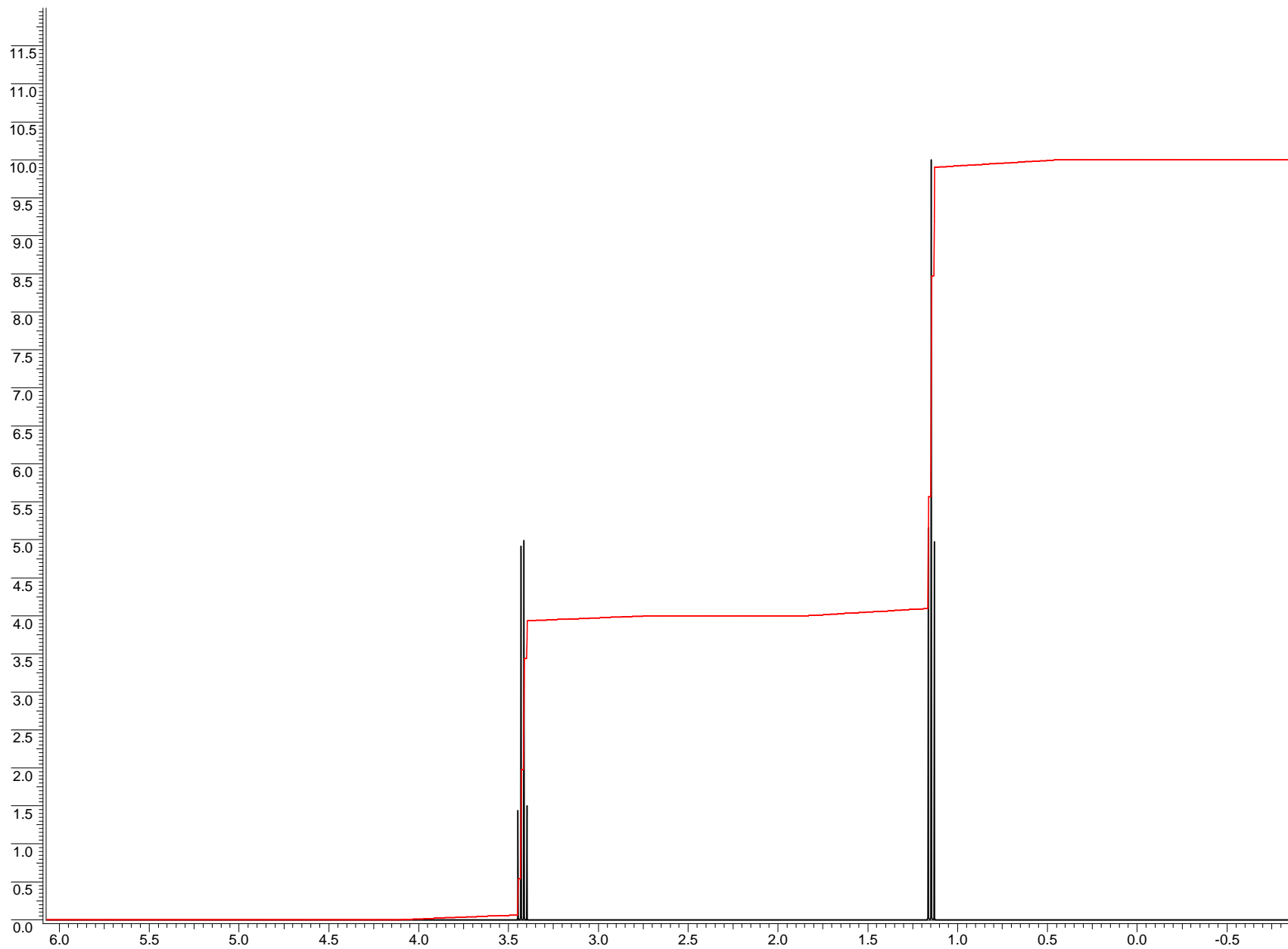
IR: 1720 (strong); 3062 (weak); 2981 (medium)
1605 (medium)

^{13}C NMR: shown on a separate page

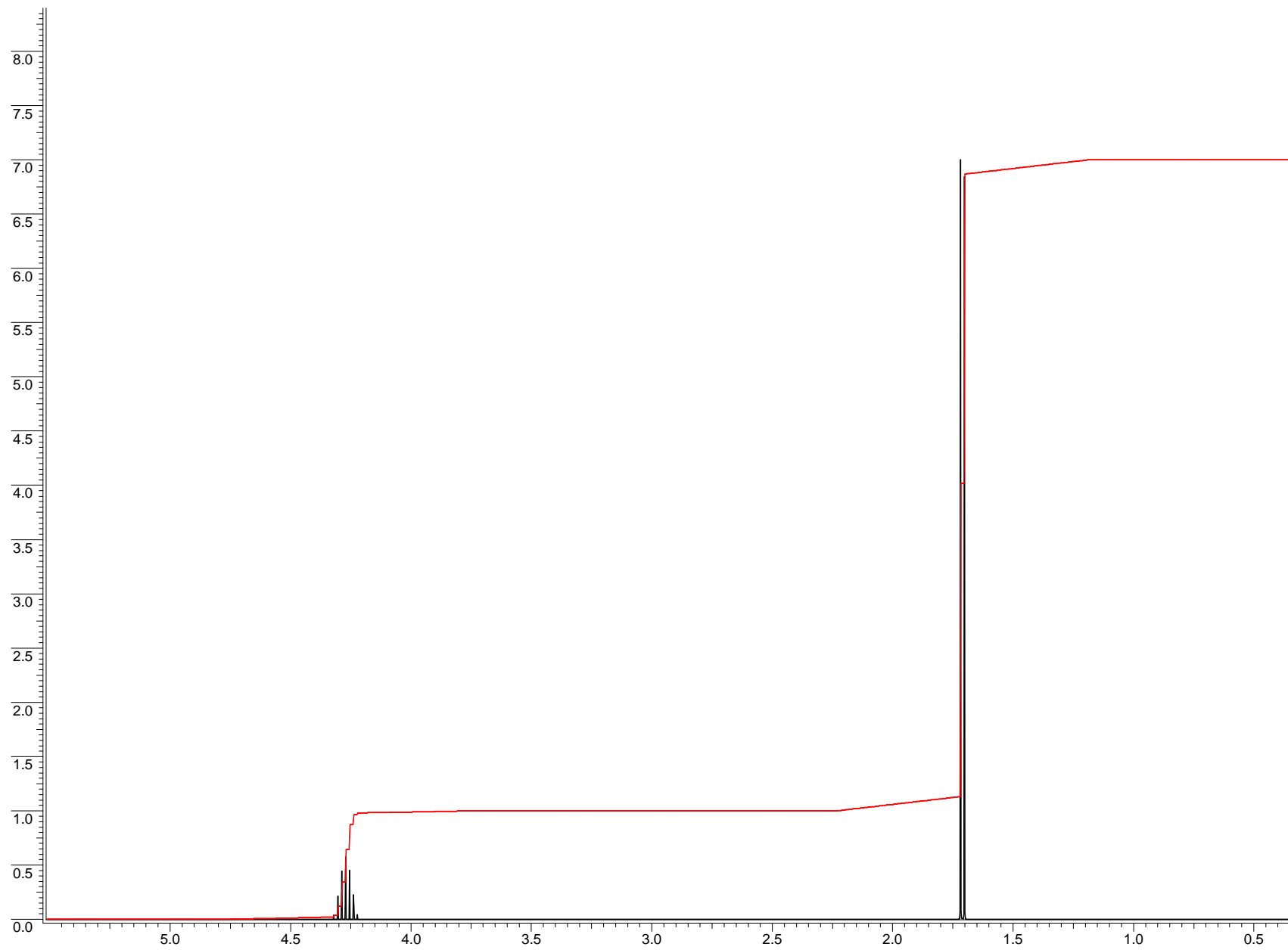
1H NMR: shown on a separate page.

HNMR for Part 2. problem 1

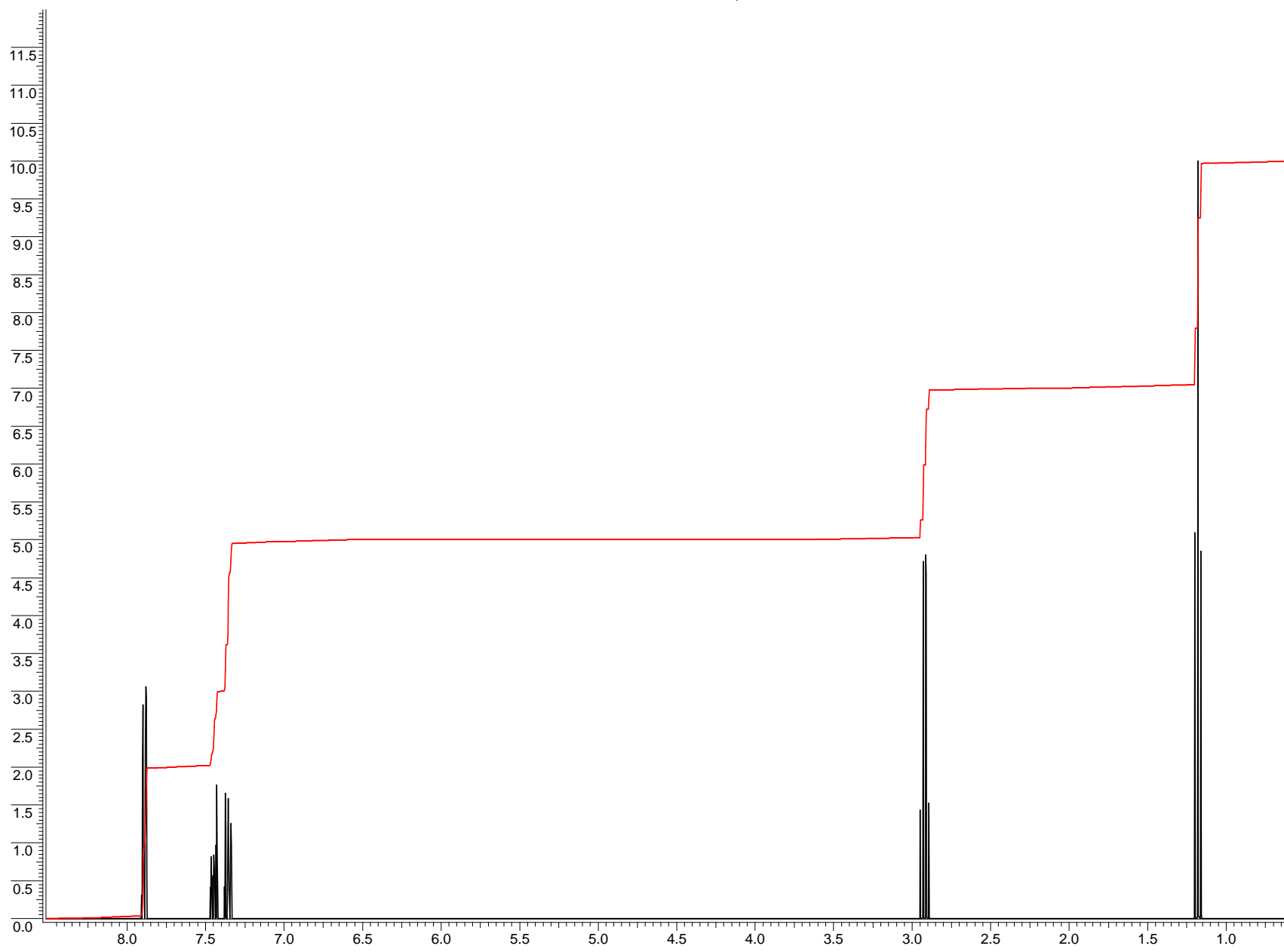
unknown X, C₄H₁₀O



Unknown Y, ¹HNMR spectrum



HNMR for unknown Z,



¹³CNMR for unknown Z

