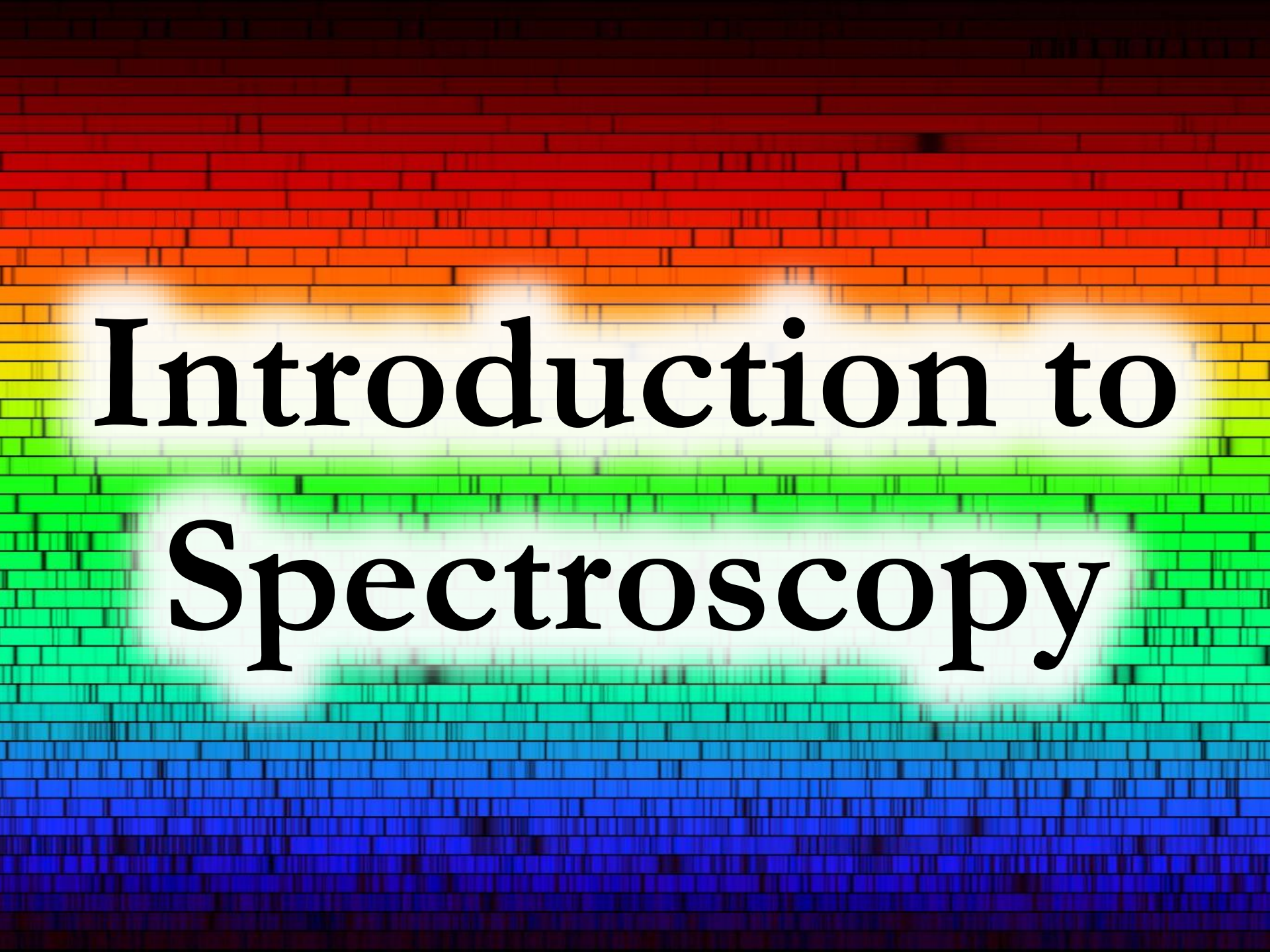
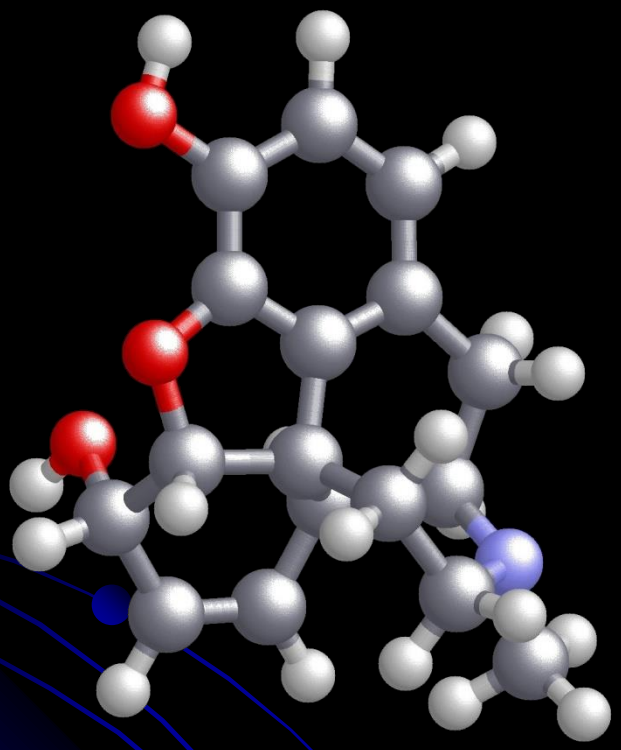
Spectroscopy

Determining the Structures of Drugs and Other Organic Compounds


Introduction to
Spectroscopy

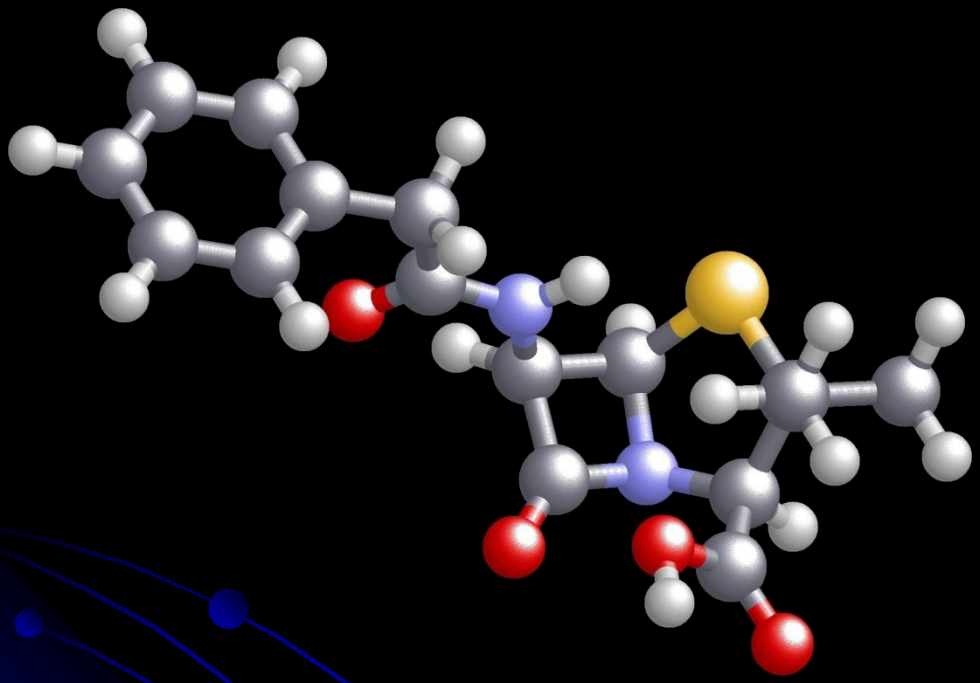
Introduction to Spectroscopy



Morphine

Once a chemical has been synthesised, it should be purified and have its structure determined. This may be carried out to *ensure* that the *correct chemical* has been synthesised, or it may be done to *characterise* a *new chemical* which has been synthesised for the very first time.

Introduction to Spectroscopy

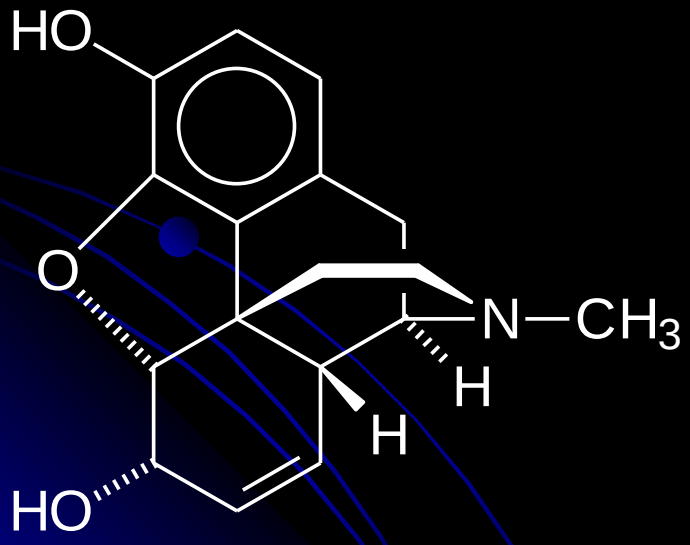


Penicillin

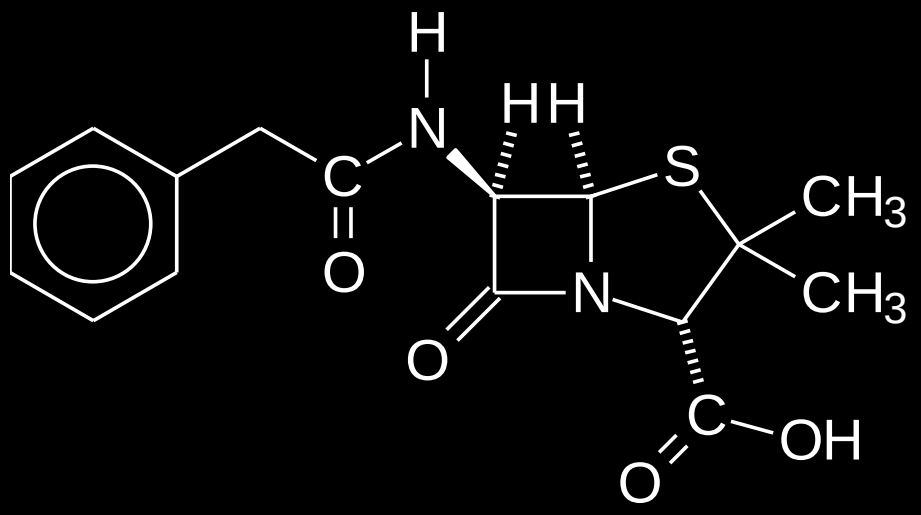
In addition, if a naturally occurring chemical is found to exhibit some sort of biological activity, then it should be purified and have its structure determined so that biochemists can identify its *mode of action* and so that organic chemists can attempt to *synthesise* it in the laboratory.

Introduction to Spectroscopy

The complete tree-dimensional structures of *morphine* and *penicillin* have been determined by analysing the data from a variety of different spectroscopic techniques. This has helped to establish the drugs' mode of action and has also allowed them to be synthesised in the laboratory.



Morphine



Penicillin

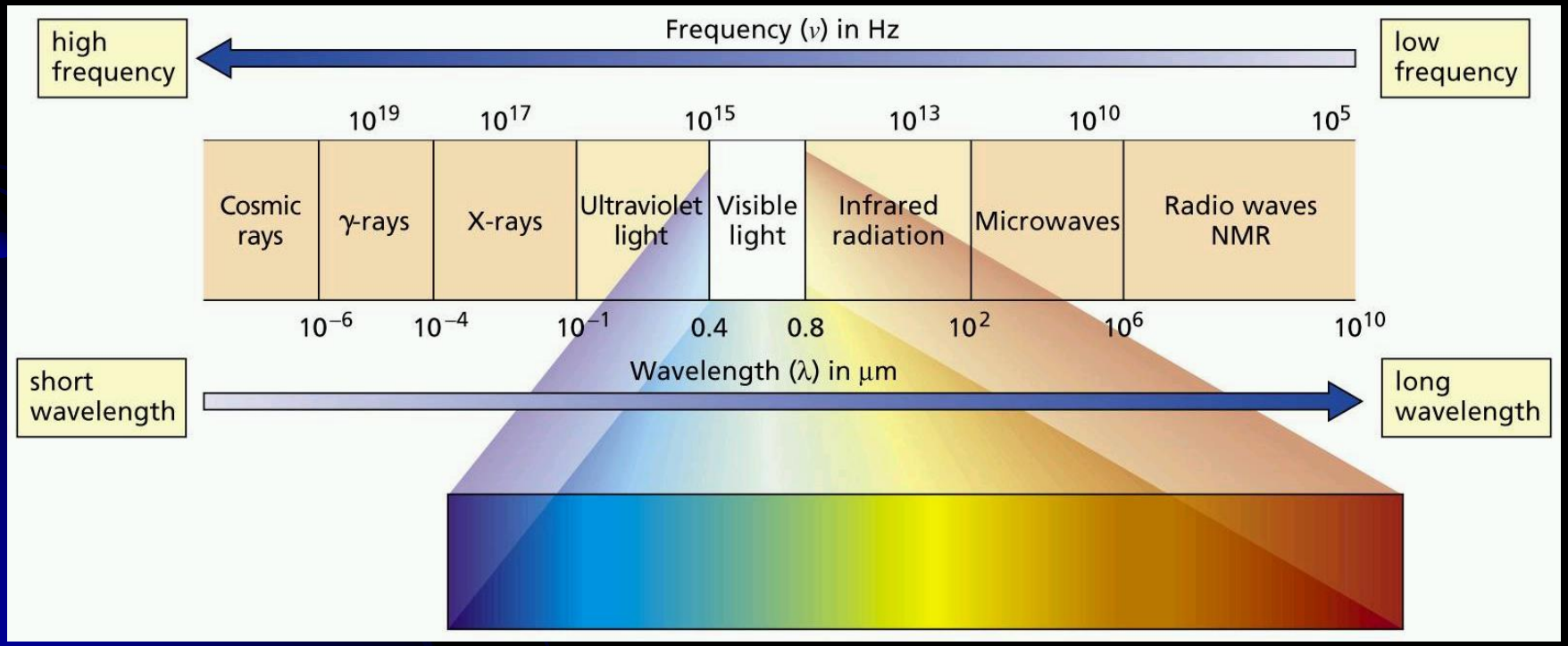
Introduction to Spectroscopy

There are many different analytical tools available to a chemist to help them establish the structure of an organic compound:

- x-ray crystallography
- mass spectroscopy
- ultraviolet spectroscopy
- visible spectroscopy
- infrared spectroscopy
- nuclear magnetic resonance spectroscopy

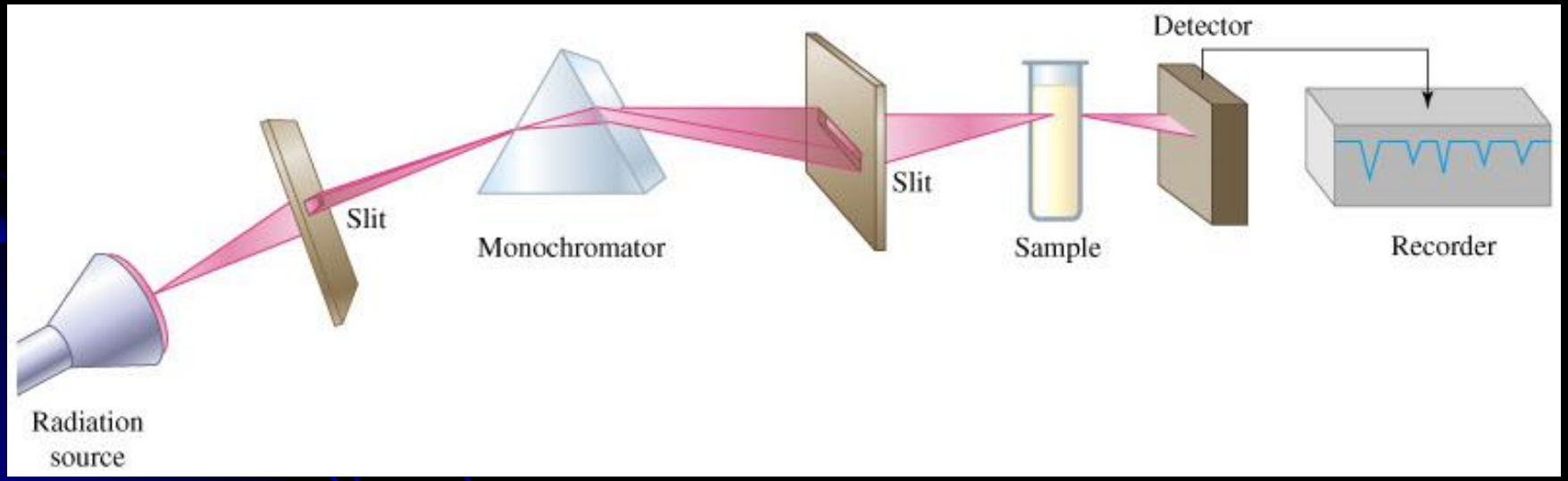
Introduction to Spectroscopy

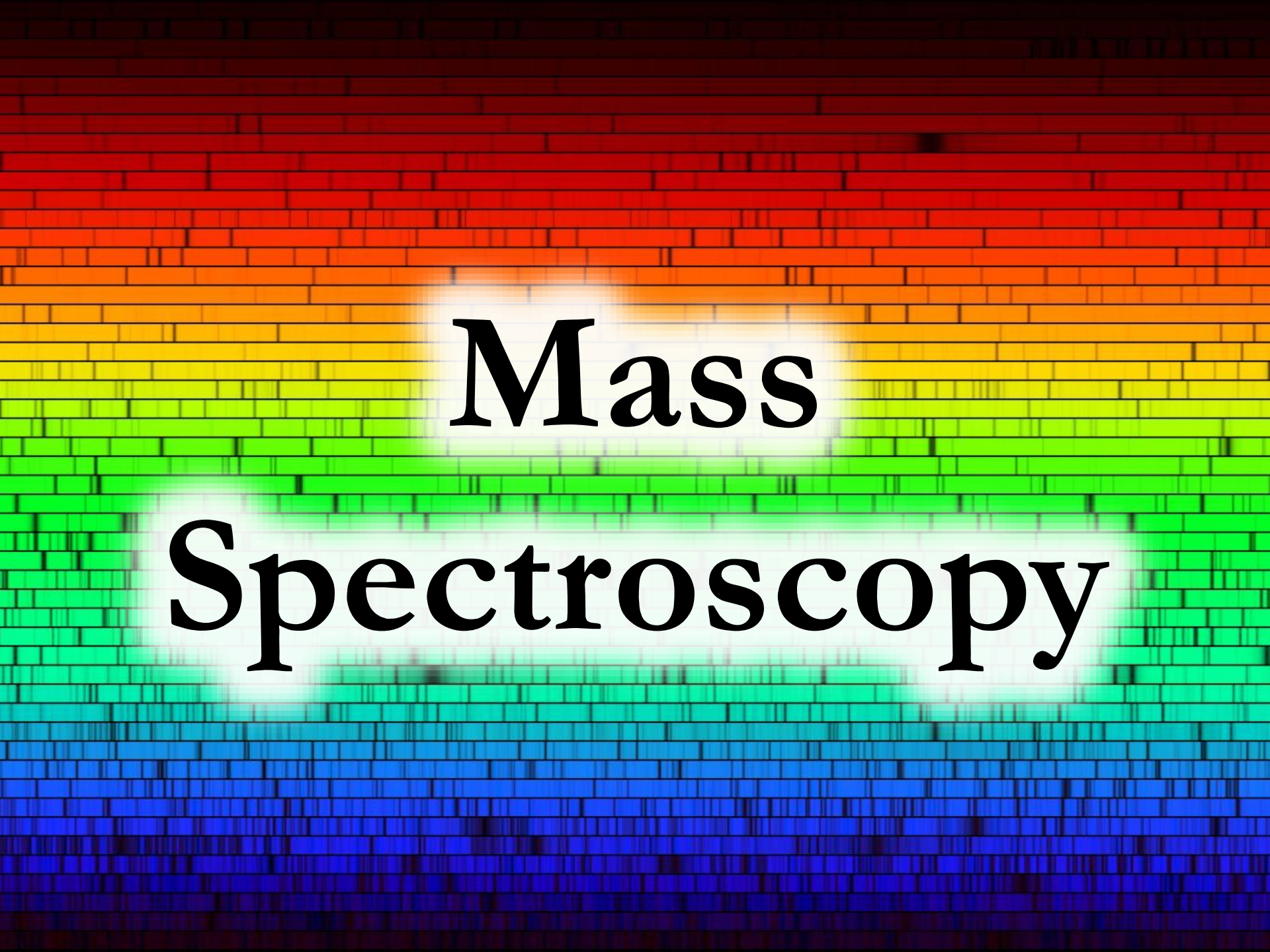
Most forms of spectroscopy involve the interaction of electromagnetic radiation with matter. By measuring which wavelengths / frequencies of electromagnetic radiation are emitted / absorbed by a molecule gives chemists an insight into the molecule's structure.



Introduction to Spectroscopy

Most types of spectroscopy expose the sample to some type of electromagnetic radiation and measure the frequencies / wavelengths that are absorbed.



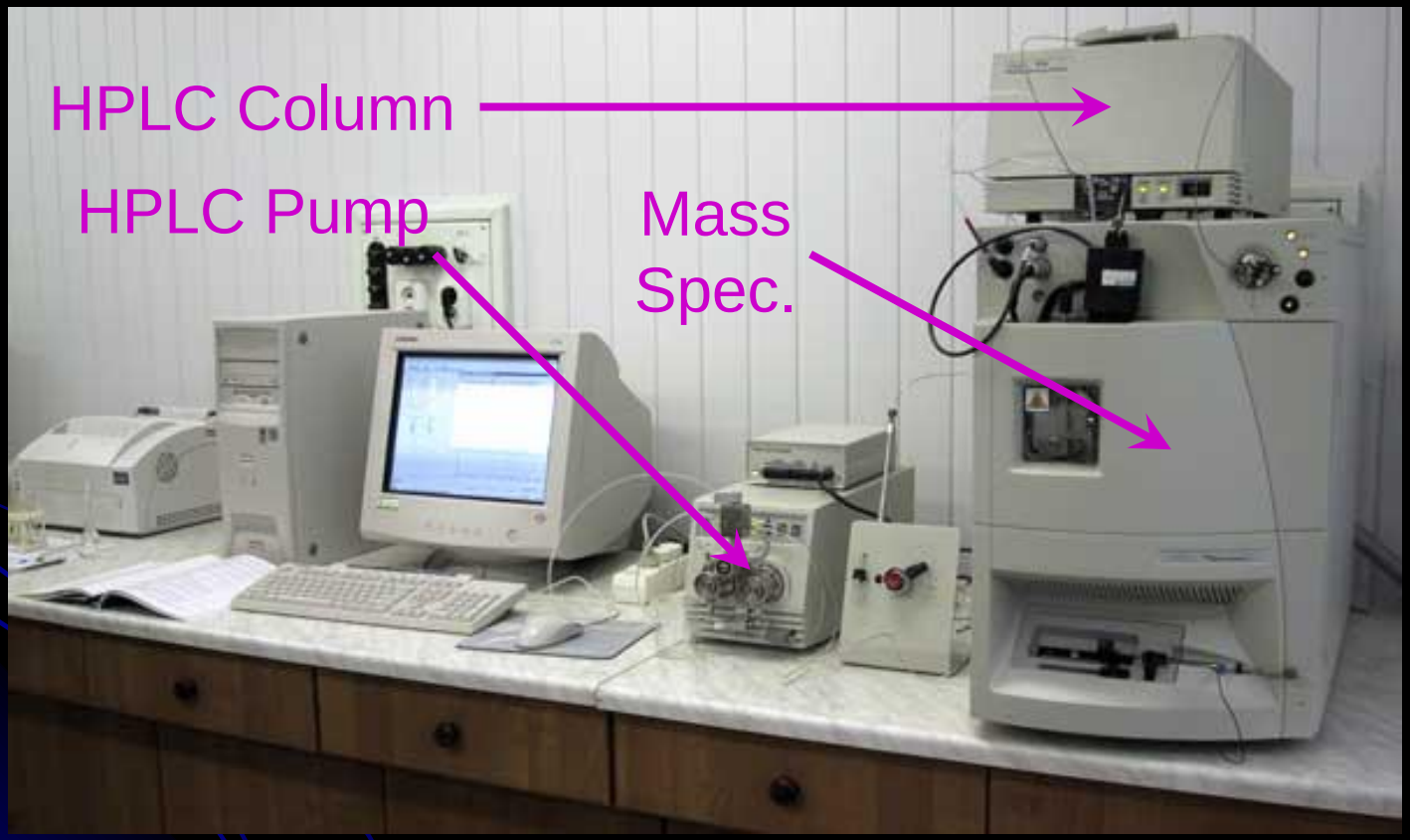

Mass
Spectroscopy

Mass Spectroscopy

The Complex Engineering of a Mass Spectrometer

Mass Spectroscopy

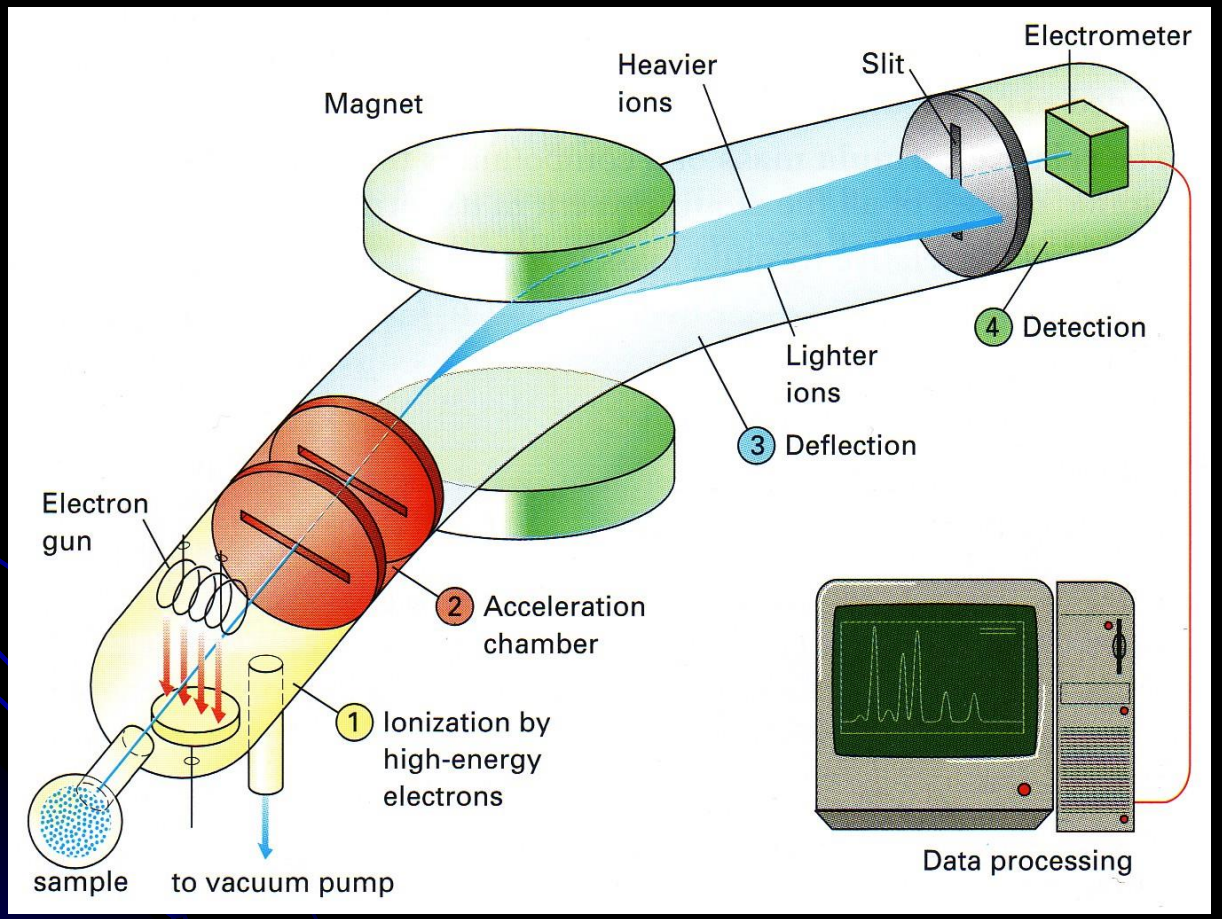
A HPLC* Connected to a Desktop Mass Spectrometer



*High Performance Liquid Chromatography – An advanced form of chromatography used to separate complex mixtures.

Mass Spectroscopy

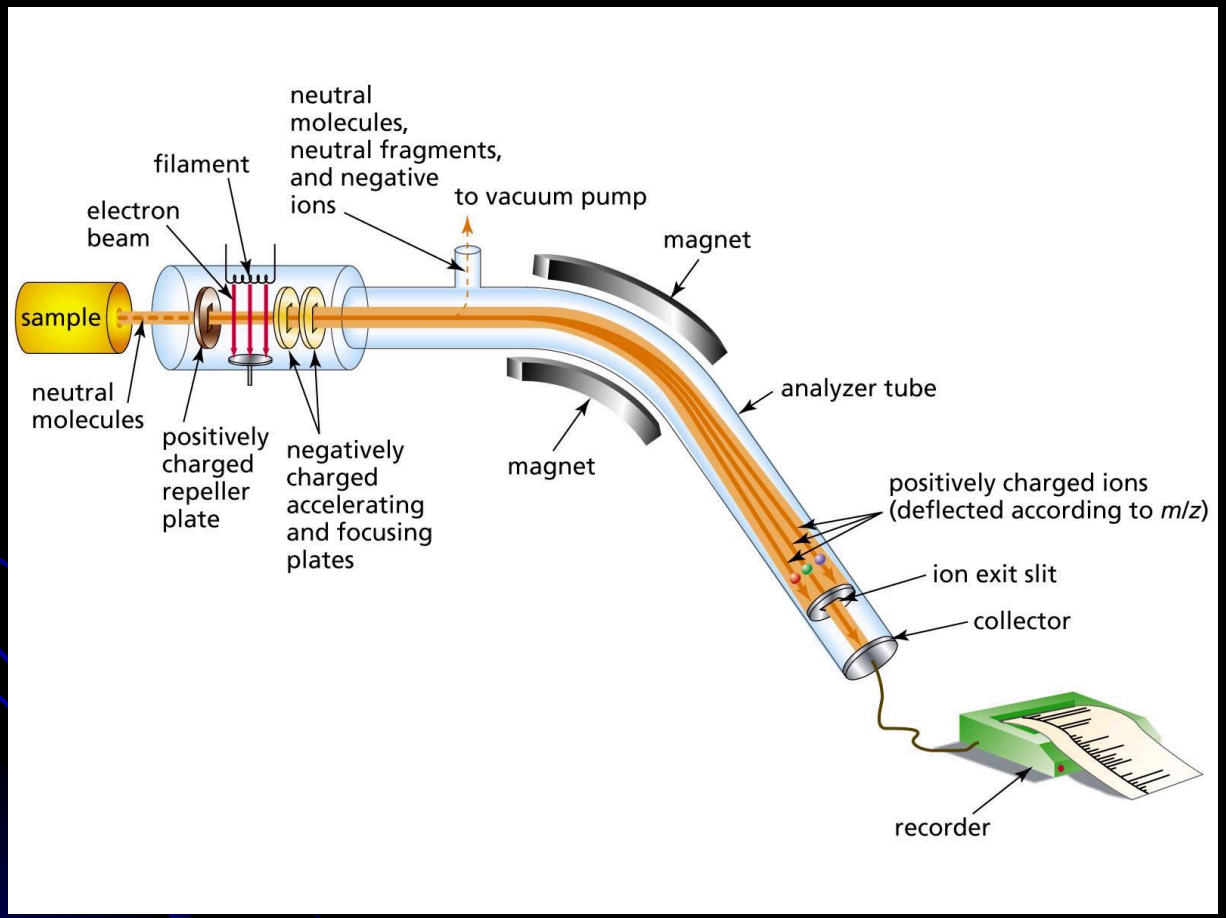
The Components of a Mass Spectrometer #1



View animation.

Mass Spectroscopy

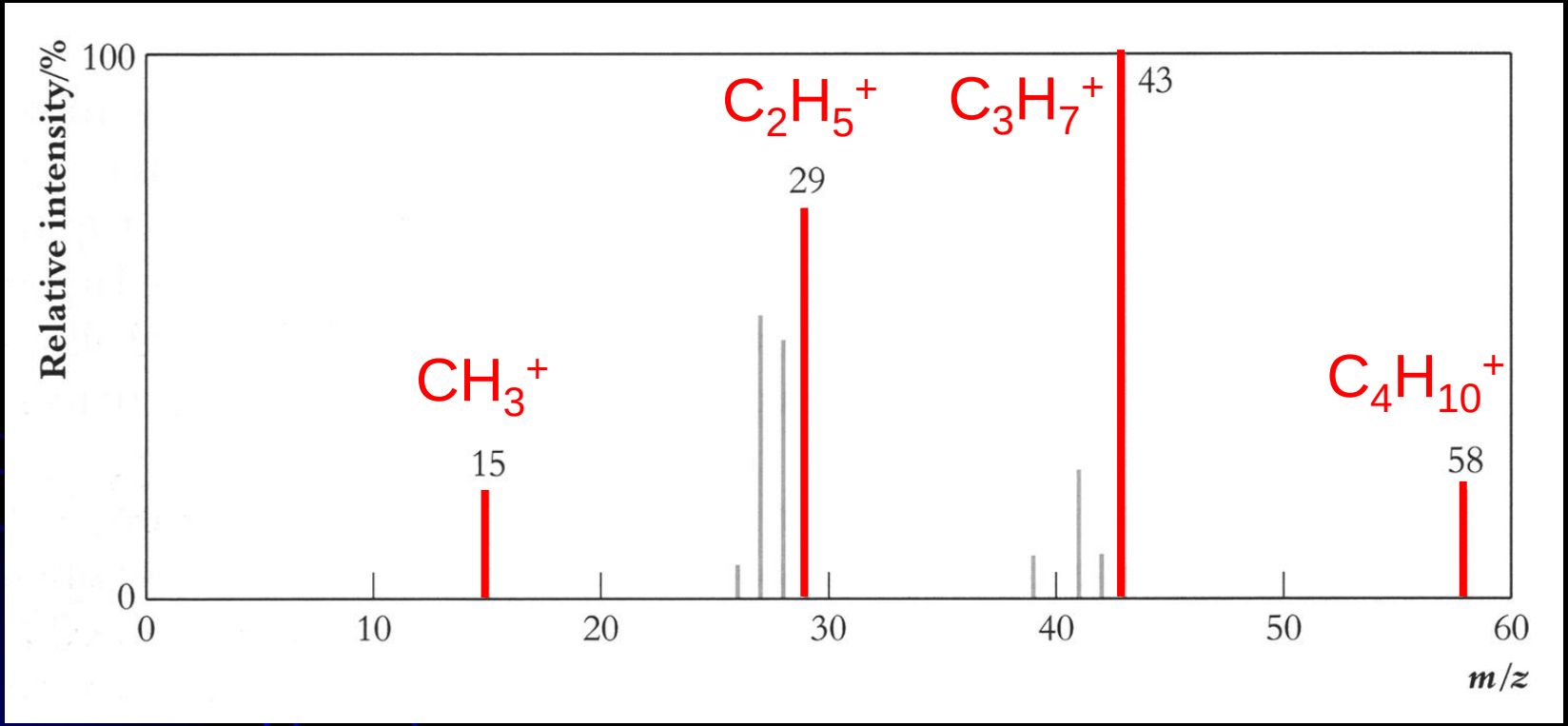
The Components of a Mass Spectrometer #2



View animation.

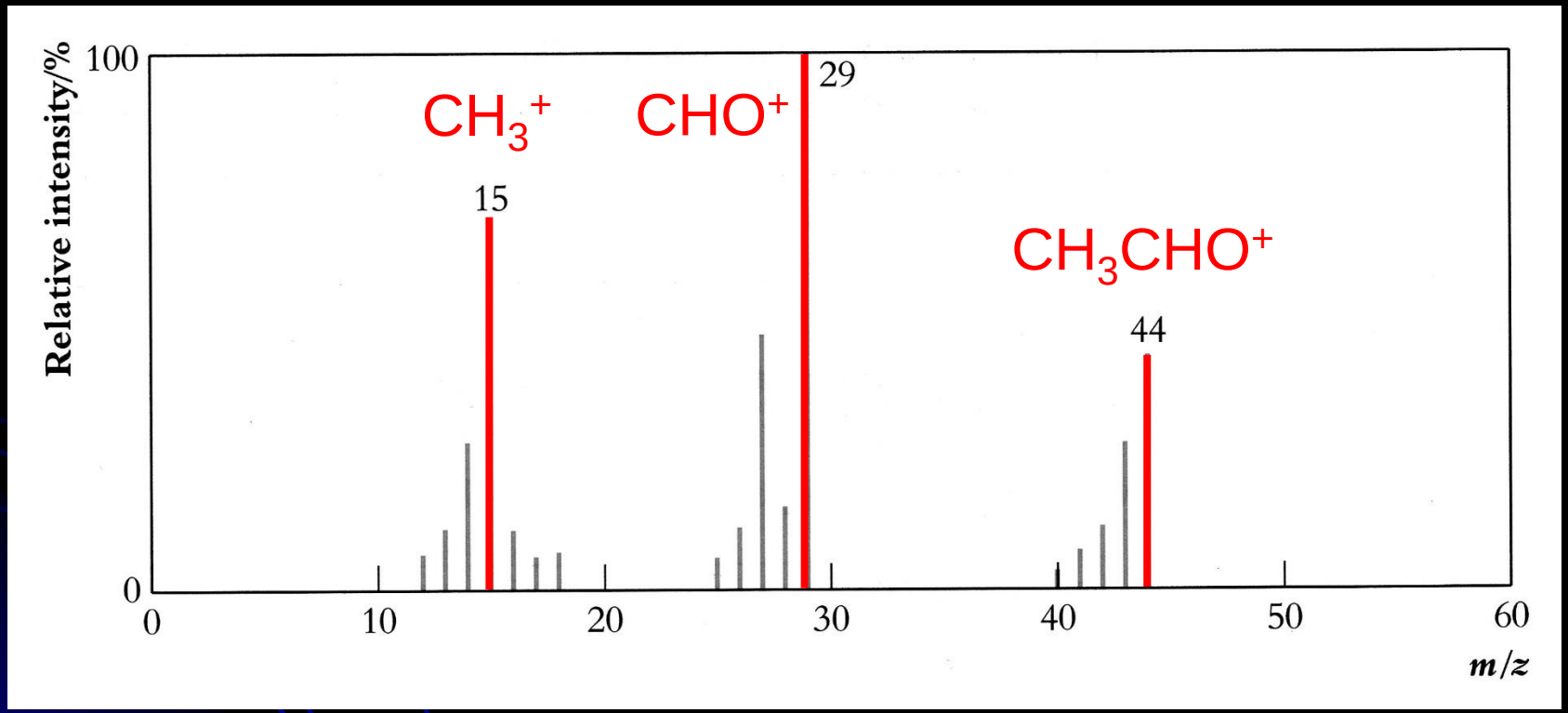
Mass Spectroscopy

Butane – C_4H_{10}



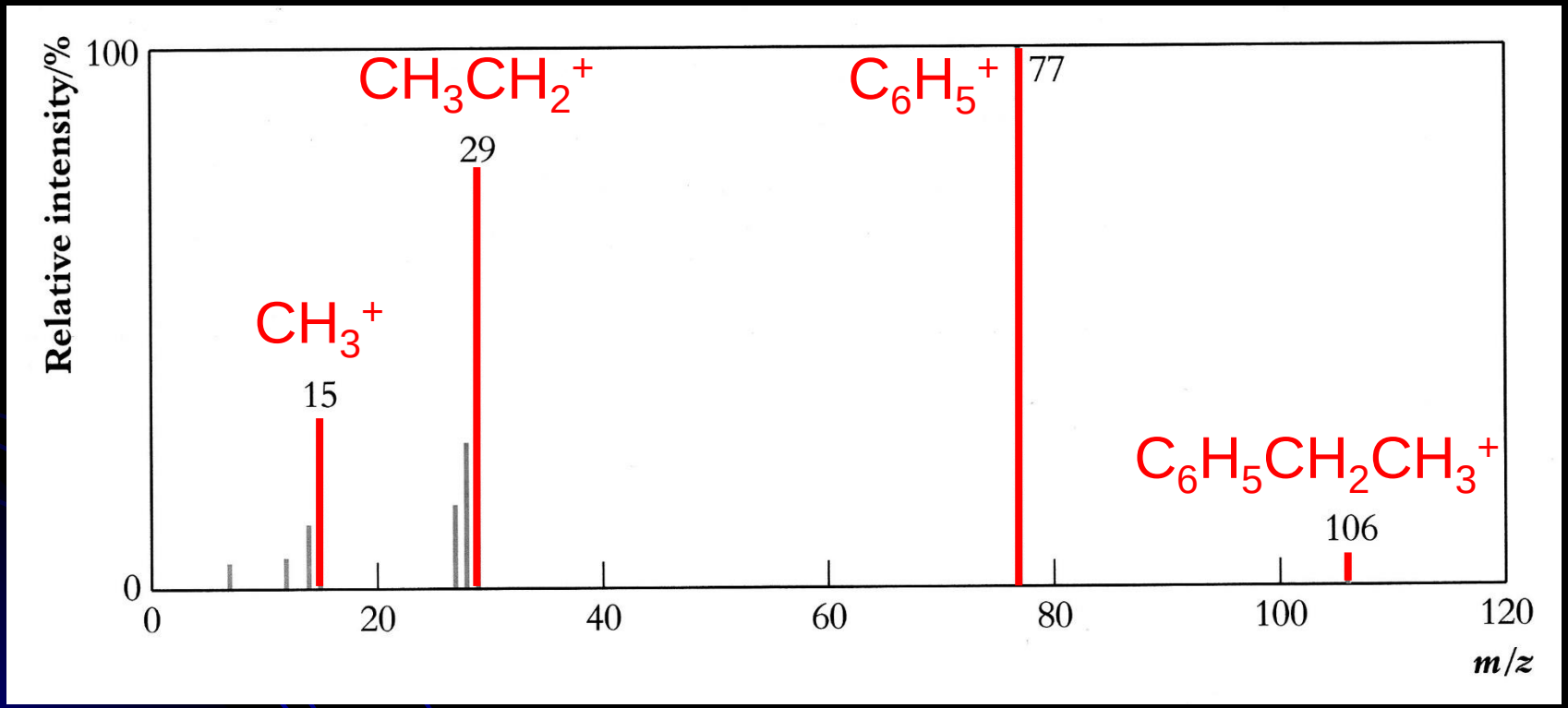
Mass Spectroscopy

Ethanal – CH_3CHO



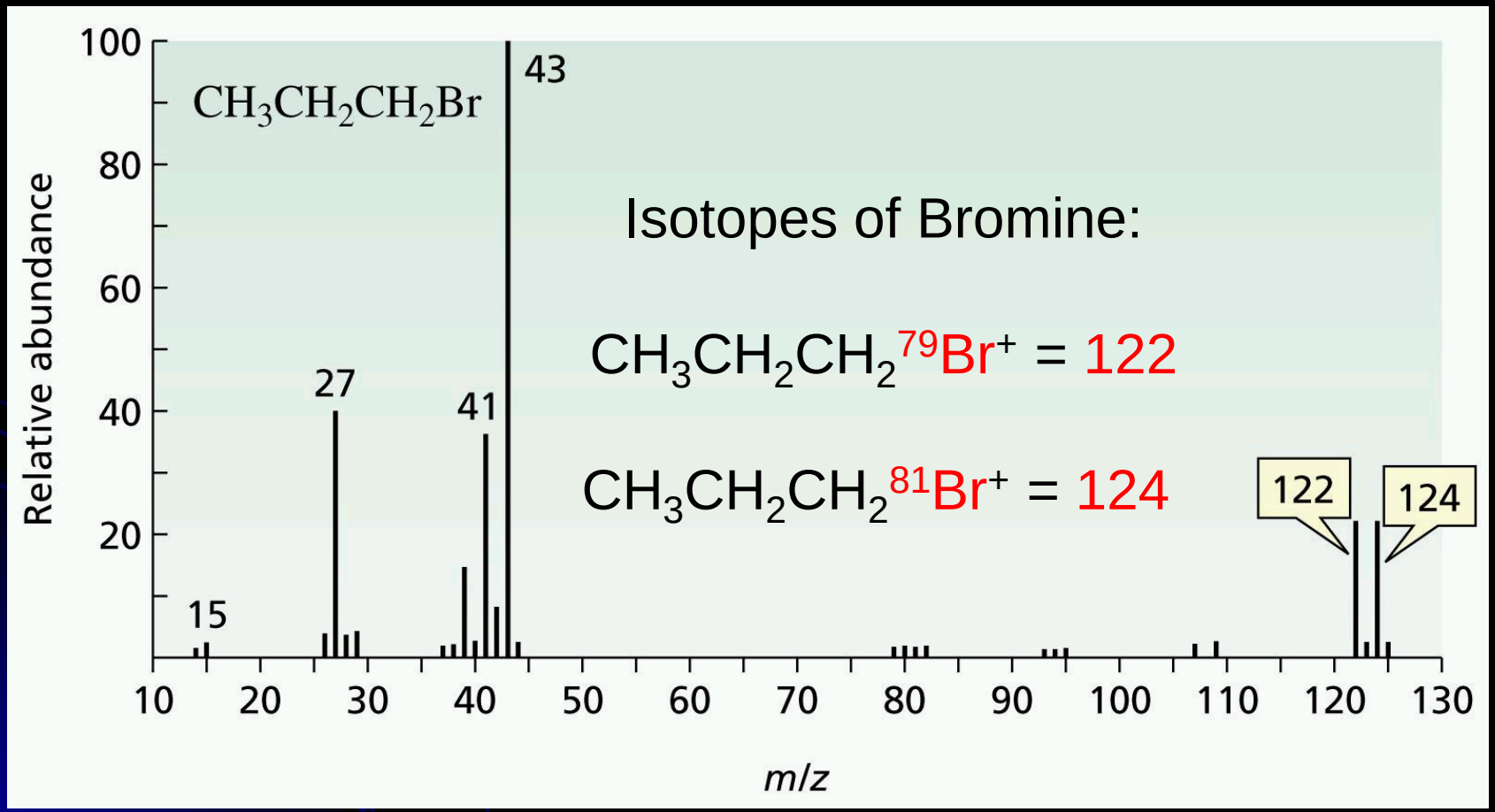
Mass Spectroscopy

Ethylbenzene – $C_6H_5CH_2CH_3$



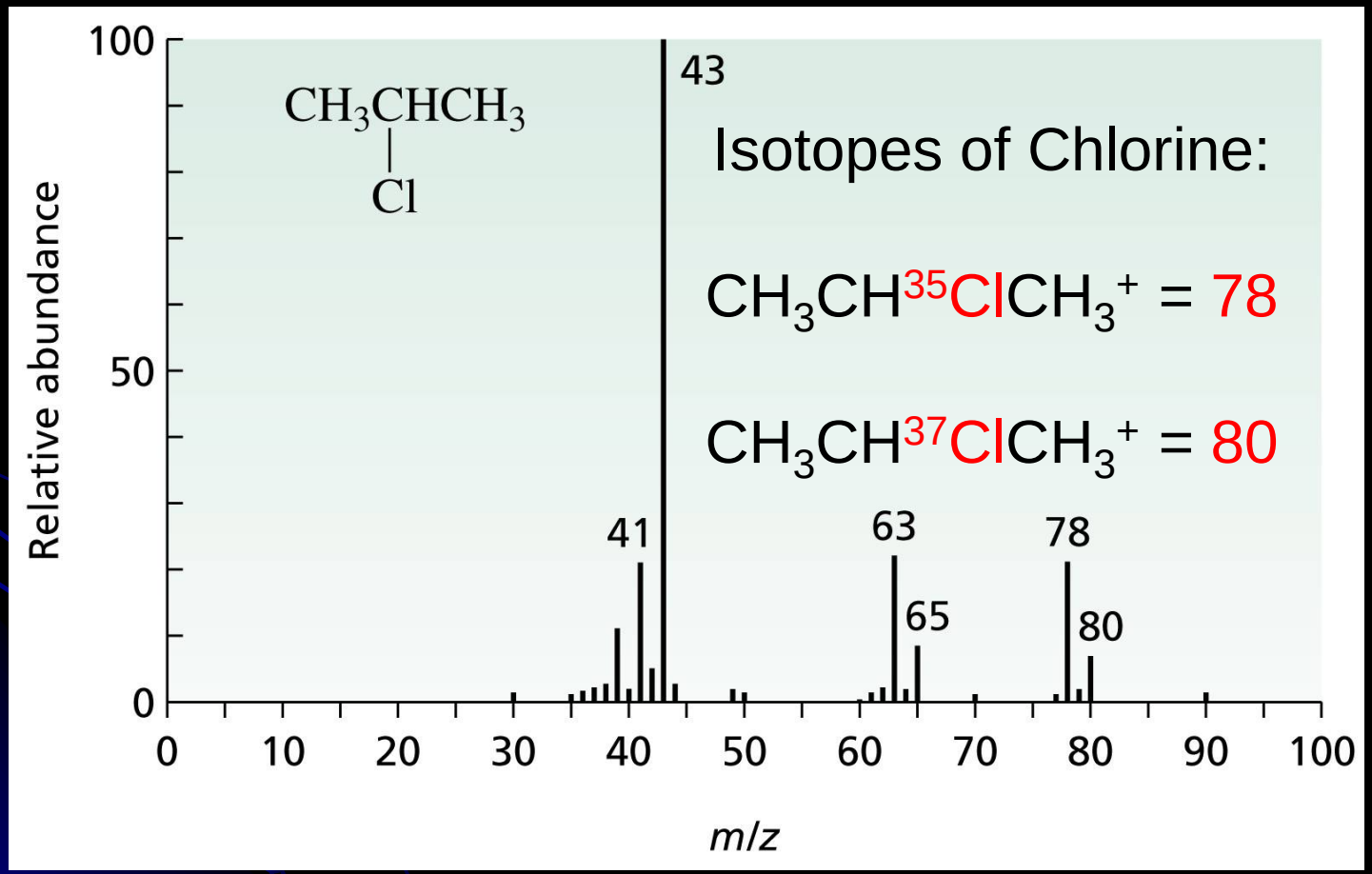
Mass Spectroscopy

1-Bromopropane – $CH_3CH_2CH_2Br$



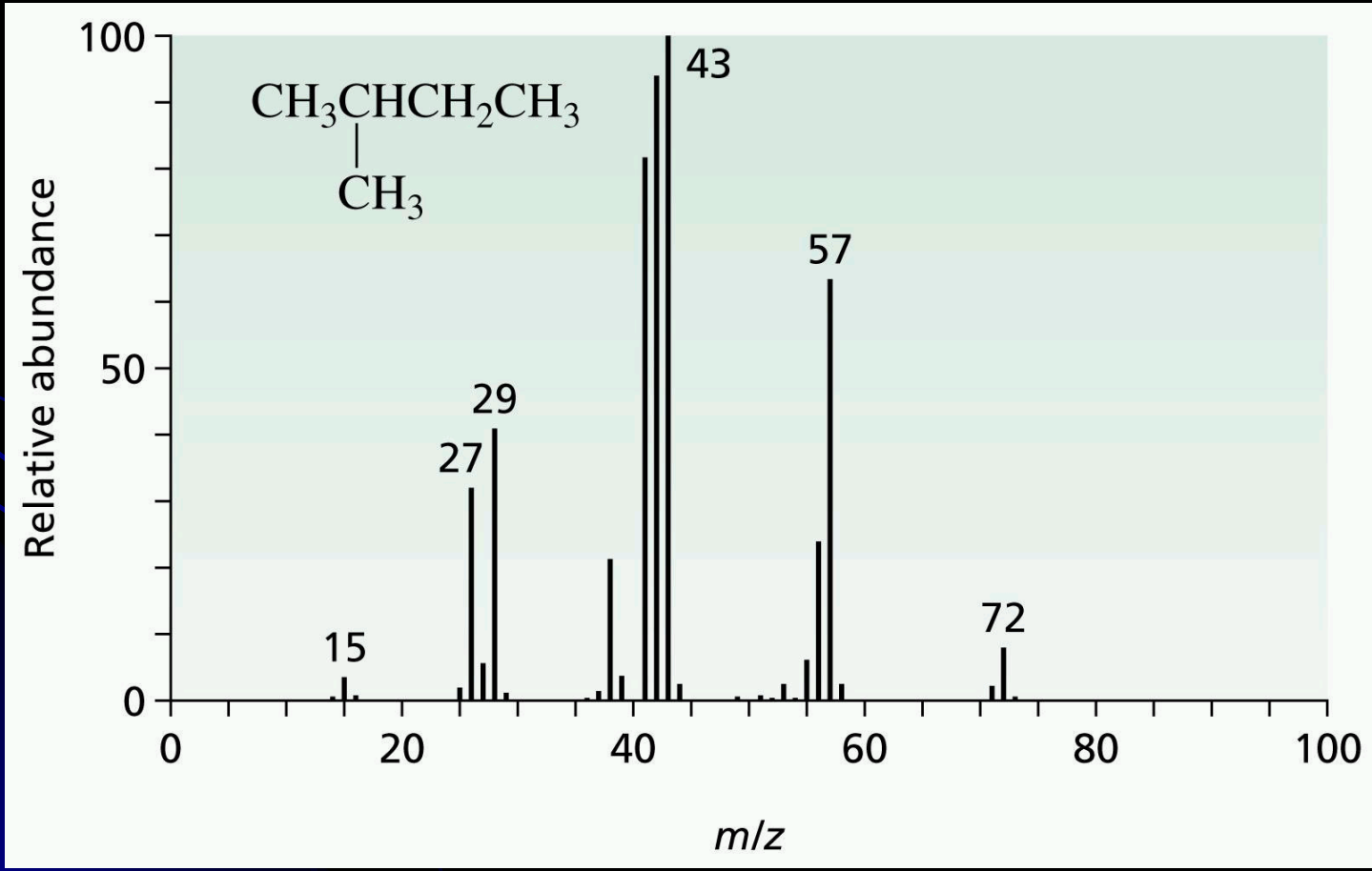
Mass Spectroscopy

2-Chloropropane – $CH_3CHClCH_3$



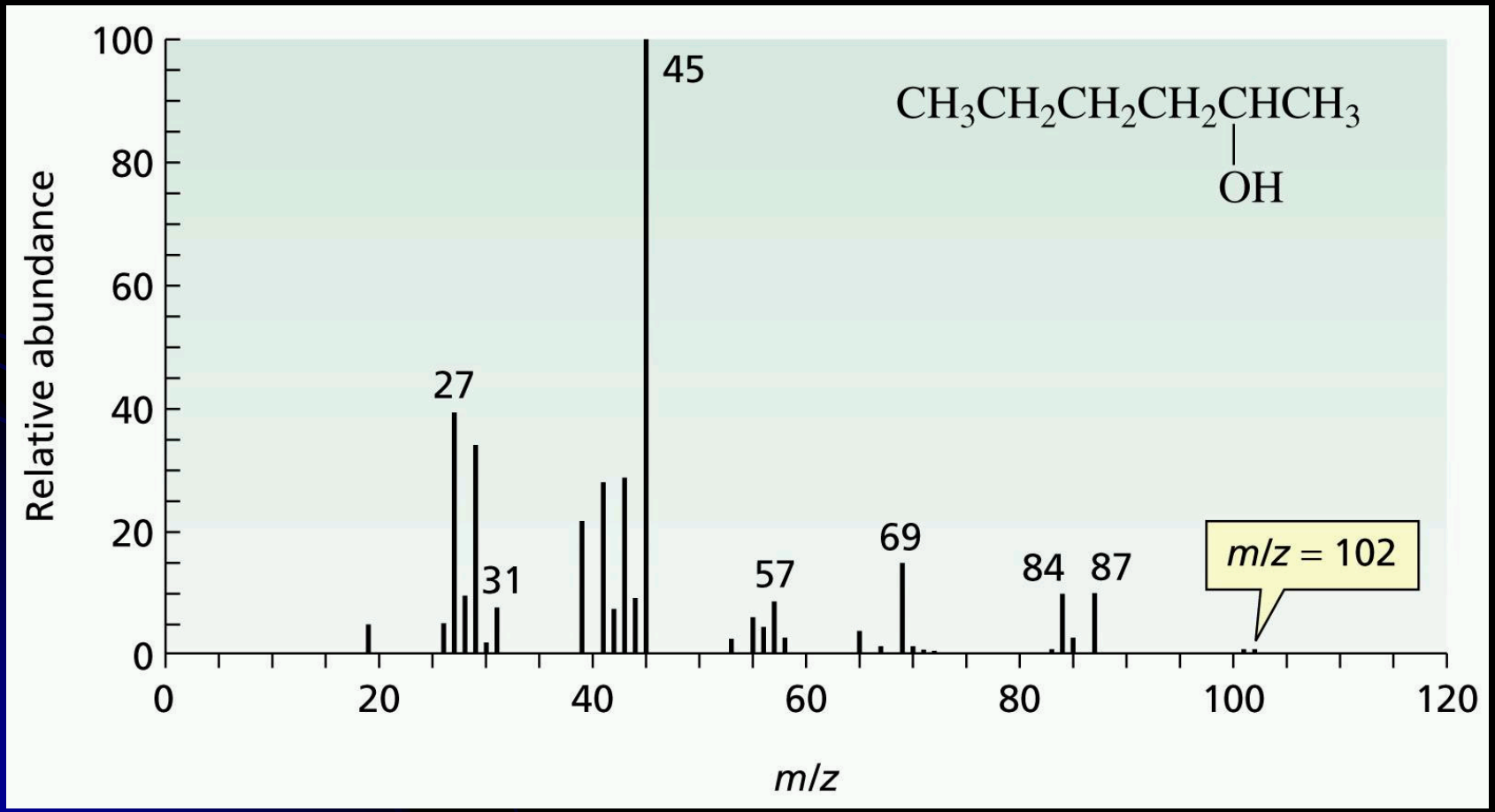
Mass Spectroscopy

Further practice – identify the peaks in the mass spectrum of 2-methylbutane – $CH_3CH(CH_3)CH_2CH_3$



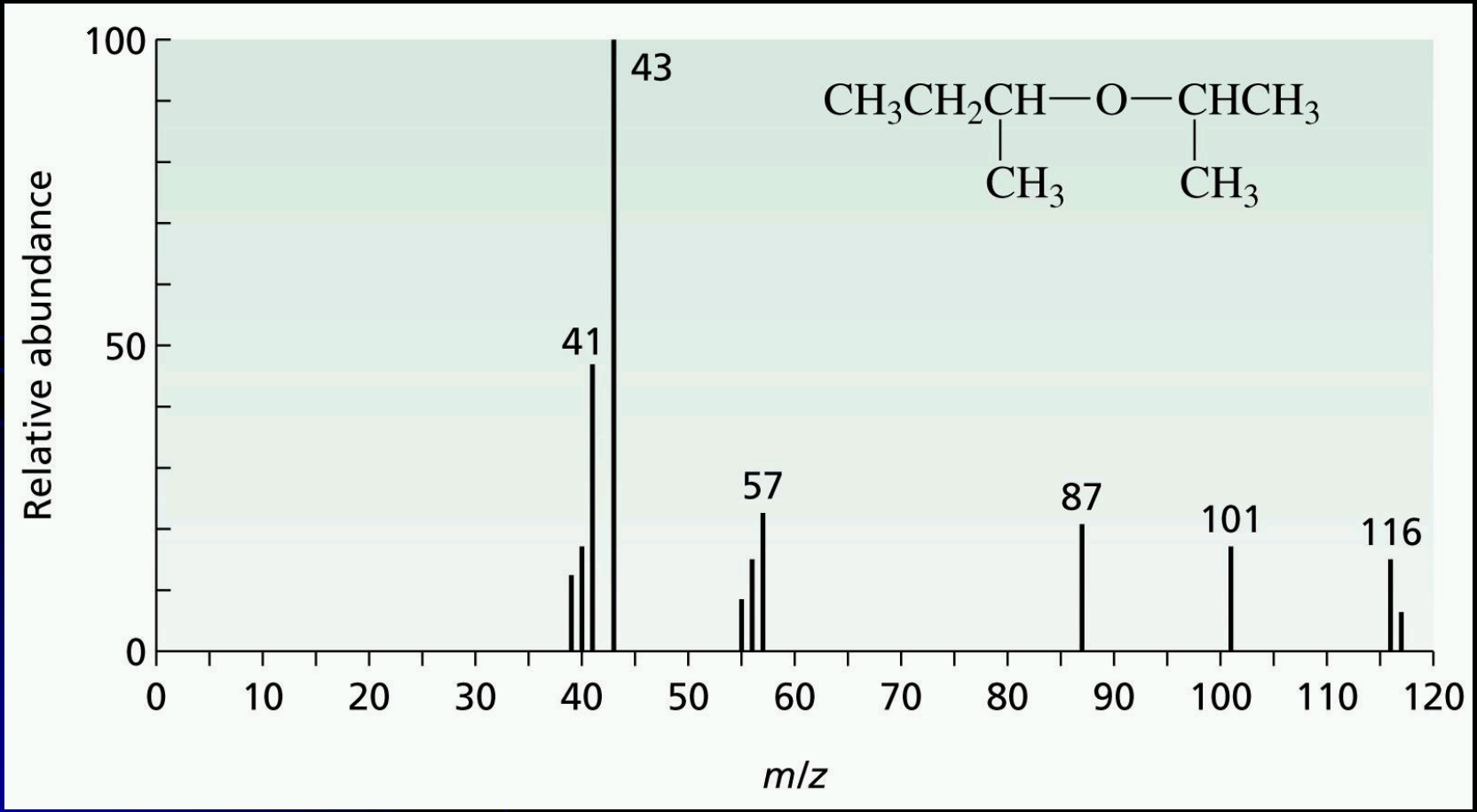
Mass Spectroscopy

Further practice – identify the peaks in the mass spectrum of hexan-2-ol – $CH_3(CH_2)_3CH(OH)CH_3$



Mass Spectroscopy

Further practice – identify the peaks in the mass spectrum of *sec*-Butyl iso-Propyl Ether – $CH_3CH_2CH(CH_3)OCH(CH_3)_2$



Infrared Spectroscopy

Infrared Spectroscopy

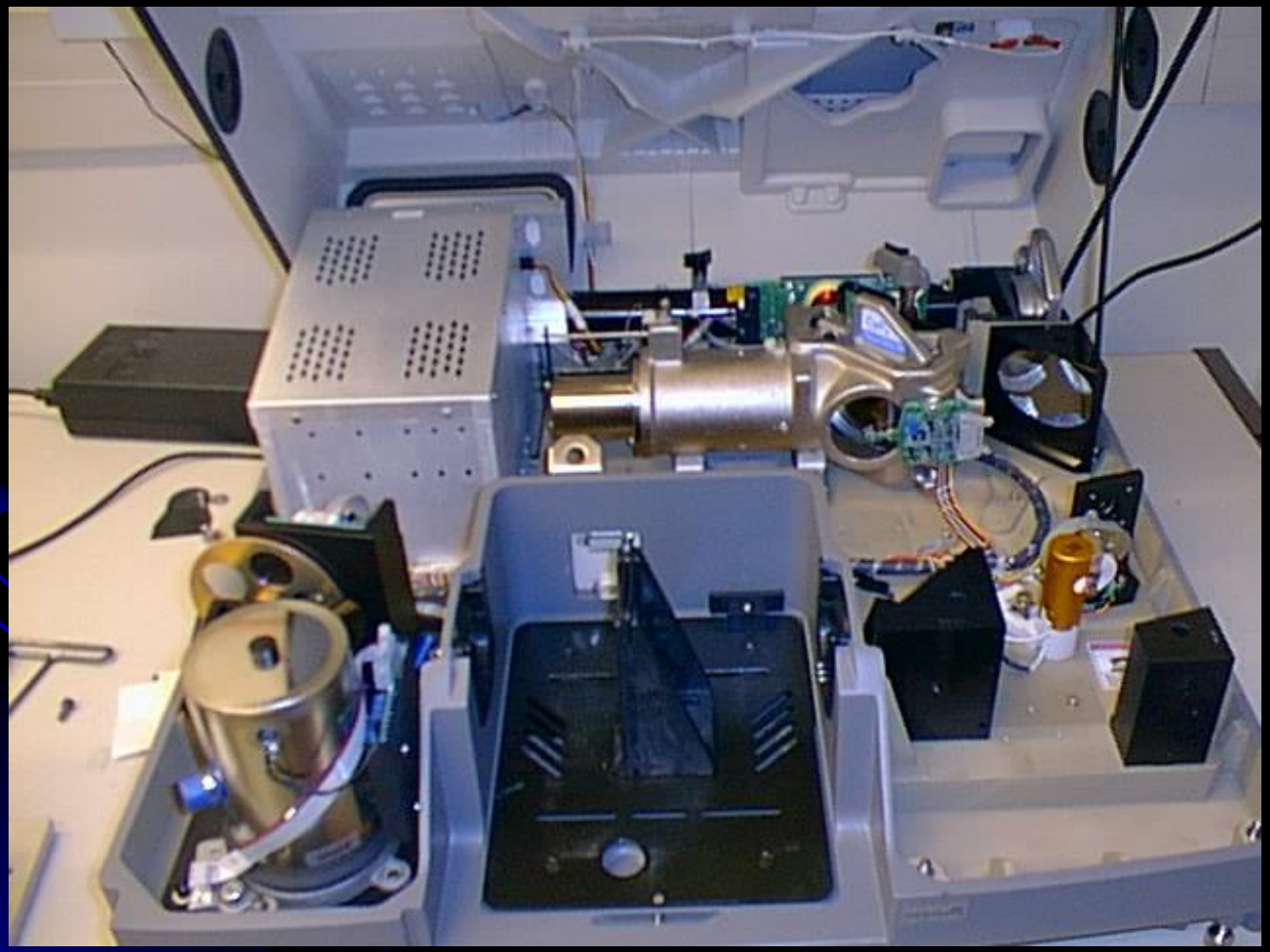
An Infrared Spectrometer Connected to a Computer

Infrared Spectroscopy

An Infrared Spectrometer – Sample Chamber Open

Infrared Spectroscopy

The Internal Components of an Infrared Spectrometer



Infrared Spectroscopy

A Cell Used to Contain Samples Dissolved in Solution or in the Gas Phase

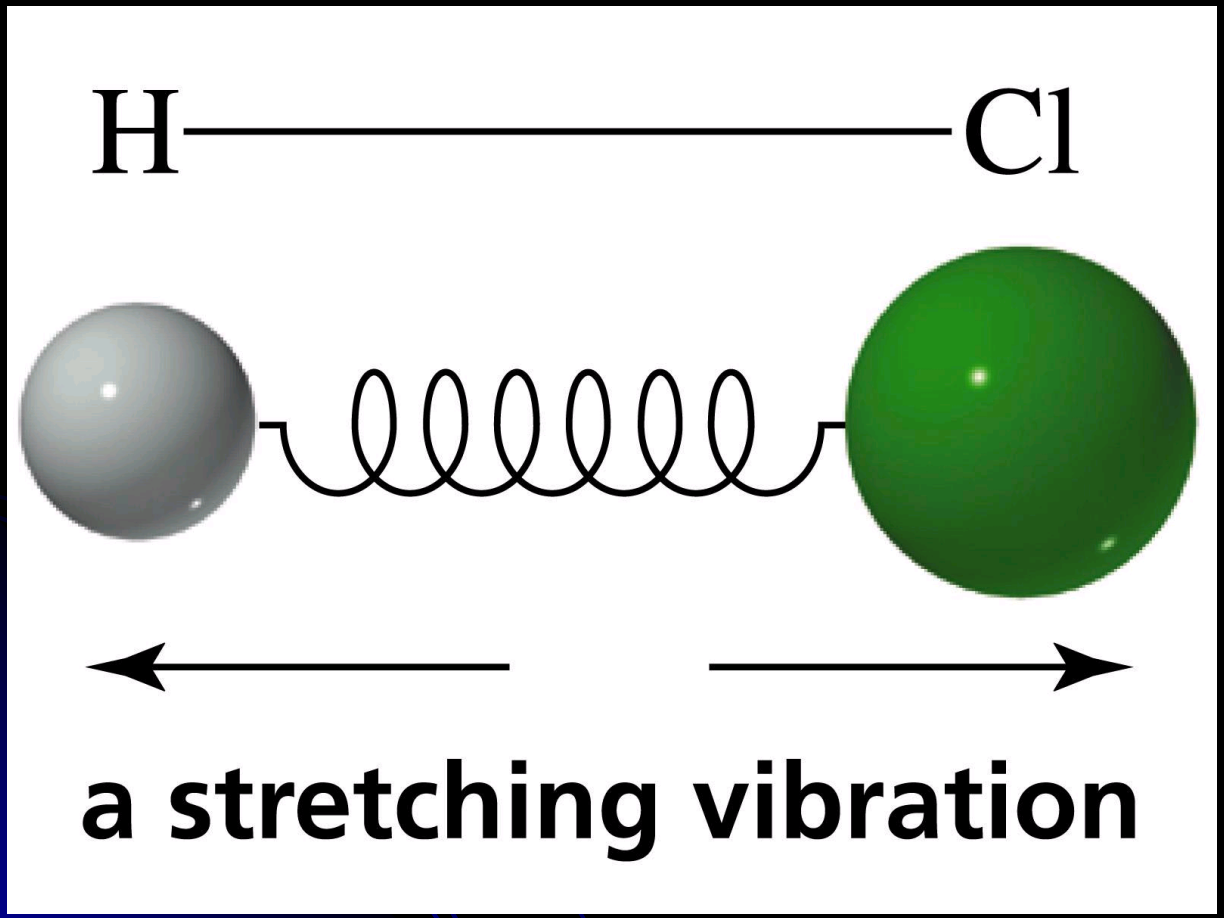
Infrared Spectroscopy

KBr Disks Used to Contain the Sample as a Thin Film

Infrared Spectroscopy

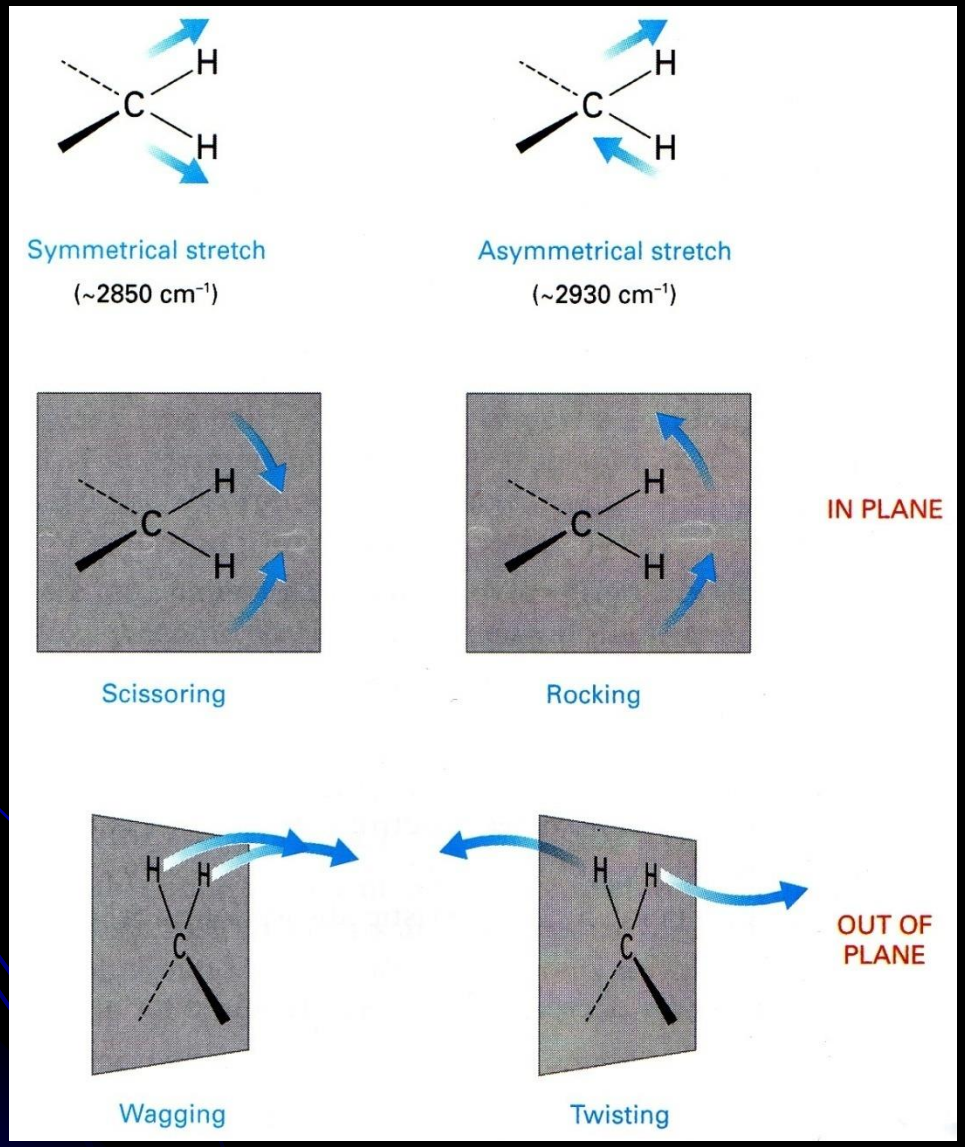
An Infrared Microscope – This Allows the Infrared Spectrum of the Sample Viewed Under the Microscope to be Taken

Infrared Spectroscopy



Covalent bonds can be considered as springs which *absorb energy* as they *bend* and *stretch*.

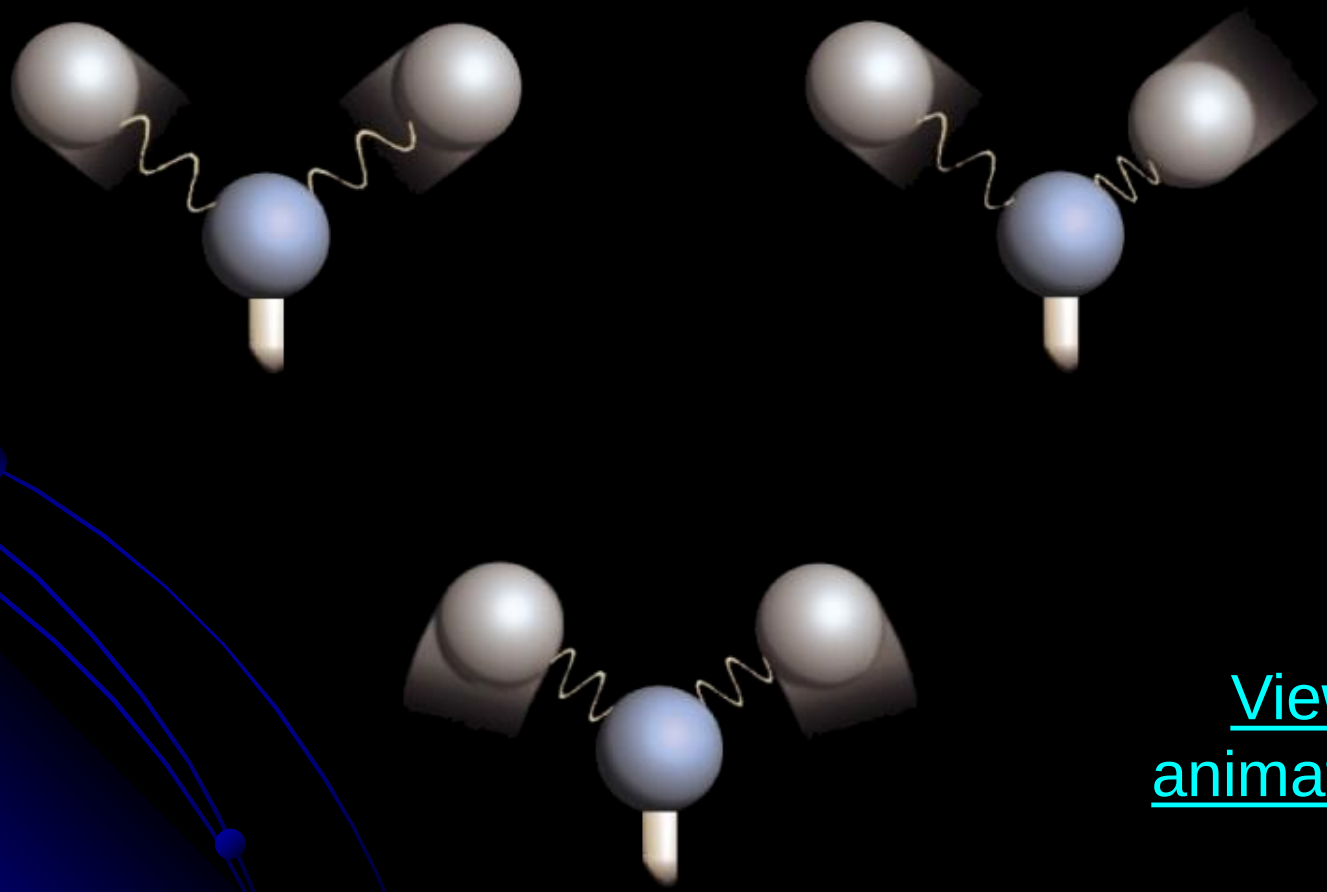
Infrared Spectroscopy



Molecular Vibrations

Infrared Spectroscopy

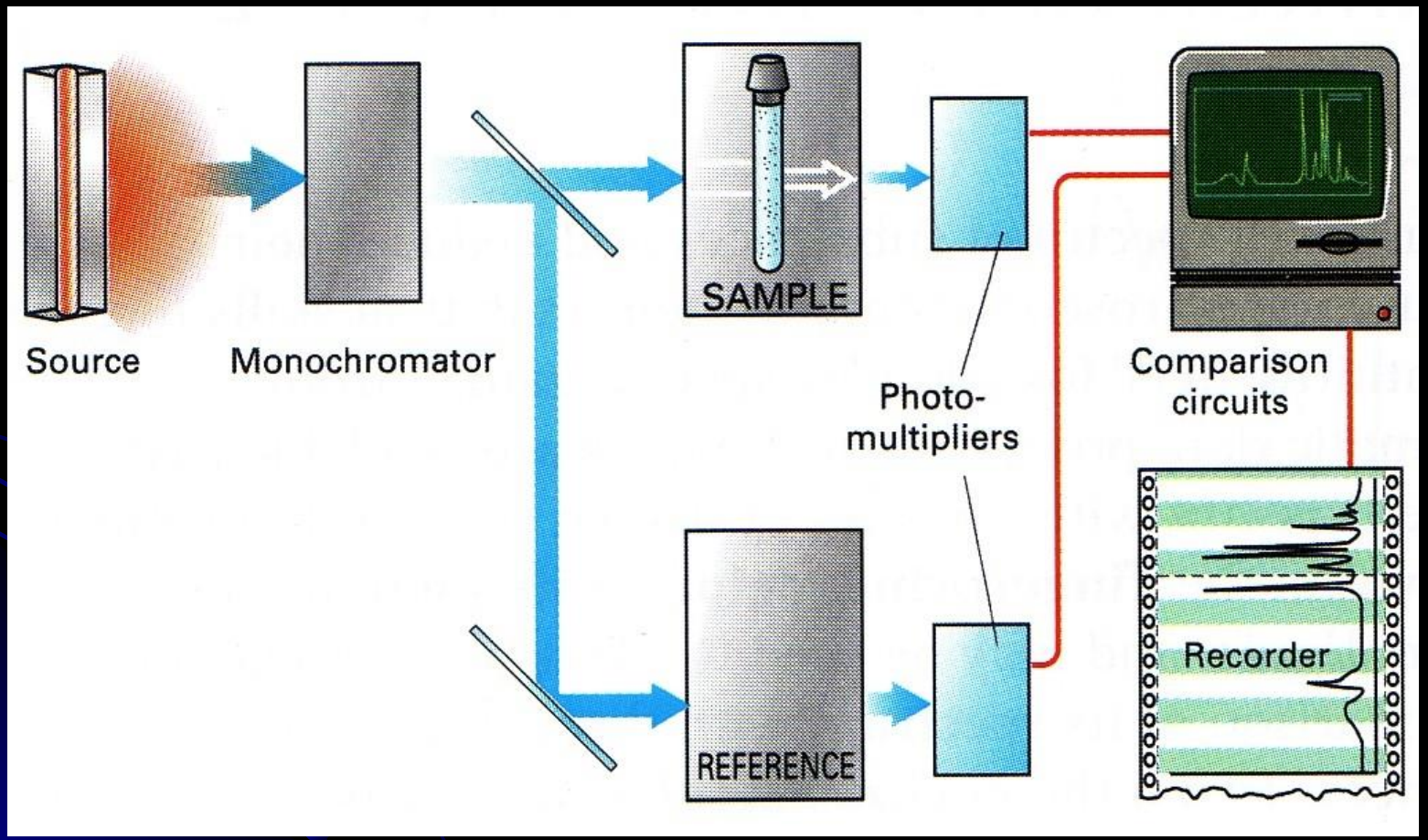
Molecular Vibrations



View animation.

Infrared Spectroscopy

The Components of an Infrared Spectrometer



Infrared Spectroscopy

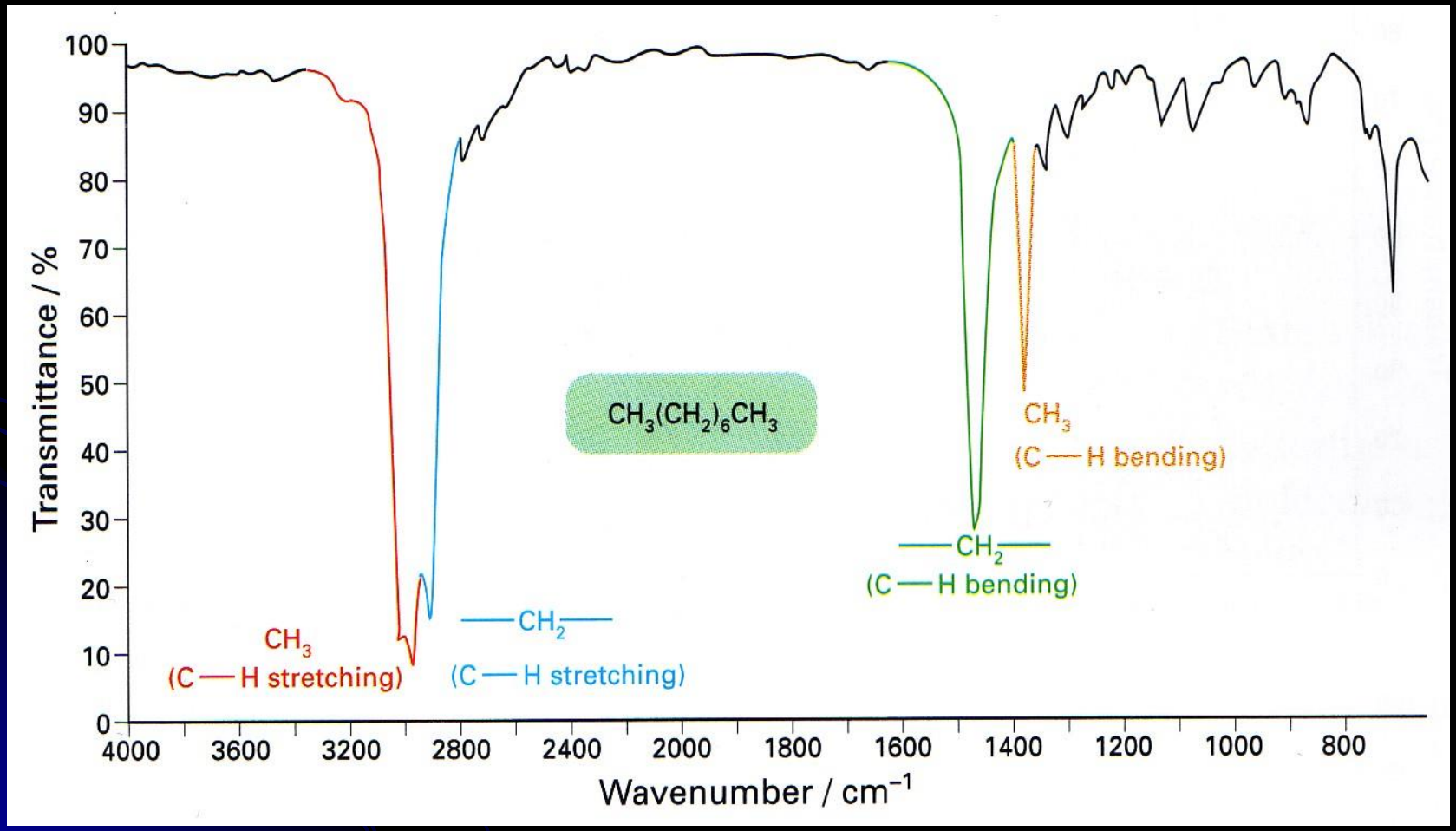
Table 13.4 Important IR Stretching Frequencies

Type of bond	Wavenumber (cm^{-1})	Intensity
C≡N	2260–2220	medium
C≡C	2260–2100	medium to weak
C=C	1680–1600	medium
C=N	1650–1550	medium
	~1600 and ~1500–1430	strong to weak
C=O	1780–1650	strong
C—O	1250–1050	strong
C—N	1230–1020	medium
O—H (alcohol)	3650–3200	strong, broad
O—H (carboxylic acid)	3300–2500	strong, very broad
N—H	3500–3300	medium, broad
C—H	3300–2700	medium

Table of Infrared Data

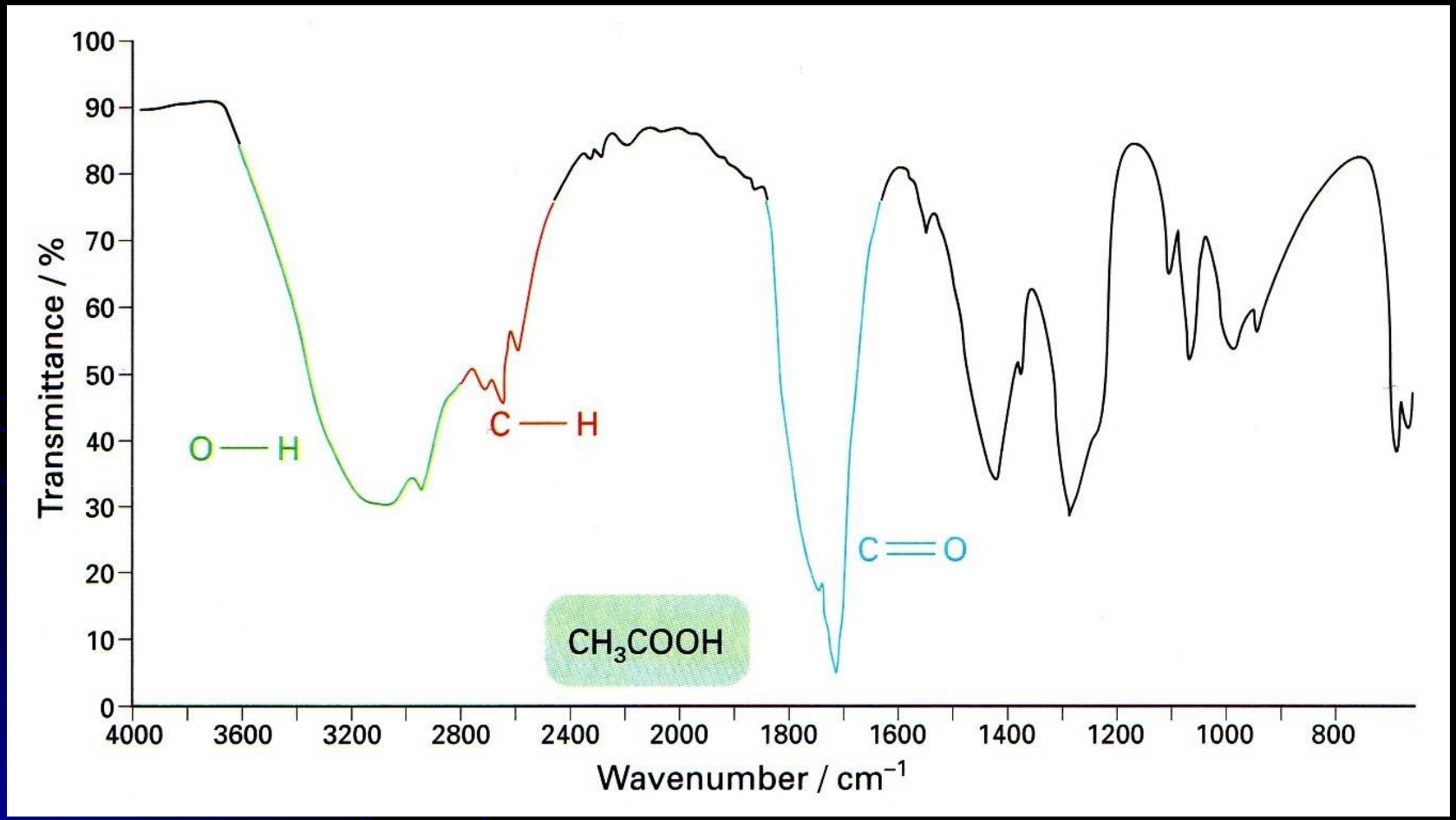
Infrared Spectroscopy

Octane – C_8H_{18}



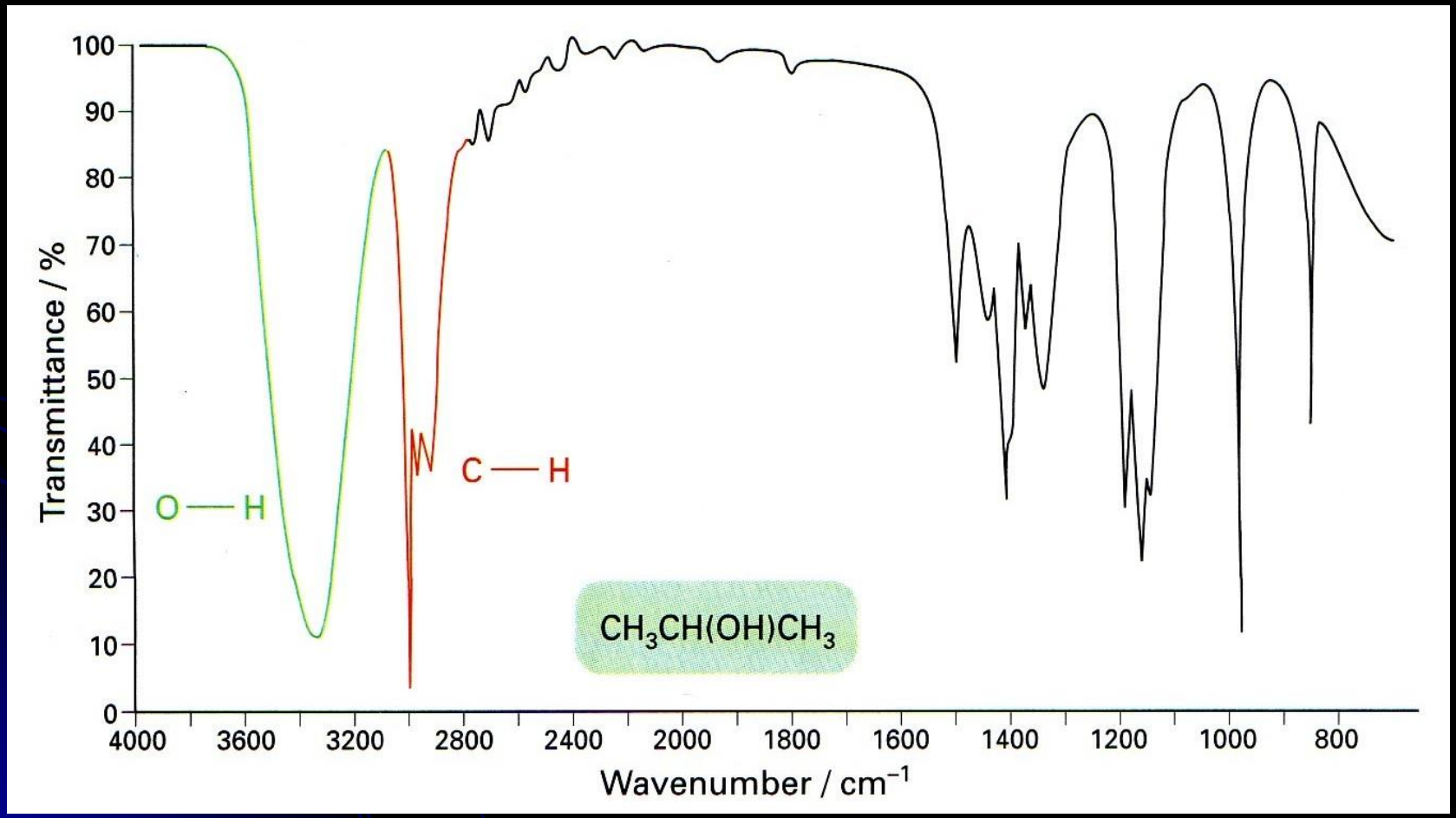
Infrared Spectroscopy

Ethanoic Acid – CH_3COOH



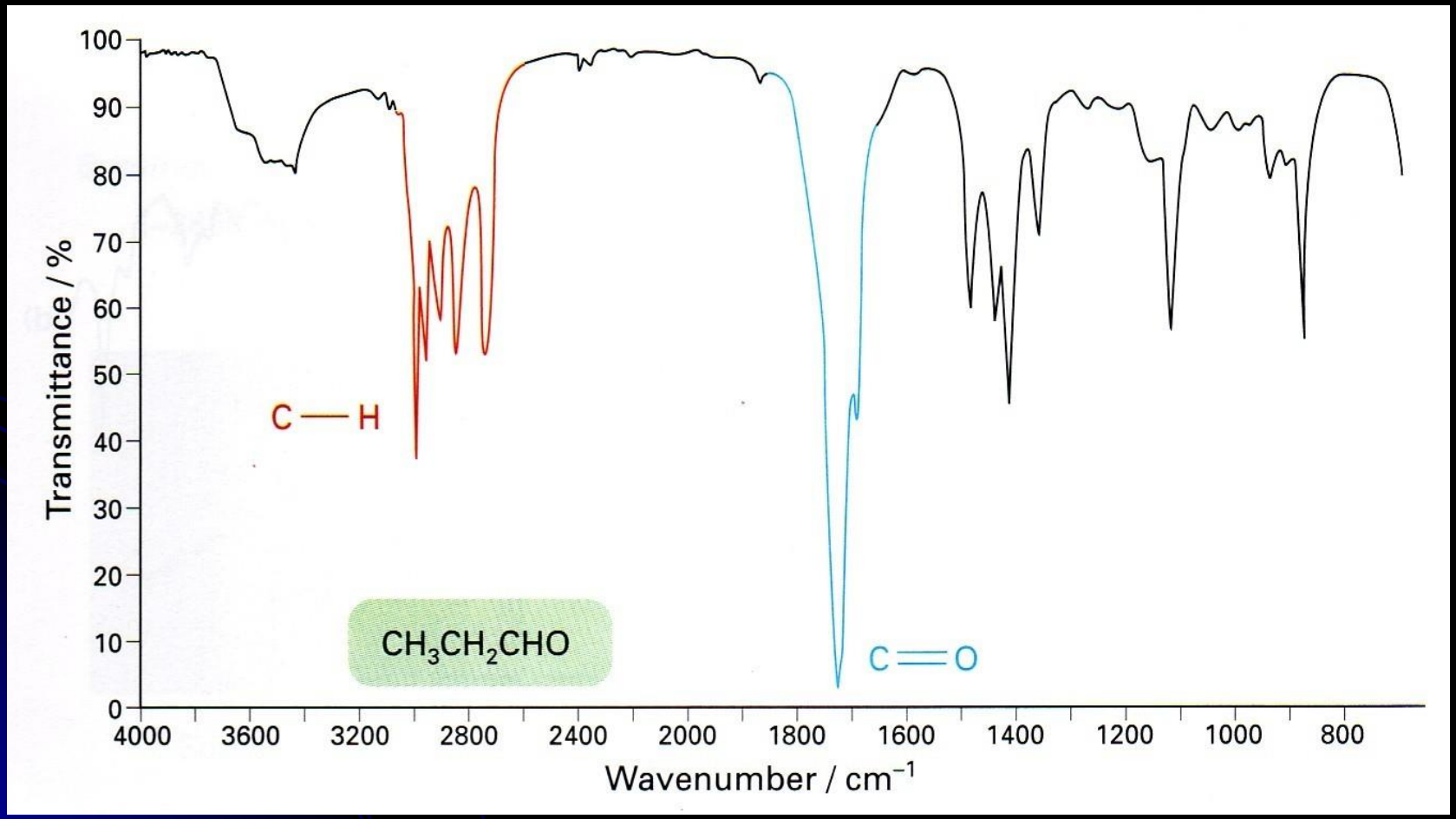
Infrared Spectroscopy

Propan-2-ol – $CH_3CH(OH)CH_3$



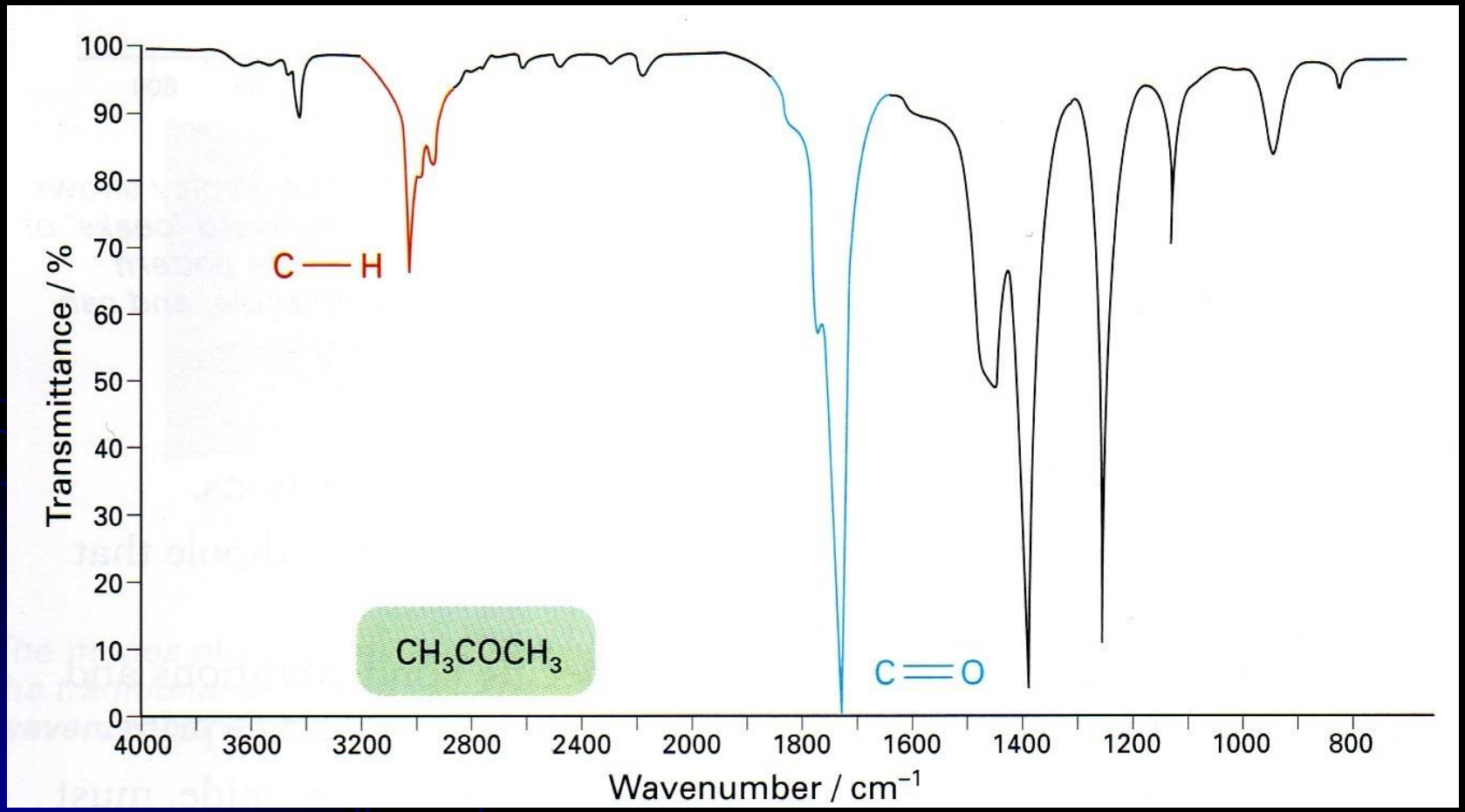
Infrared Spectroscopy

Propanal – CH_3CH_2CHO



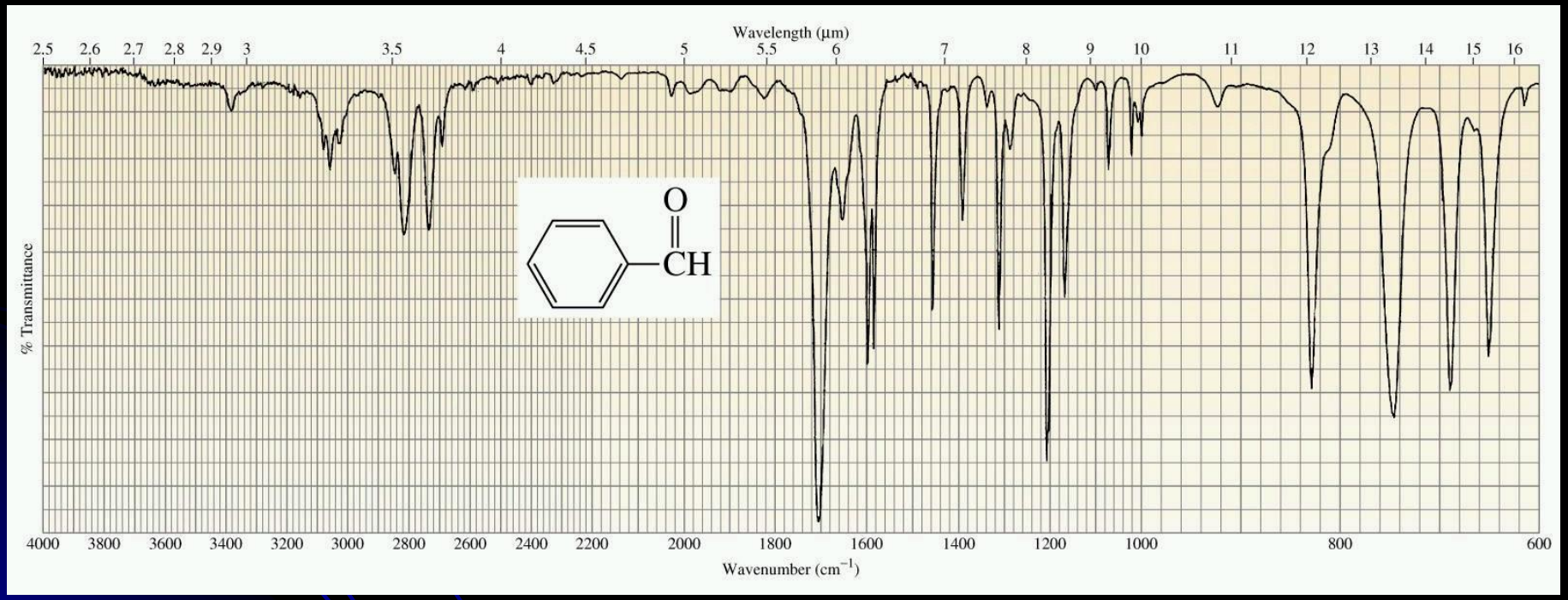
Infrared Spectroscopy

Propanone – CH_3COCH_3



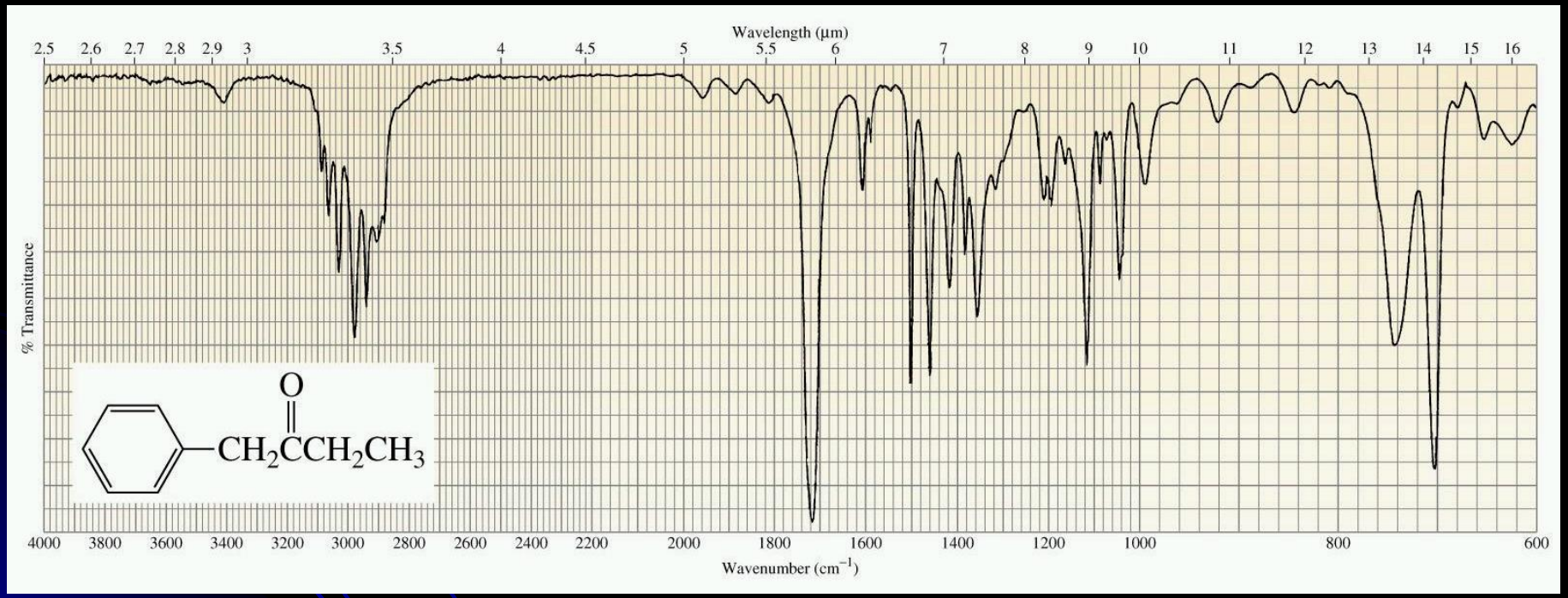
Infrared Spectroscopy

Further practice – identify the signals in the IR spectrum of Benzaldehyde – C_6H_5CHO



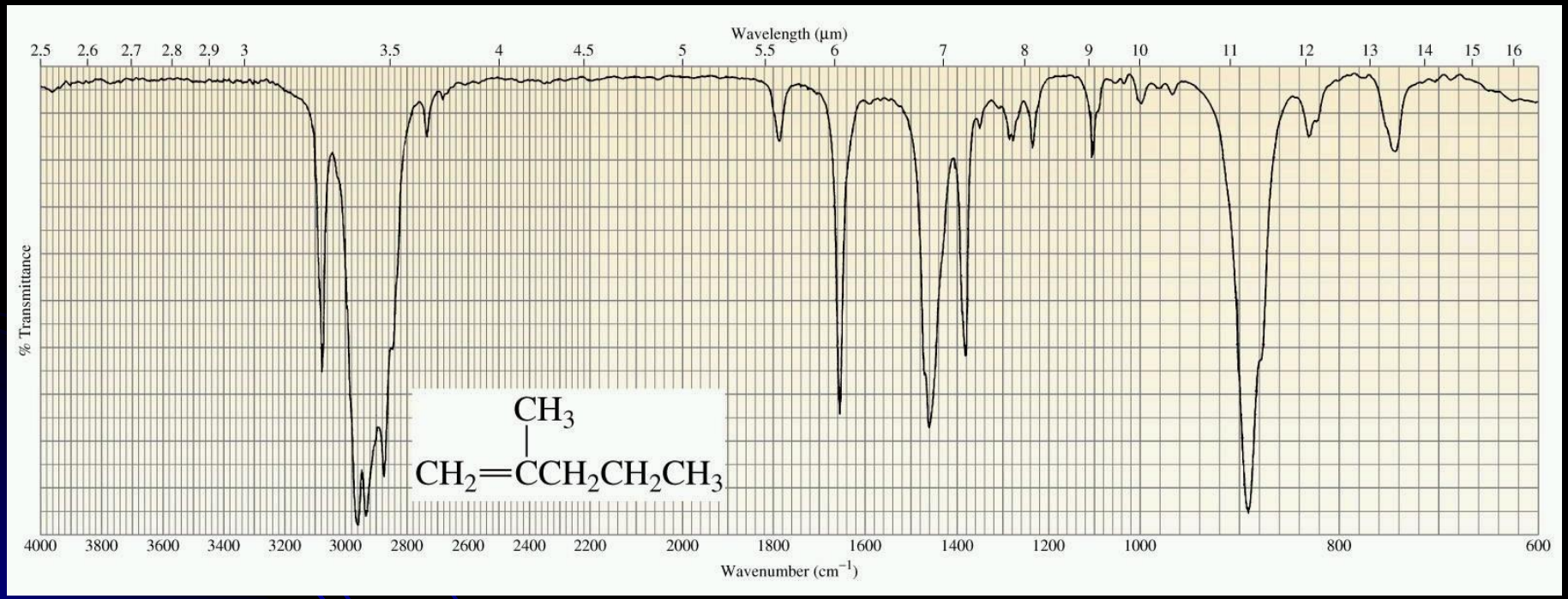
Infrared Spectroscopy

Further practice – identify the signals in the IR spectrum of 1-Phenylbutan-2-one – $C_6H_5CH_2COCH_2CH_3$



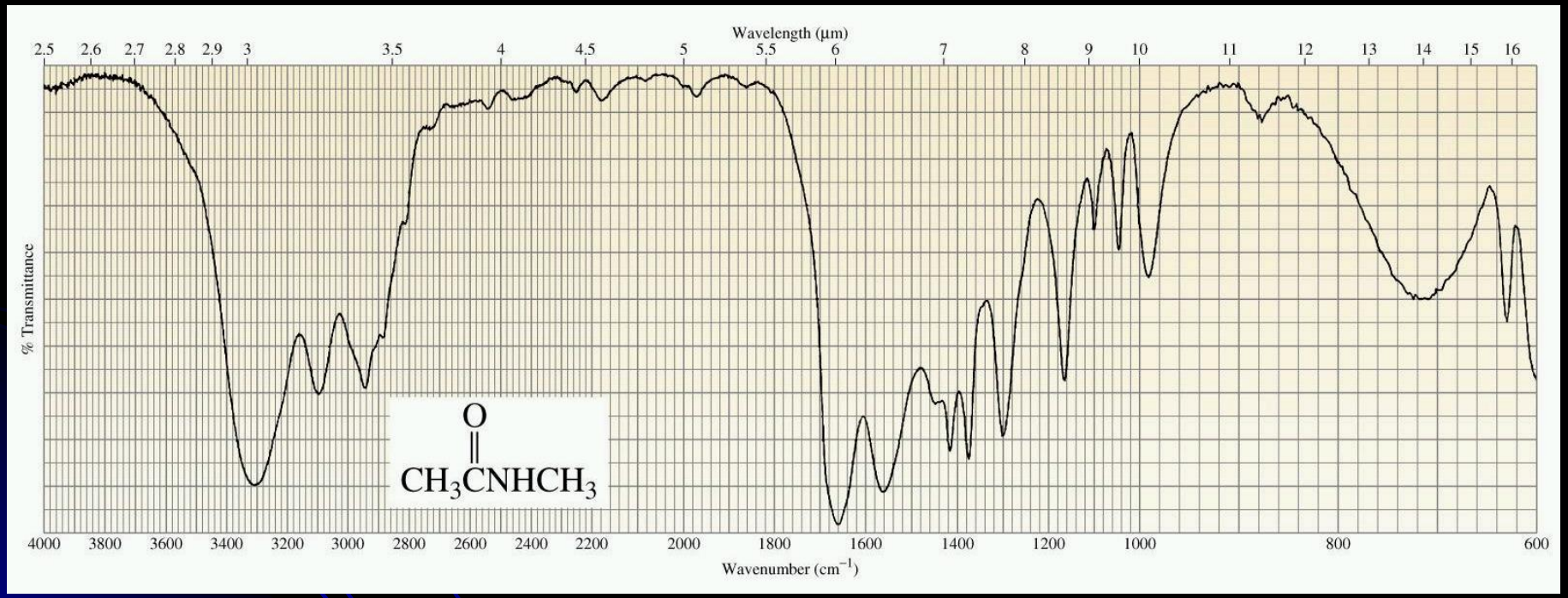
Infrared Spectroscopy

Further practice – identify the signals in the IR spectrum of 2-Methylpent-1-ene – $CH_2C(CH_3)CH_2CH_2CH_3$



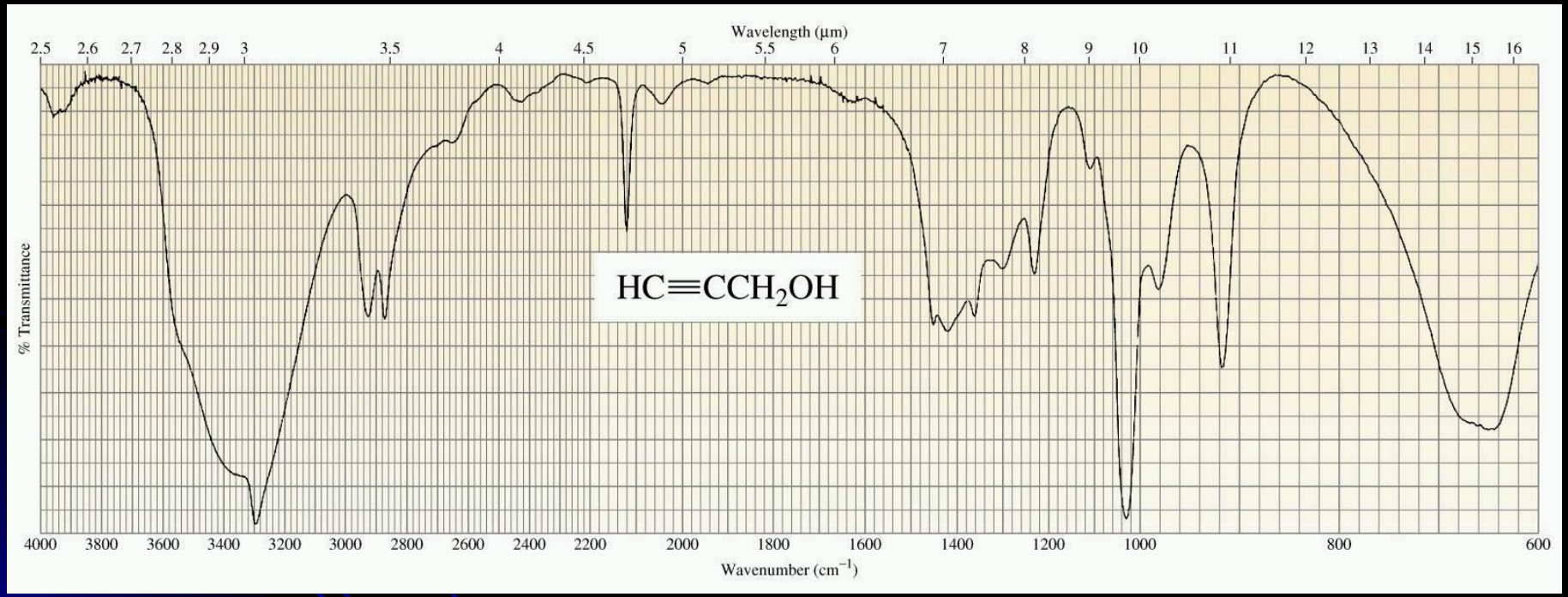
Infrared Spectroscopy

Further practice – identify the signals in the IR spectrum of N-Methyl Ethanamide – $CH_3CONHCH_3$



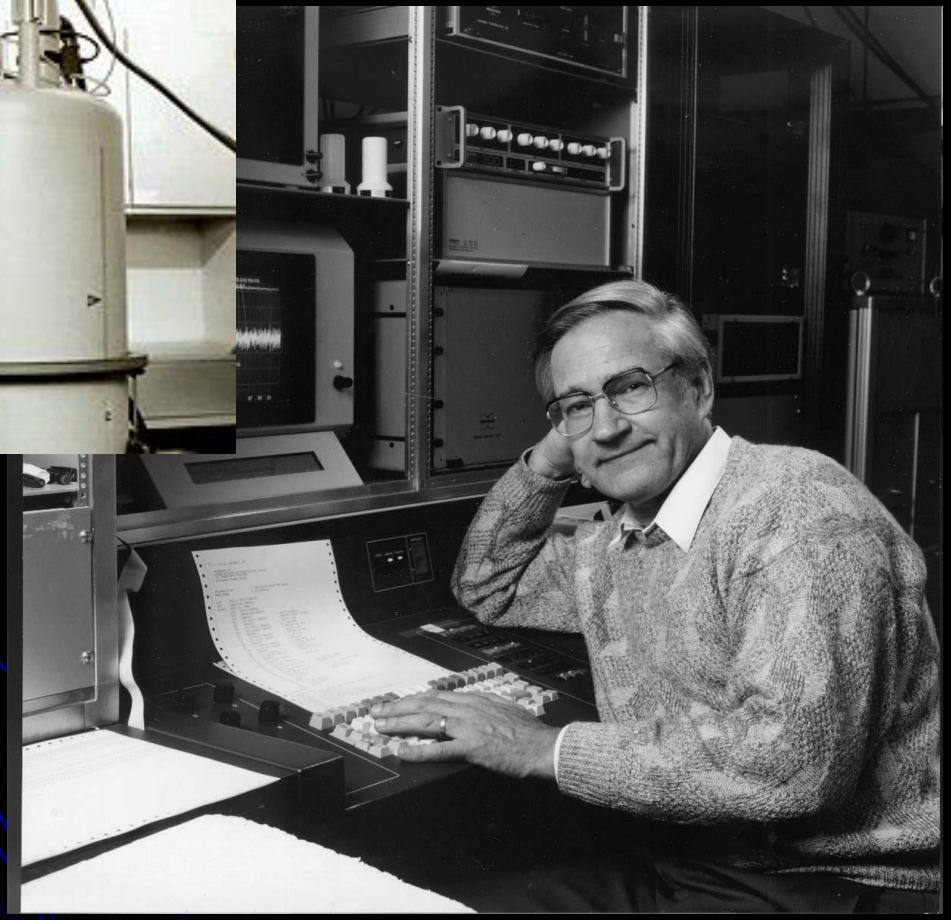
Infrared Spectroscopy

Further practice – identify the signals in the IR spectrum of Prop-2-yn-1-ol – $HCCCH_2OH$



^{1}H Nuclear Magnetic Resonance (NMR) Spectroscopy

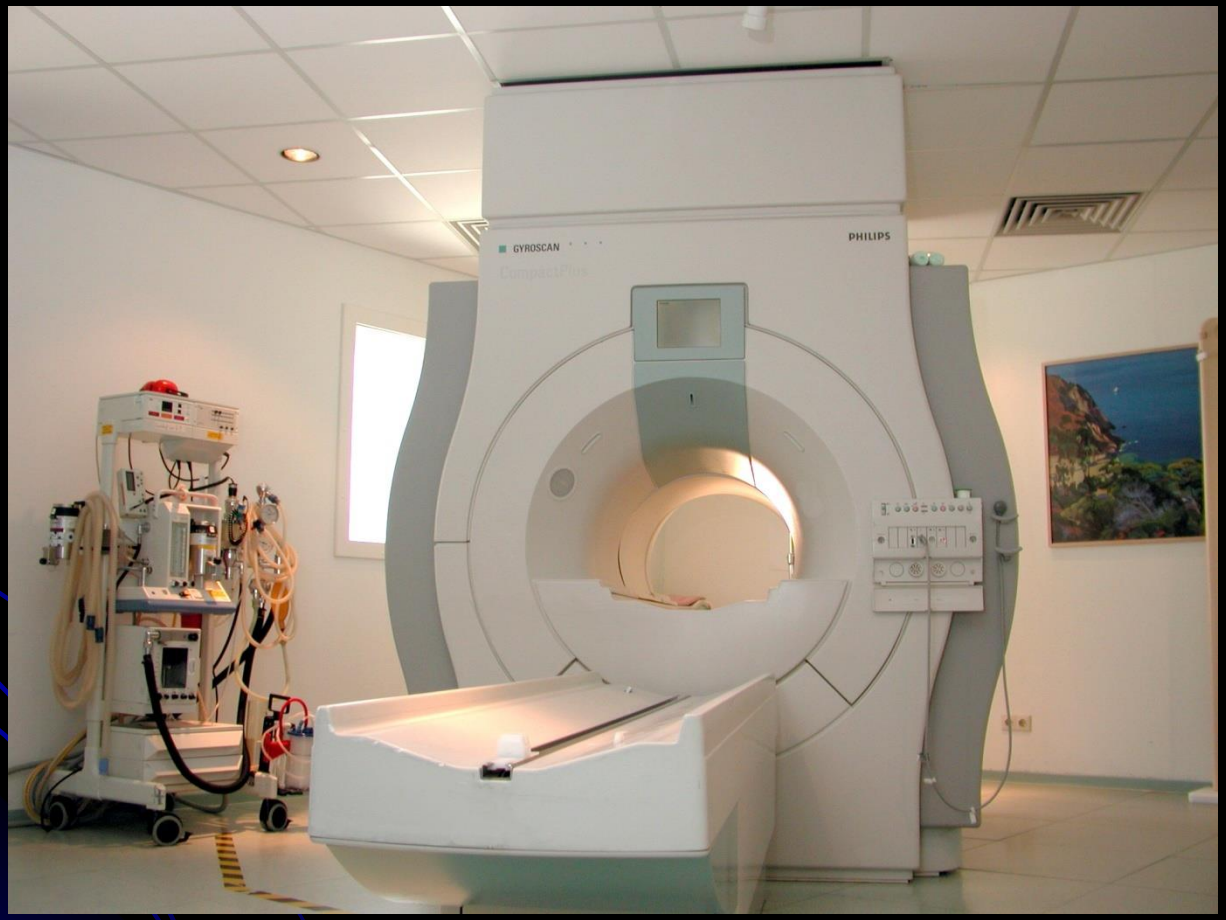
Nuclear Magnetic Resonance (NMR)



Richard Ernst
(Born 1933)
Awarded the Nobel Prize for Chemistry in 1991.

Magnetic Resonance Imaging (MRI)

A whole body MRI scanner located in a hospital's radiography unit:

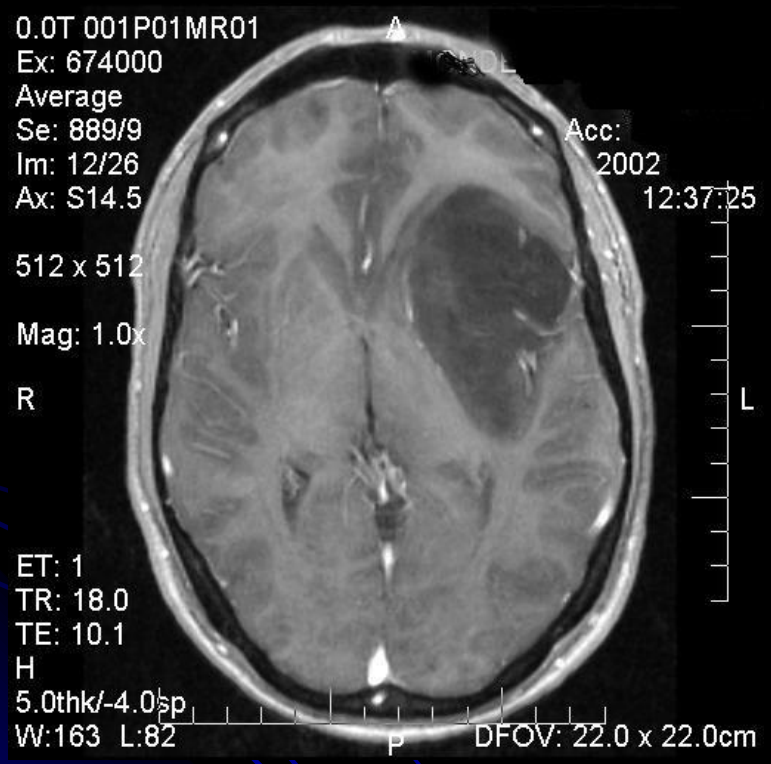


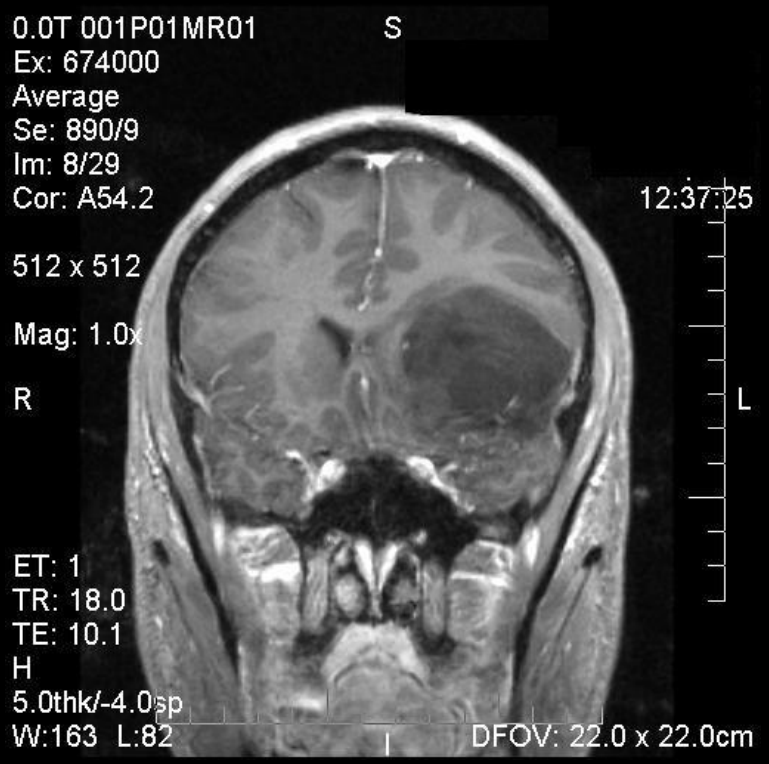
Magnetic Resonance Imaging (MRI)

The monitor of the MRI scanner showing the results of a complete body scan:

Magnetic Resonance Imaging (MRI)

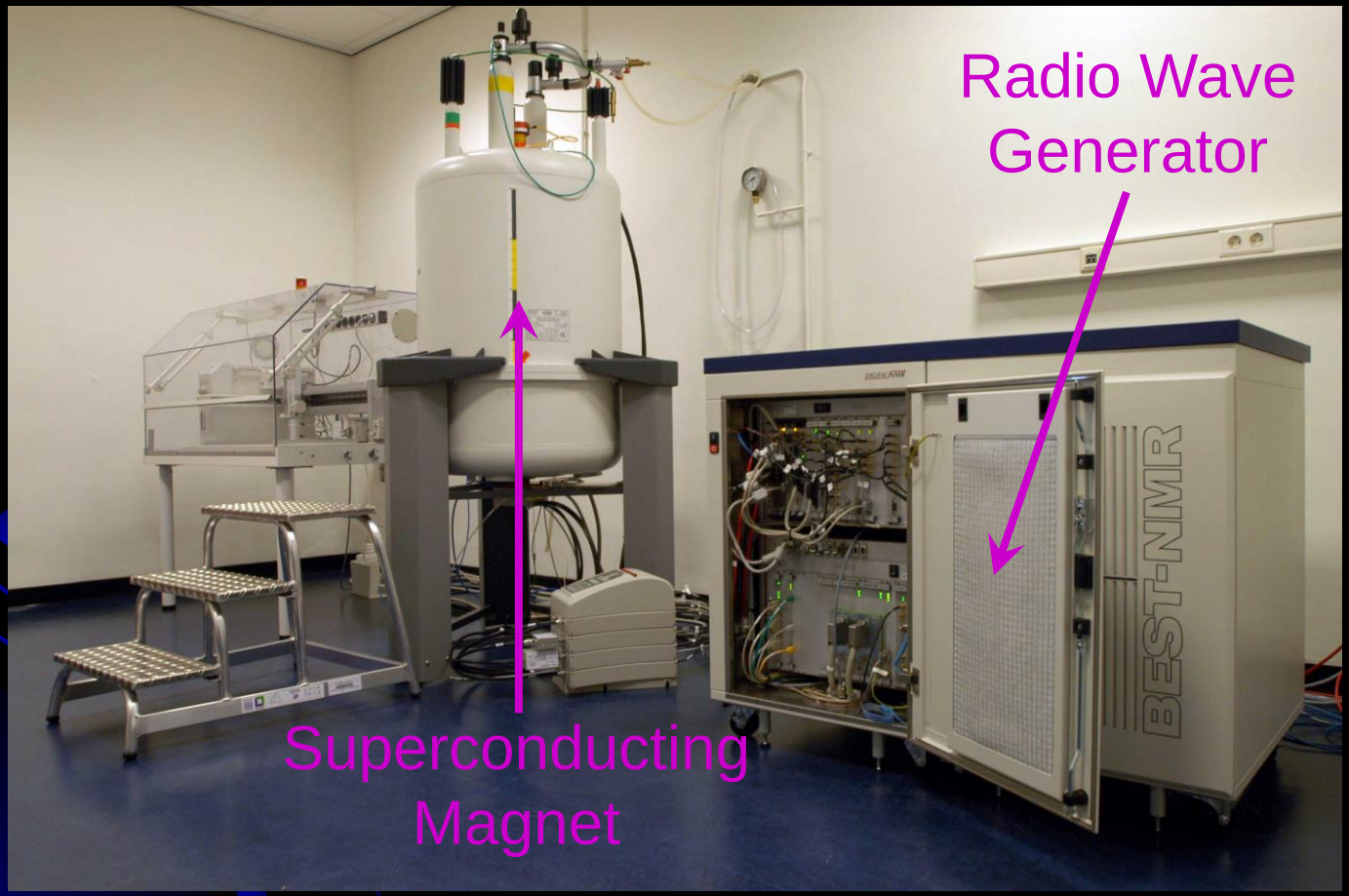
The results of an MRI brain scan showing a large tumour in the right cerebral cortex:





Nuclear Magnetic Resonance (NMR)

An NMR Spectrometer:



View animation.

Nuclear Magnetic Resonance (NMR)

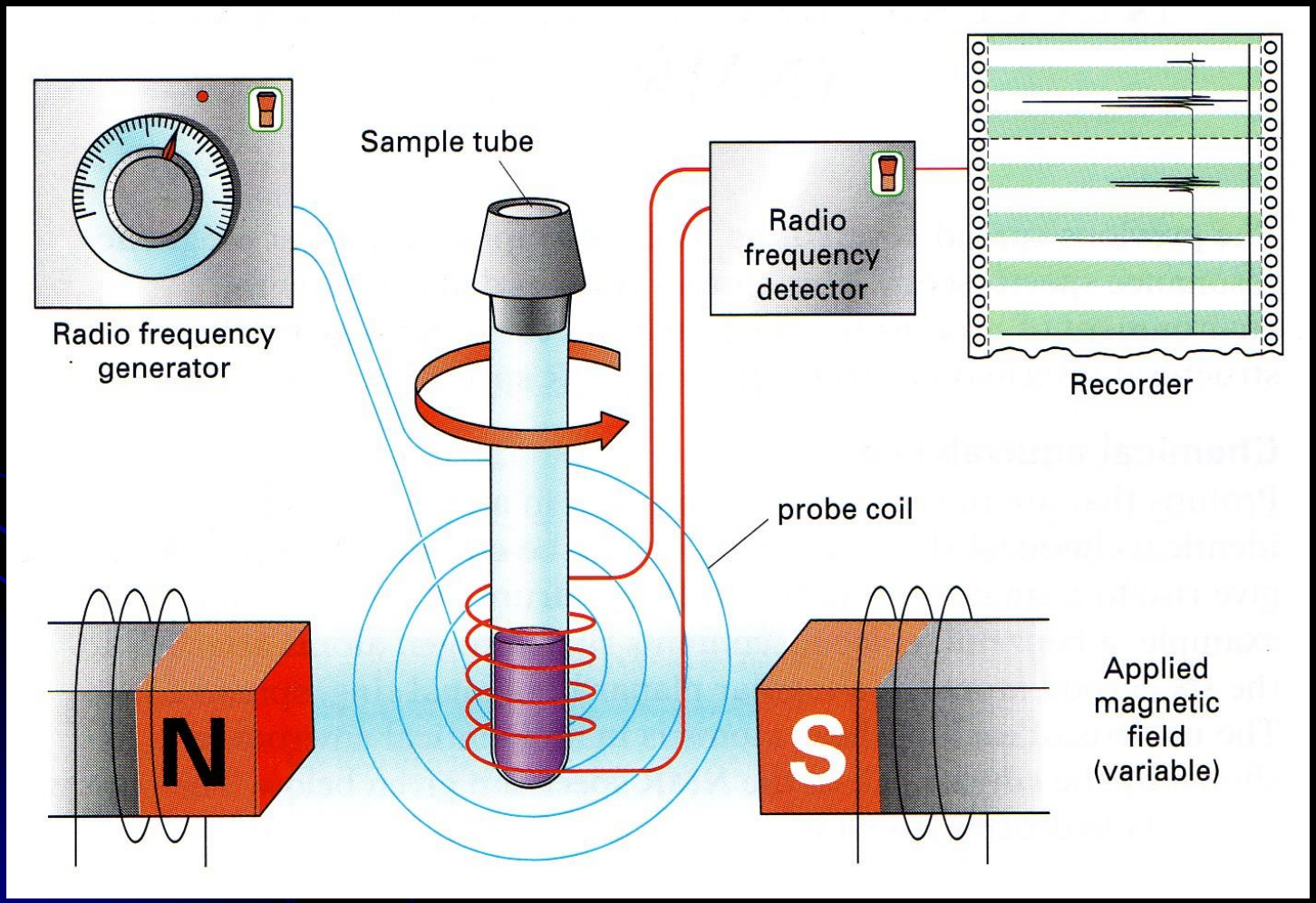
What are the hazards associated with operating an NMR spectrometer?

STUDENT ADVISORY

ADVANCED CONCEPTS

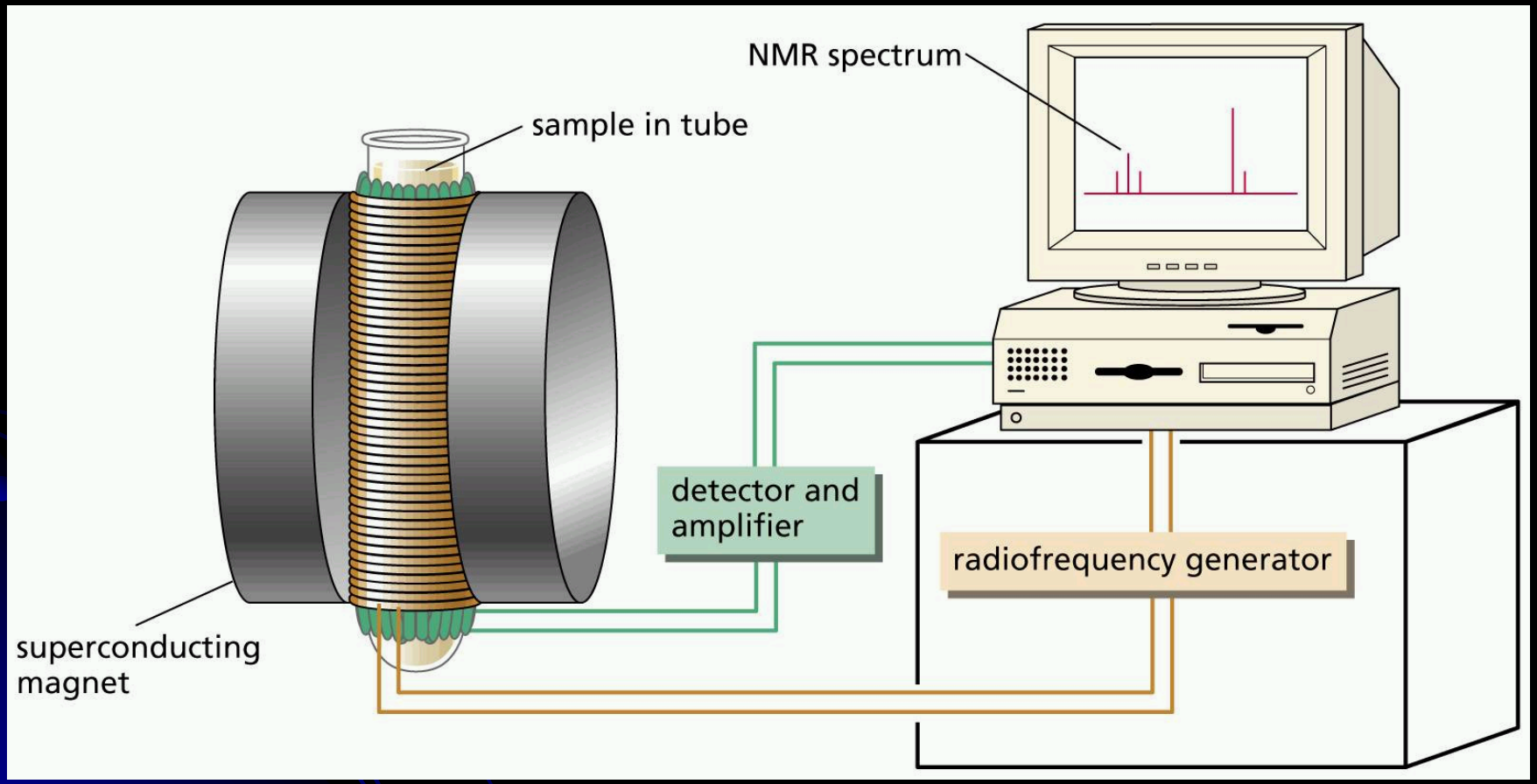
Nuclear Magnetic Resonance (NMR)

The Components of an NMR Spectrometer #1



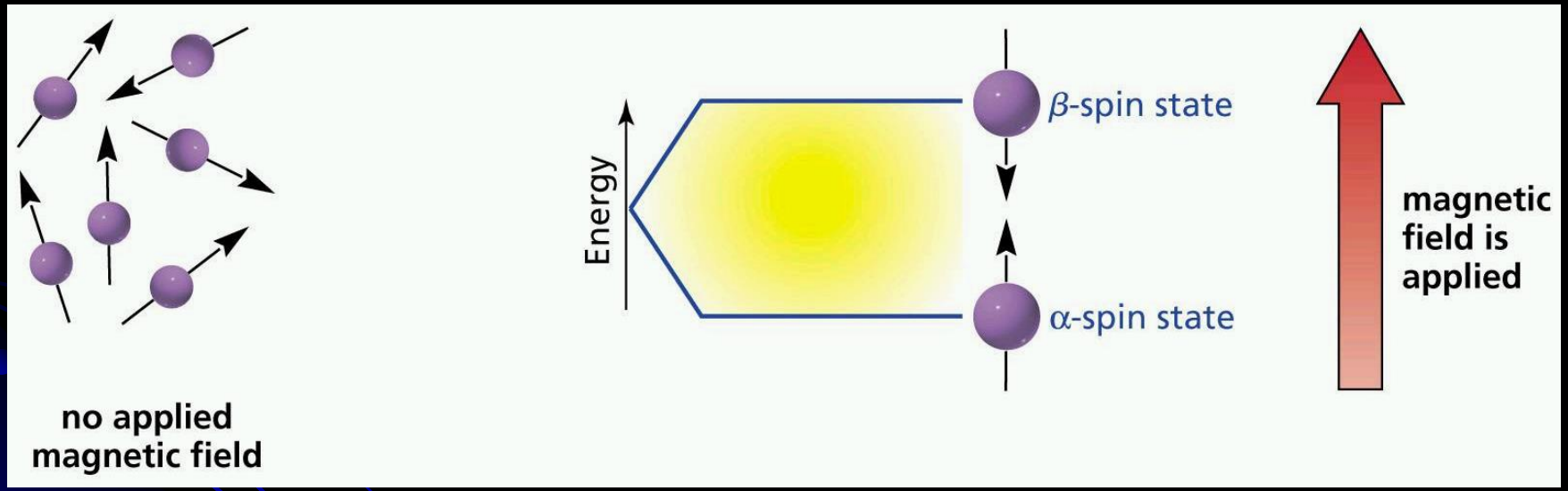
Nuclear Magnetic Resonance (NMR)

The Components of an NMR Spectrometer #2



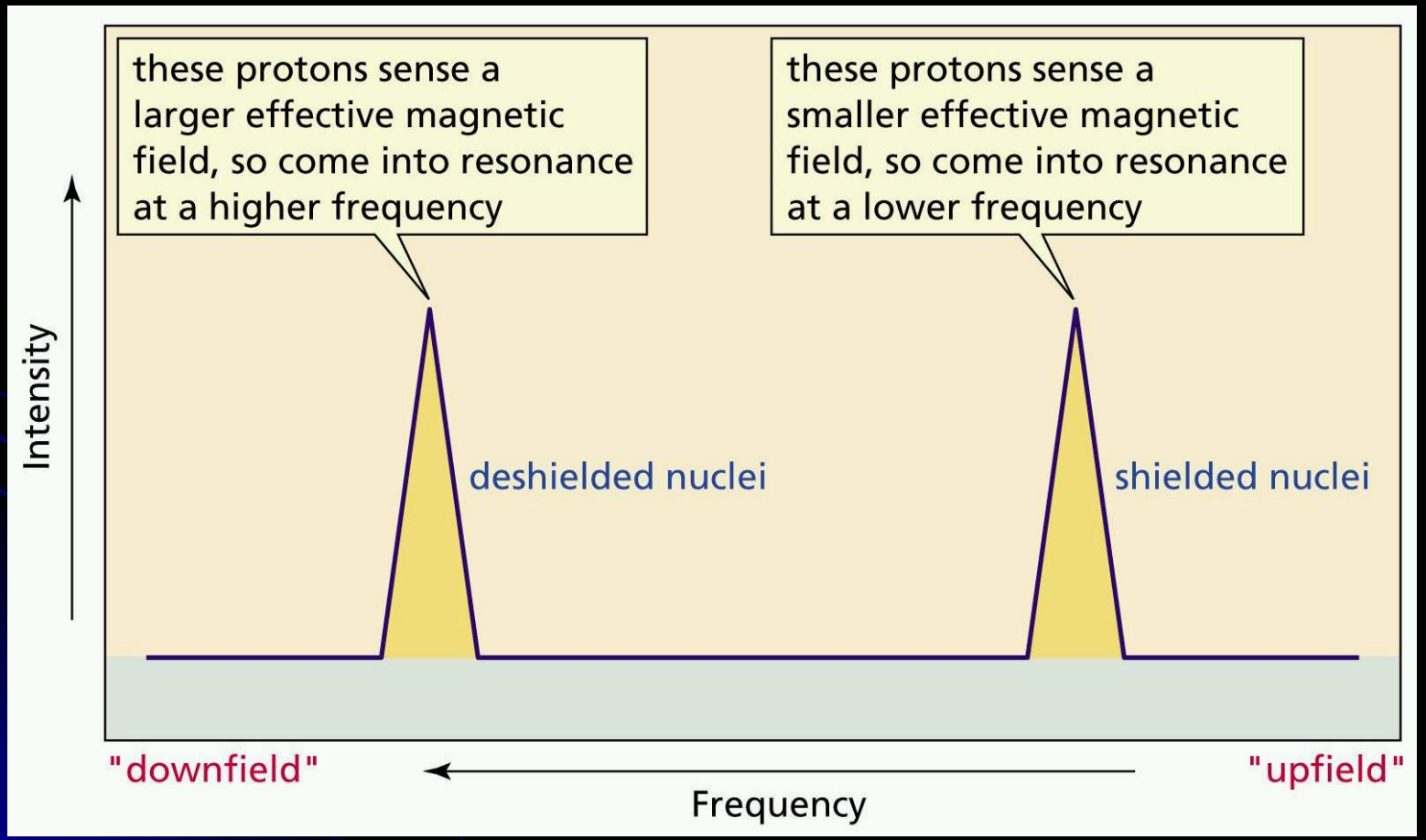
Nuclear Magnetic Resonance (NMR)

Principles of ^{1}H NMR Spectroscopy



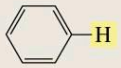
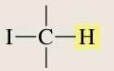
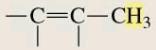
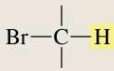
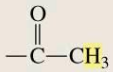
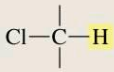
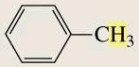
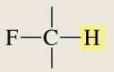
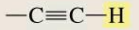
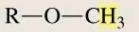
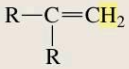
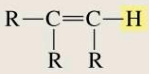
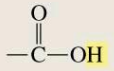
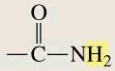
Nuclear Magnetic Resonance (NMR)

The Relative Positions of "Shielded" and "Deshielded" ^{1}H Nuclei in a ^{1}H NMR Spectrum



Nuclear Magnetic Resonance (NMR)

Table 14.1 Approximate Values of Chemical Shifts for ^{1}H NMR[a]

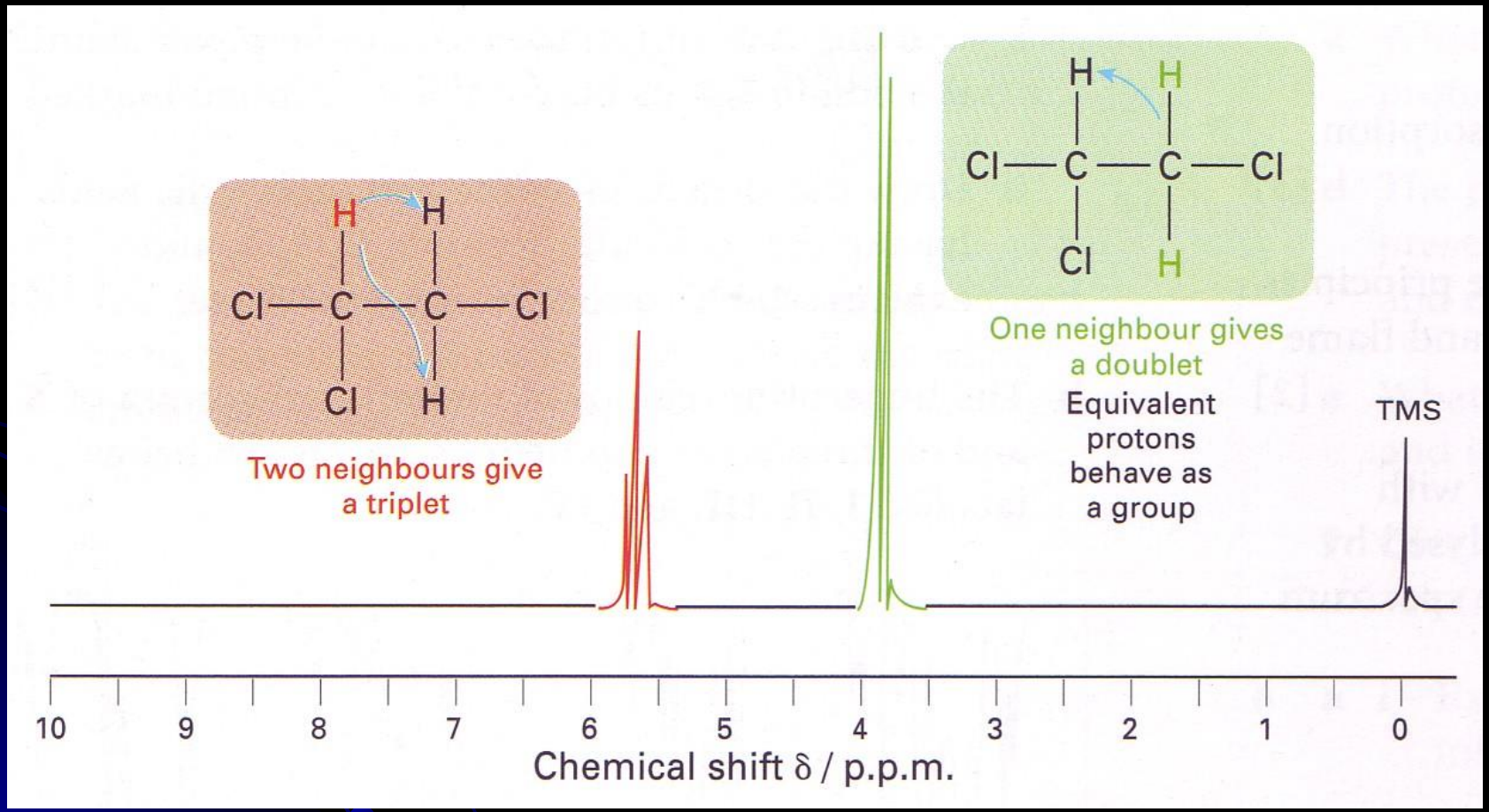
Type of proton	Approximate chemical shift (ppm)	Type of proton	Approximate chemical shift (ppm)
$(CH_3)_4Si$	0		6.5–8
$-CH_3$	0.9		
$-CH_2-$	1.3		9.0–10
	1.4		2.5–4
	1.7		
			2.5–4
	2.1		
			3–4
	2.3		
			4–4.5
	2.4		
	3.3	RNH_2	Variable, 1.5–4
	4.7	ROH	Variable, 2–5
		ArOH	Variable, 4–7
	5.3		Variable, 10–12
			Variable, 5–8

[a]The values are approximate because they are affected by neighboring substituents.

Table of Chemical Shifts for ^{1}H NMR Spectroscopy

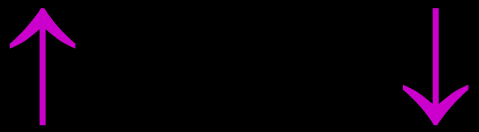
Nuclear Magnetic Resonance (NMR)

1,1,2-Trichloroethane – $CHCl_2CH_2Cl$



Nuclear Magnetic Resonance (NMR)

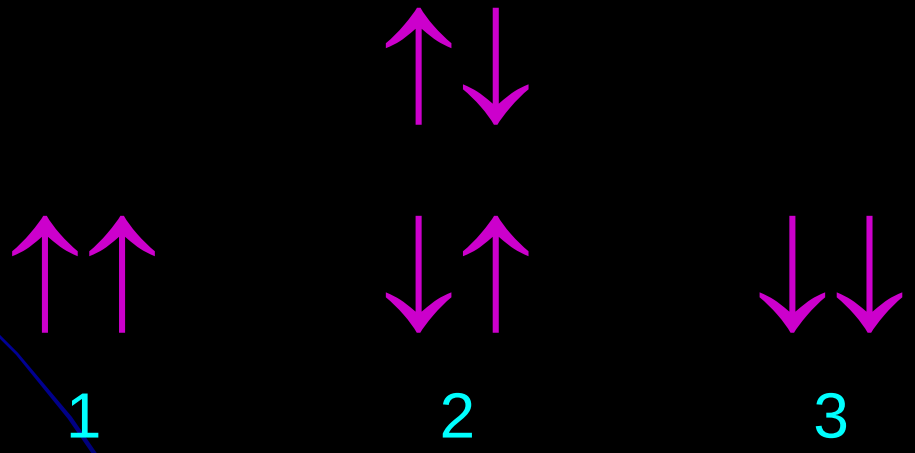
One ^{1}H nucleus (-C*H*-) can spin on its axis in *two* possible ways, and consequently split the signal of any neighbouring ^{1}H nuclei into *two* peaks (called a *doublet*):



1 2

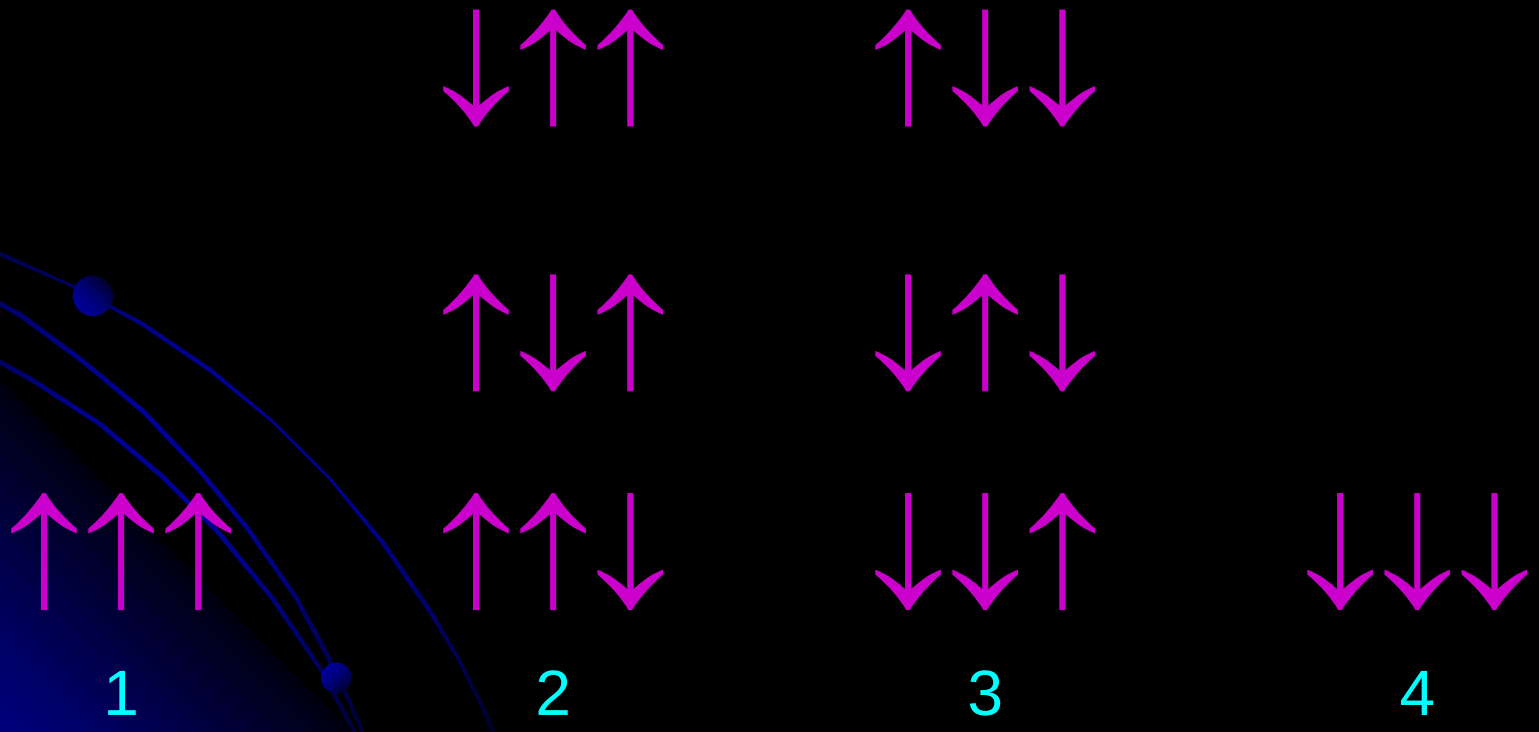
Nuclear Magnetic Resonance (NMR)

Two ^{1}H nuclei (-CH_2-) can spin on their axes in *three* possible combinations, and consequently split the signal of any neighbouring ^{1}H nuclei into *three* peaks (called a *triplet*):



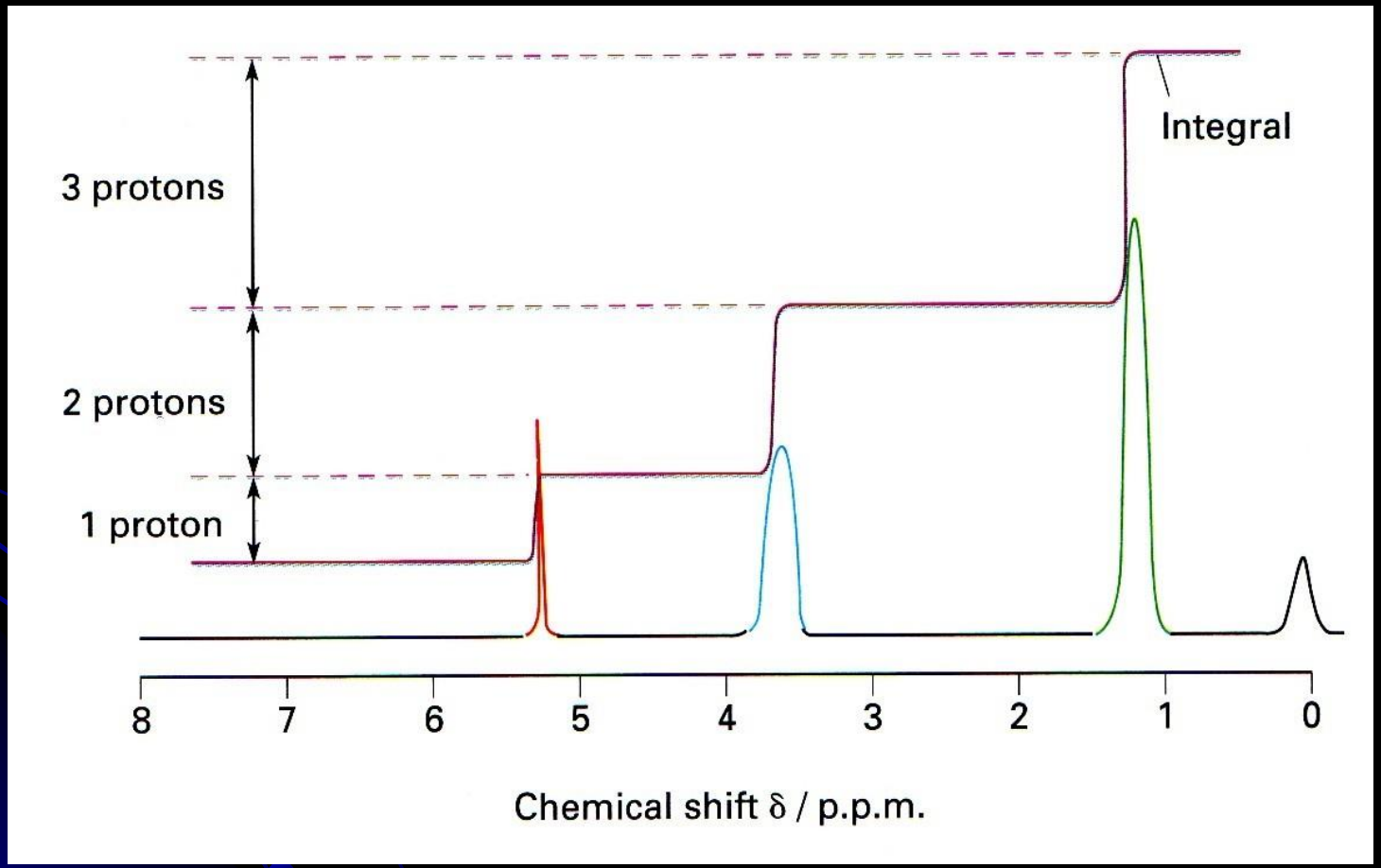
Nuclear Magnetic Resonance (NMR)

Three ^{1}H nuclei (-CH_3) can spin on their axes in *four* possible combinations, and consequently split the signal of any neighbouring ^{1}H nuclei into *four* peaks (called a *quartet*):



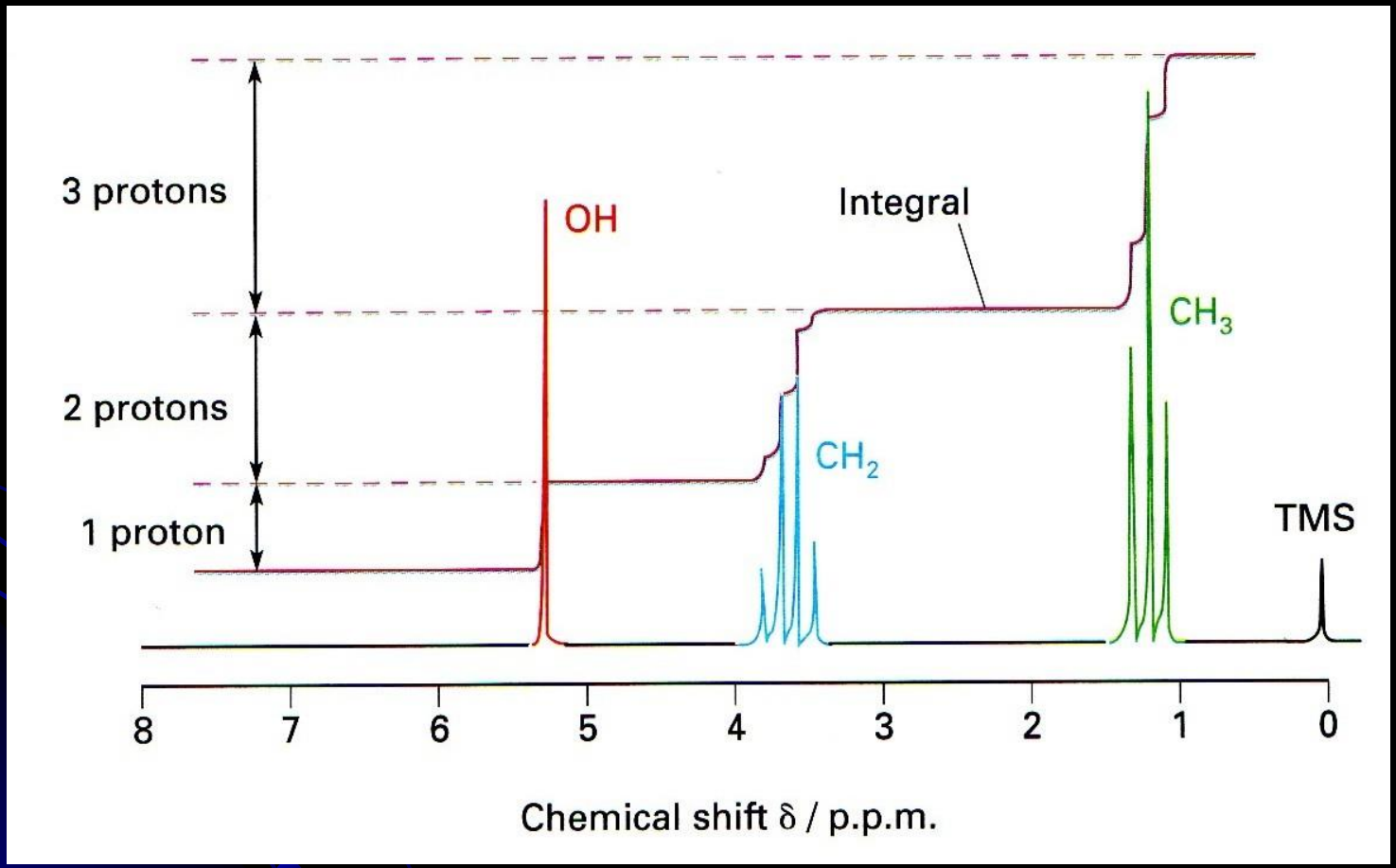
Nuclear Magnetic Resonance (NMR)

Ethanol – CH_3CH_2OH (Low Resolution)



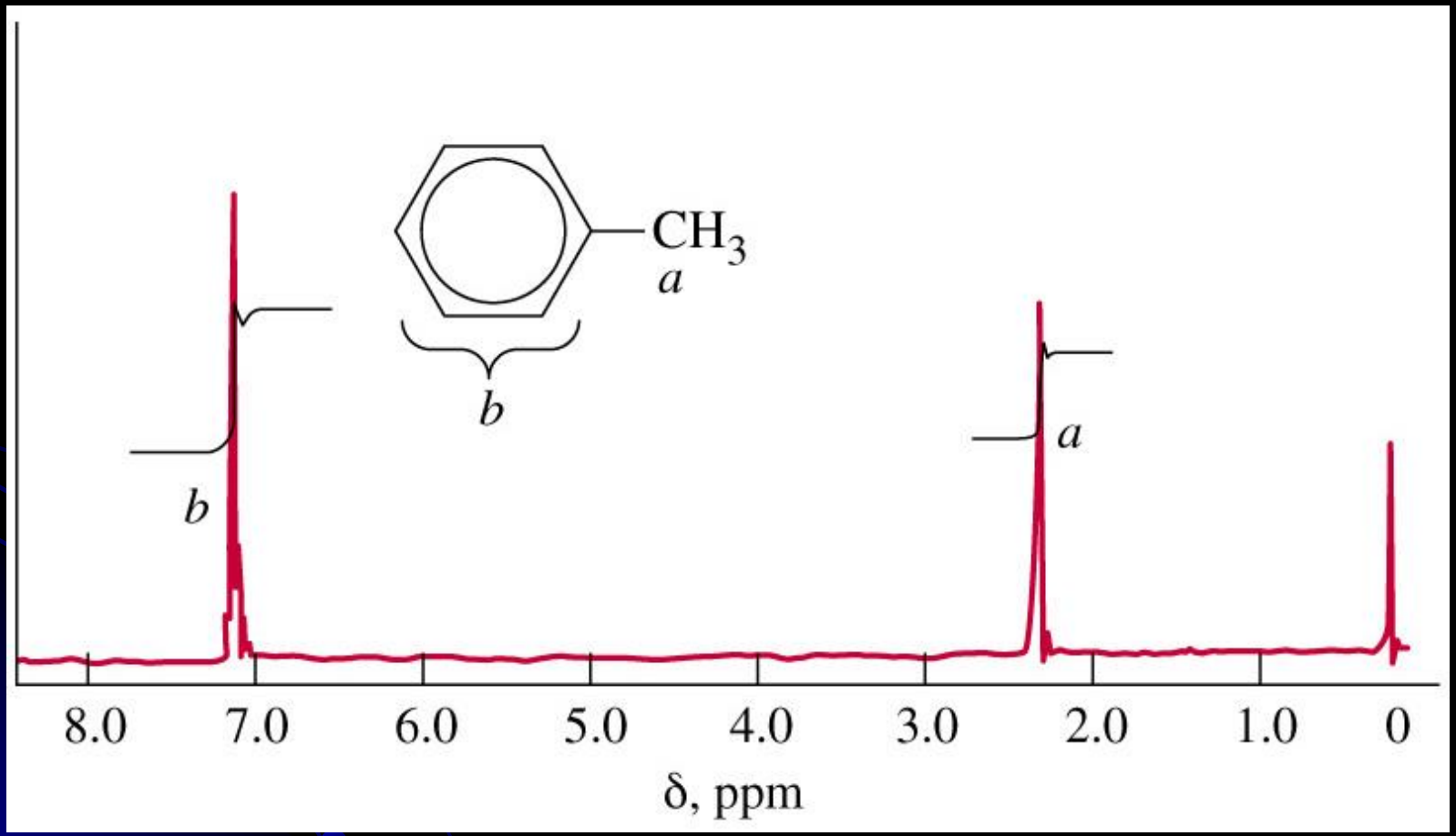
Nuclear Magnetic Resonance (NMR)

Ethanol – CH_3CH_2OH (High Resolution)



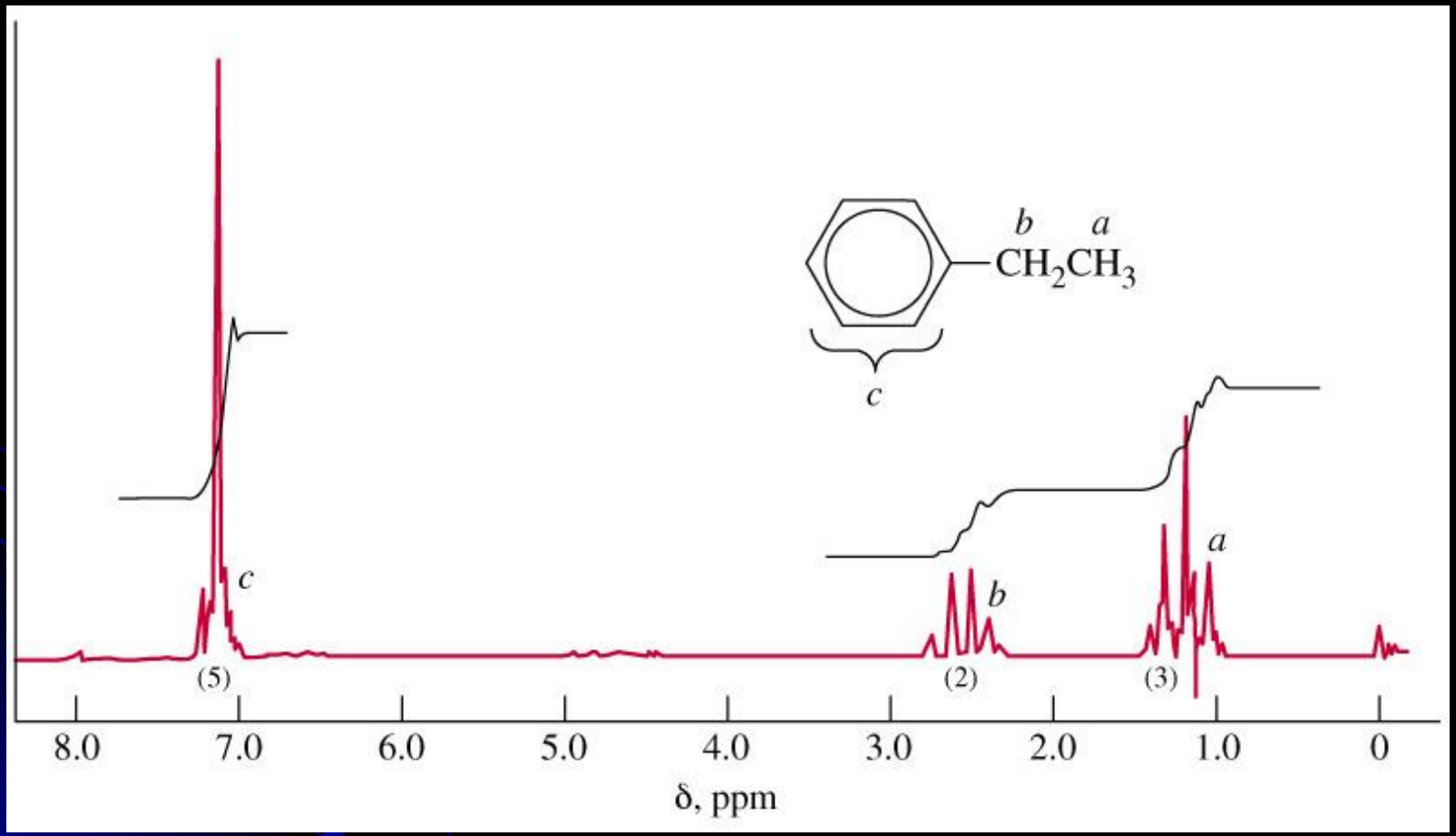
Nuclear Magnetic Resonance (NMR)

Methylbenzene – $C_6H_5CH_3$



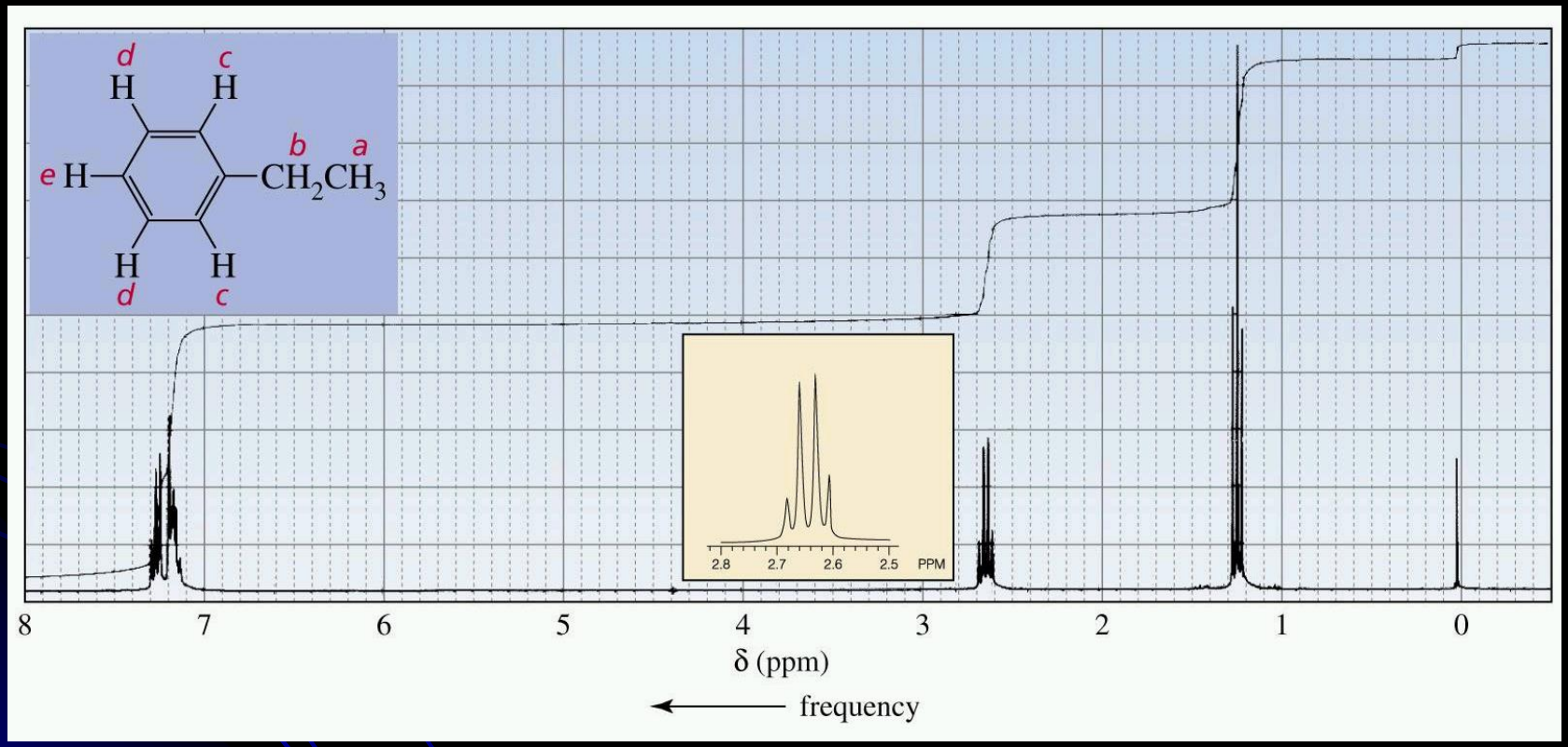
Nuclear Magnetic Resonance (NMR)

Ethylbenzene – $C_6H_5CH_2CH_3$



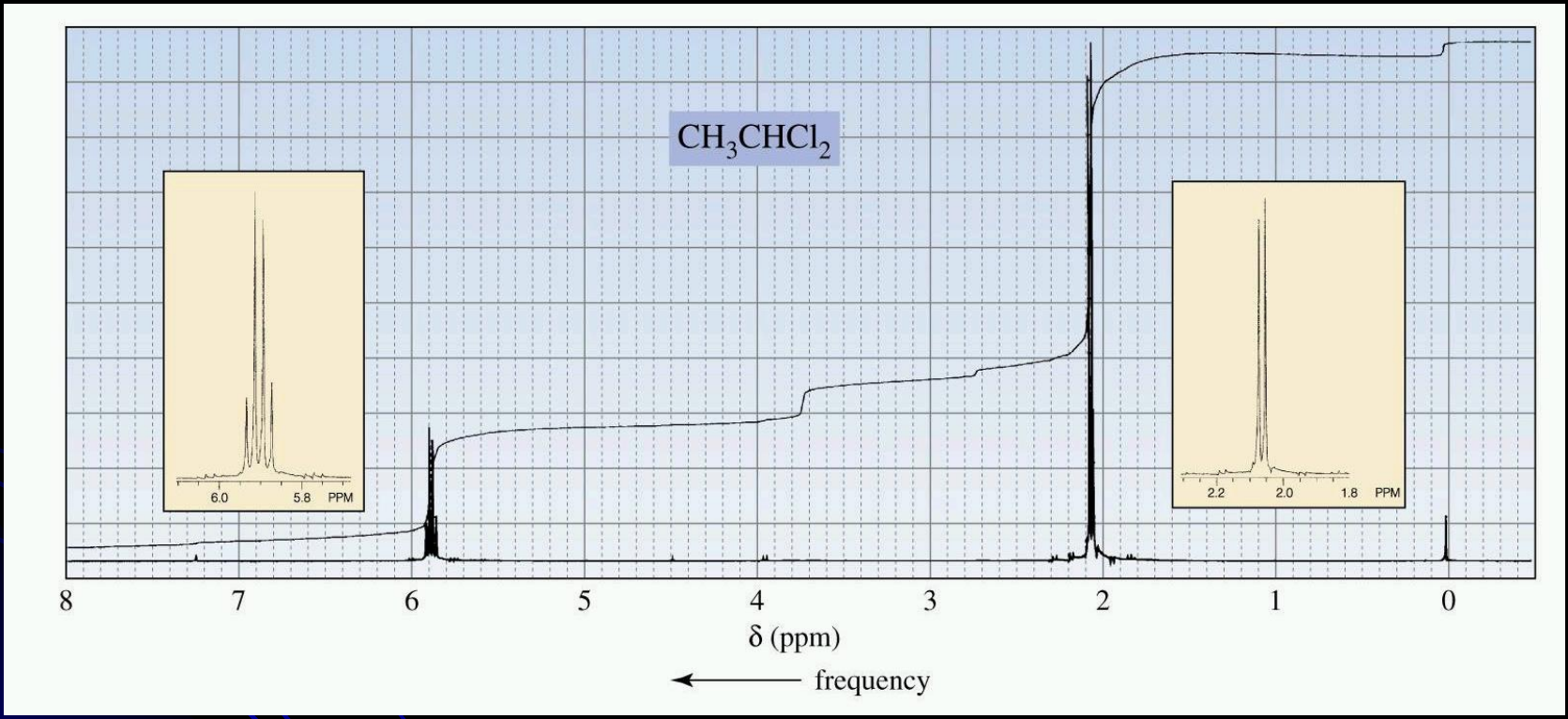
Nuclear Magnetic Resonance (NMR)

Ethylbenzene – $C_6H_5CH_2CH_3$



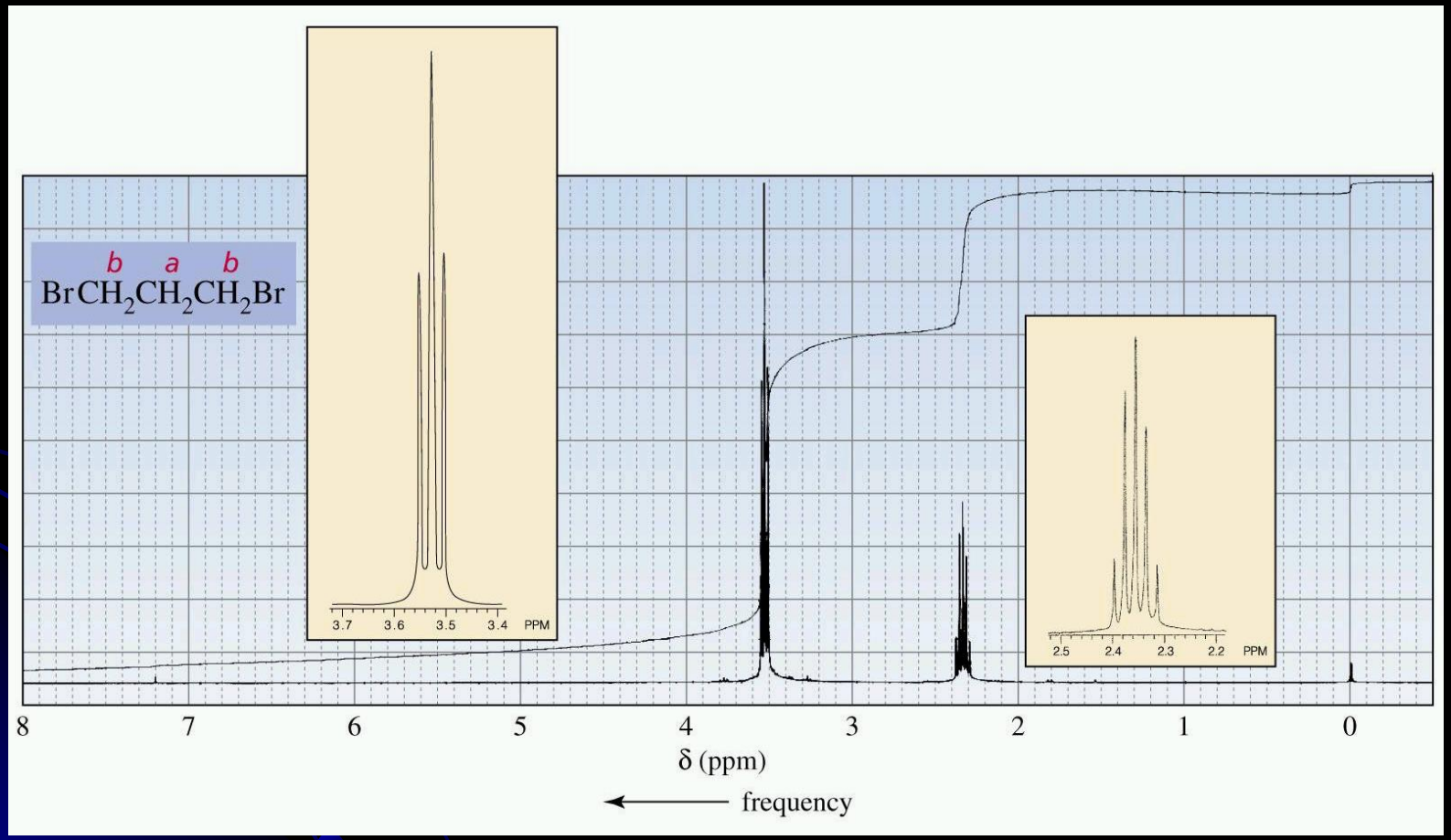
Nuclear Magnetic Resonance (NMR)

1,1-Dichloroethane – CH_3CHCl_2



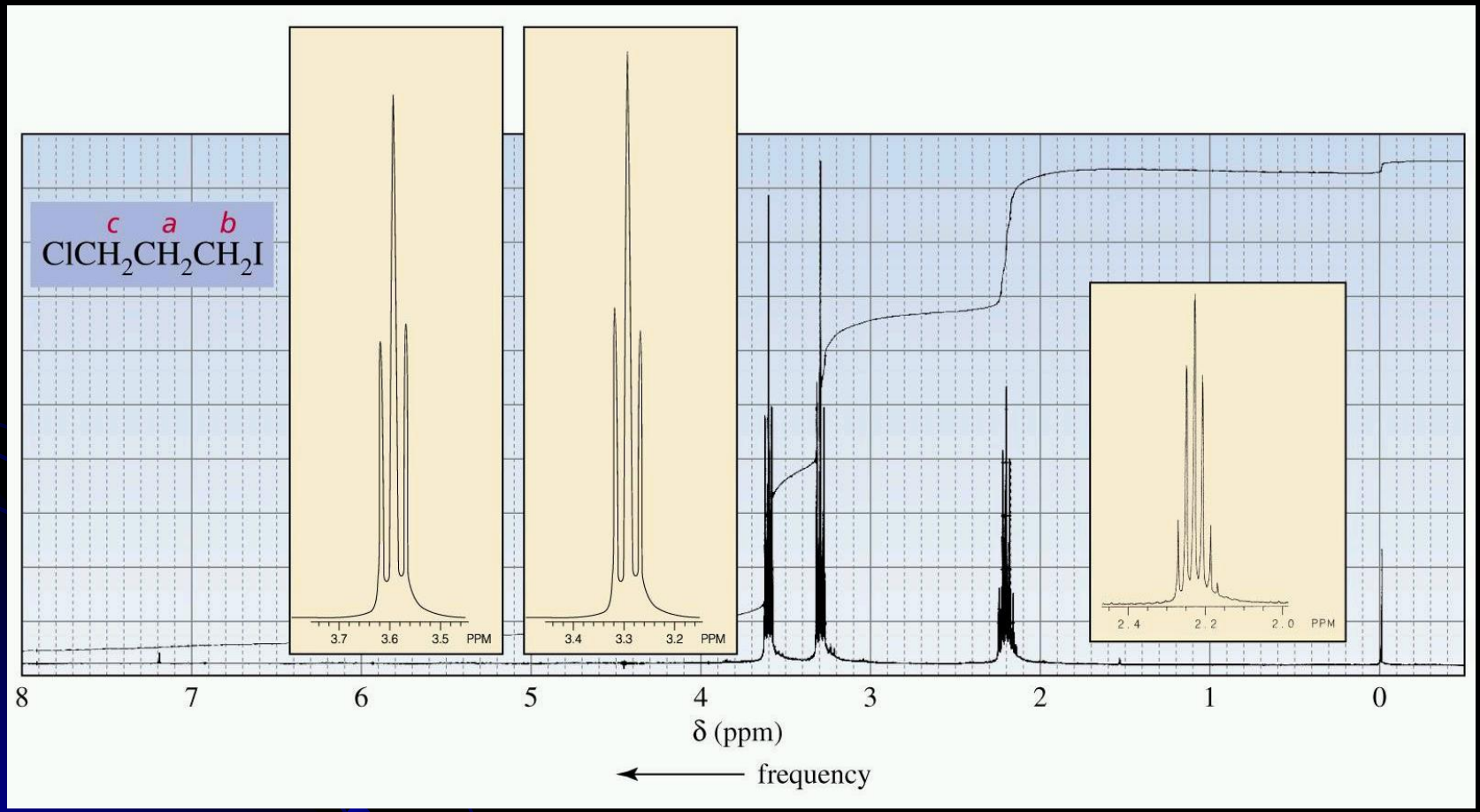
Nuclear Magnetic Resonance (NMR)

1,3-Dibromopropane – $BrCH_2CH_2CH_2Br$



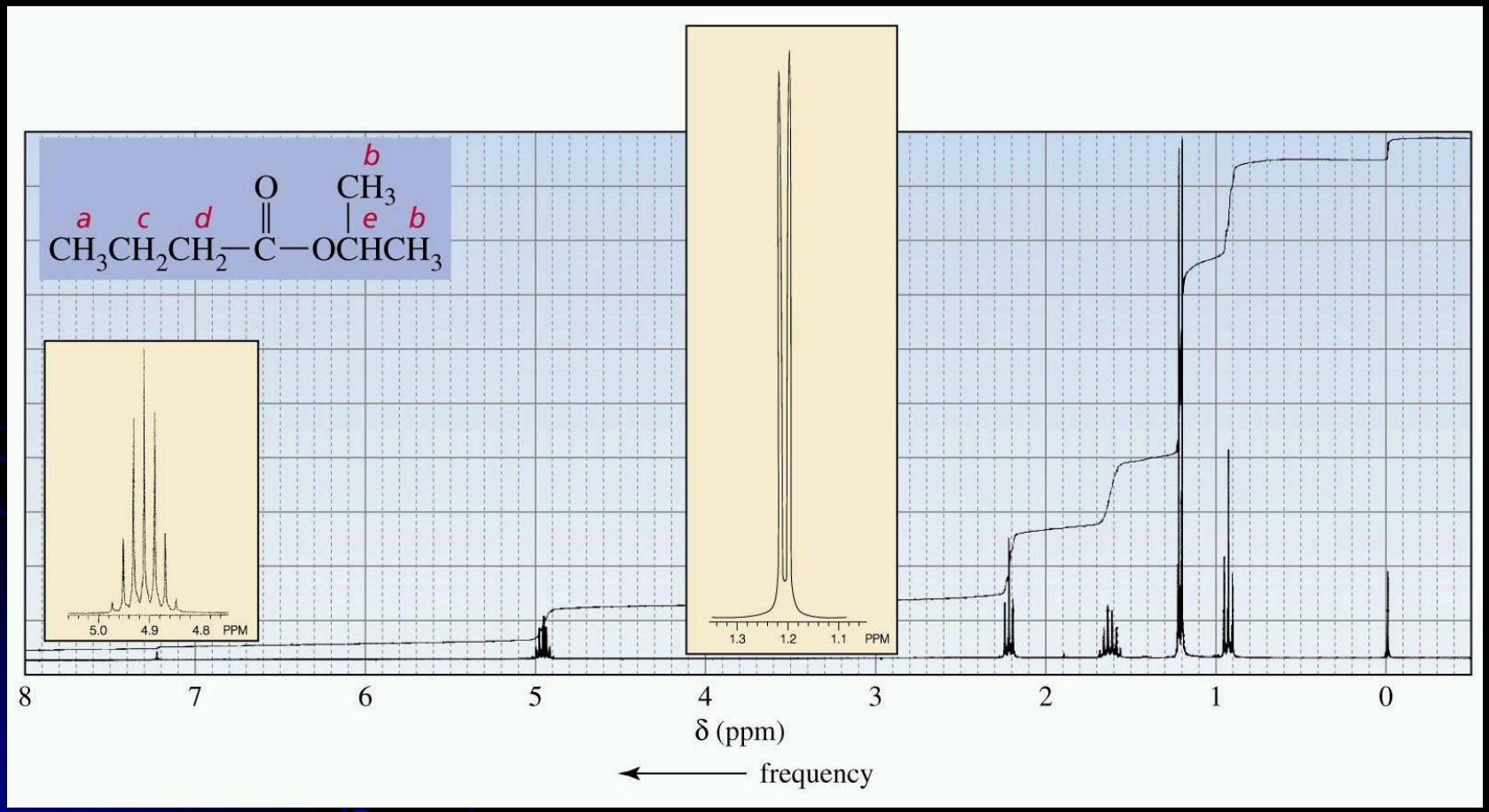
Nuclear Magnetic Resonance (NMR)

1-Chloro-3-iodopropane – $ClCH_2CH_2CH_2I$



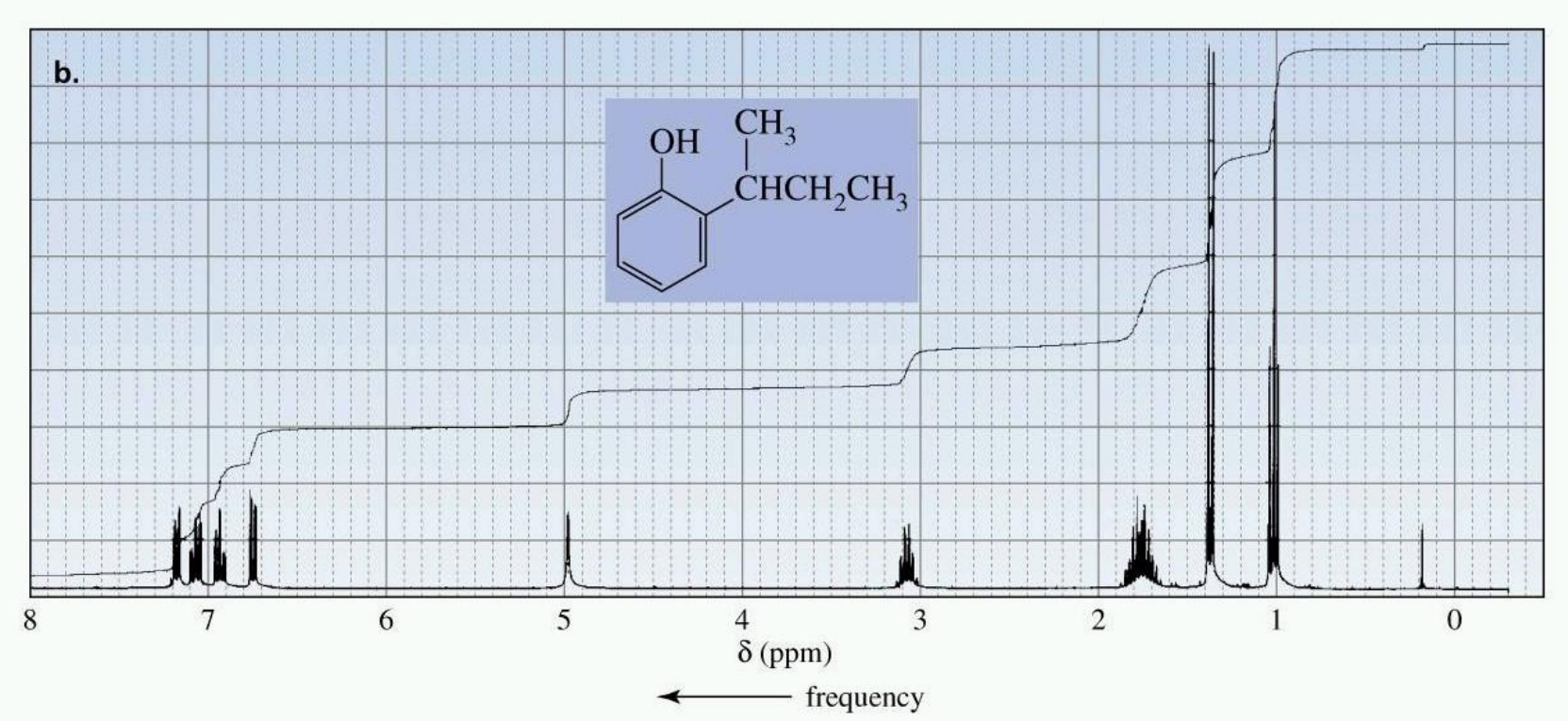
Nuclear Magnetic Resonance (NMR)

iso-Propyl Butanoate – $CH_3(CH_2)_2COOCH(CH_3)_2$



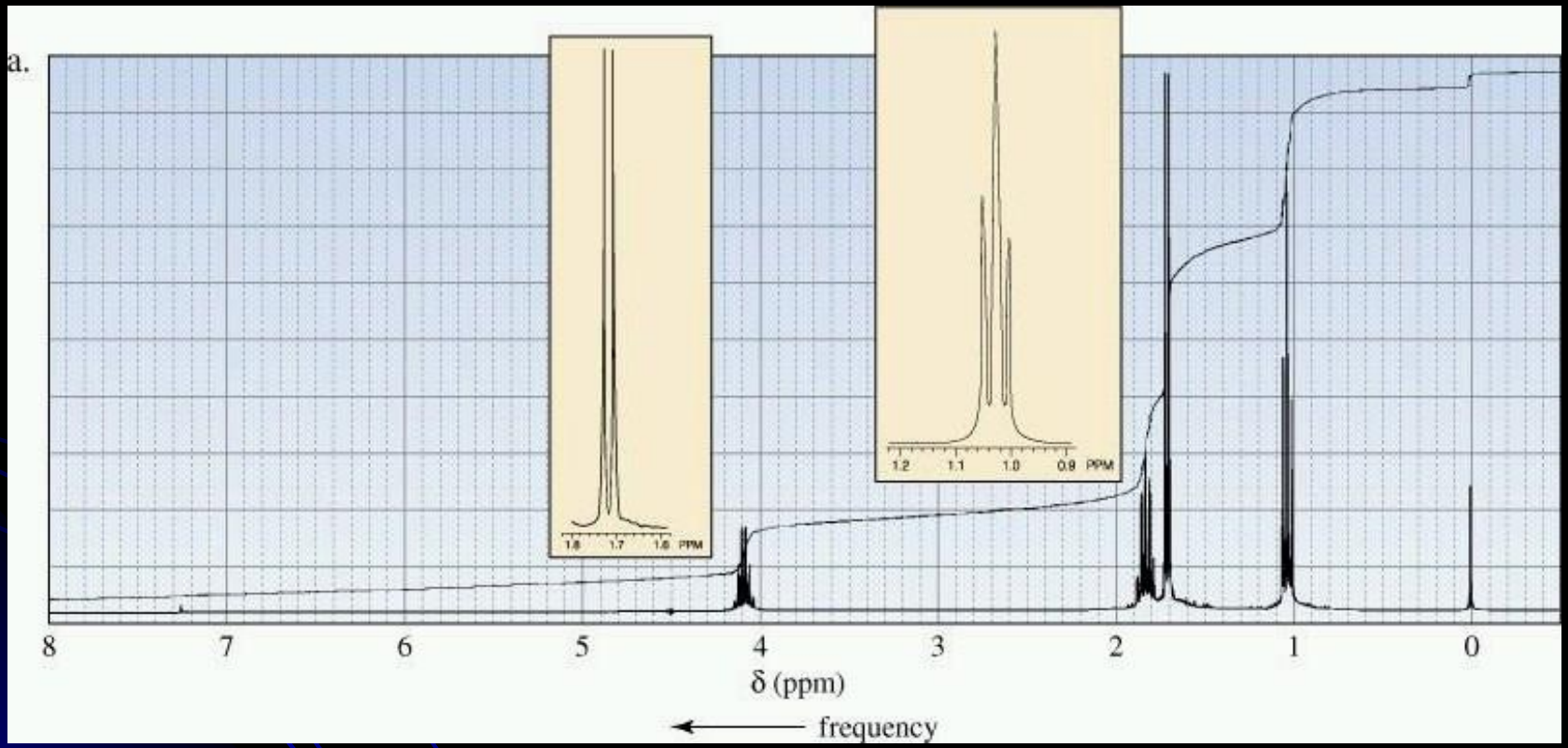
Nuclear Magnetic Resonance (NMR)

sec-2-Butylphenol – $C_6H_4(OH)CH(CH_3)CH_2CH_3$



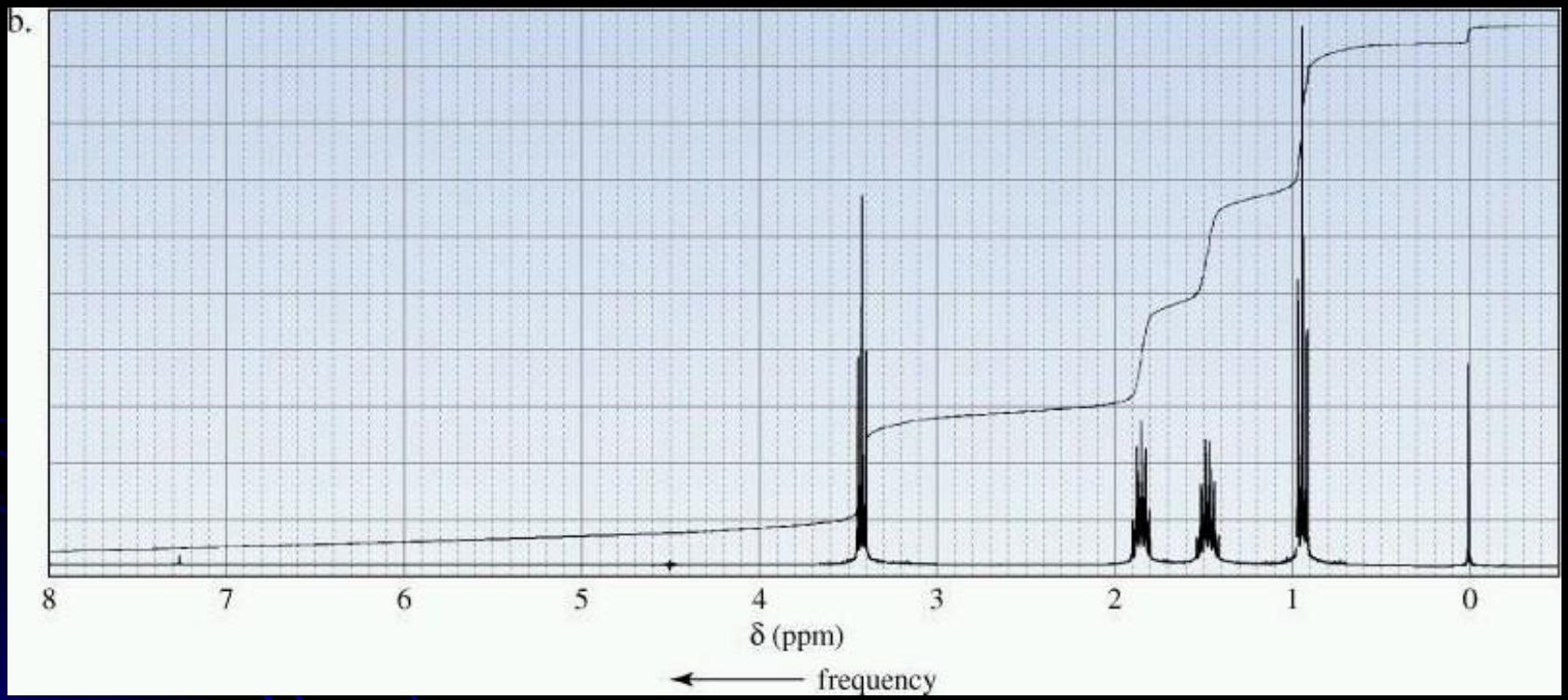
Nuclear Magnetic Resonance (NMR)

Isomer of C_4H_9 – 2-Bromobutane



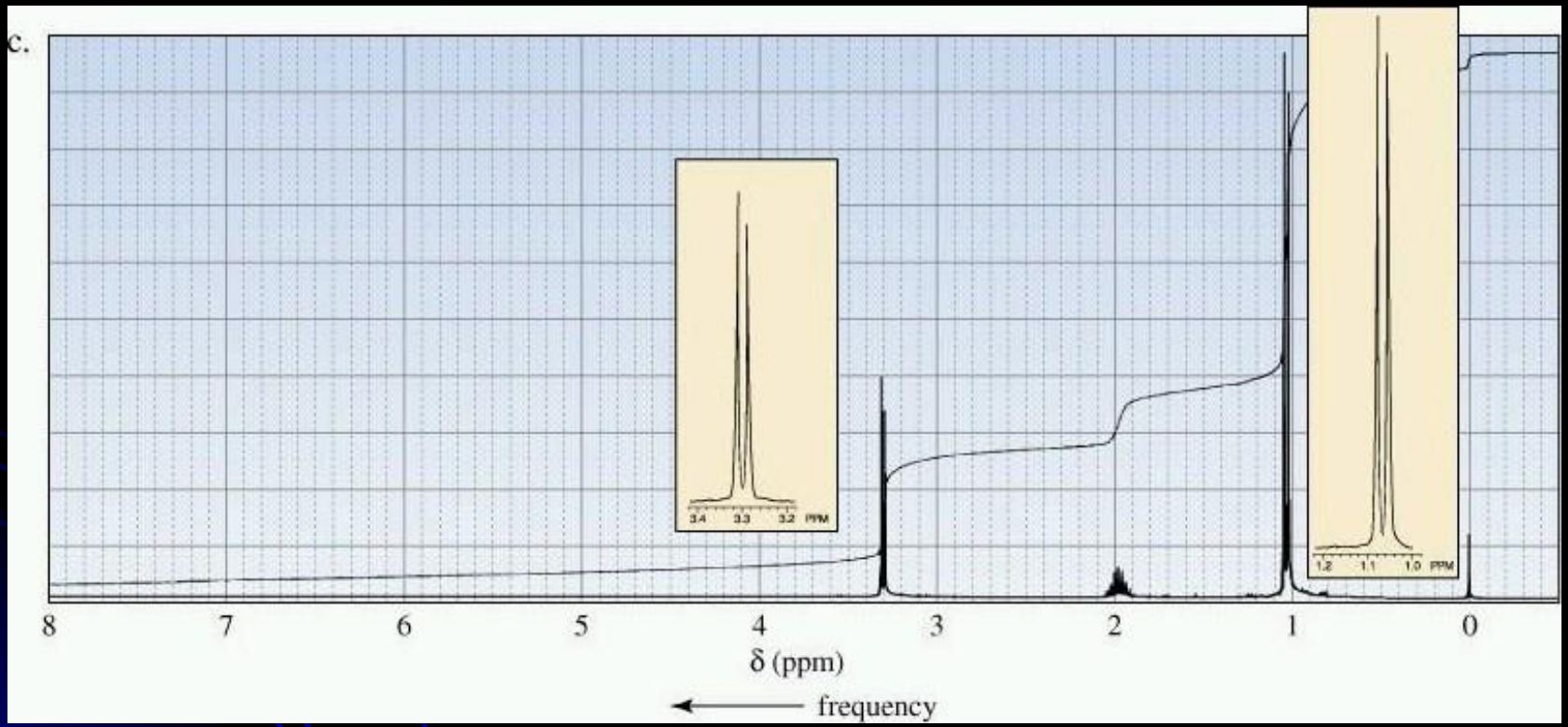
Nuclear Magnetic Resonance (NMR)

Isomer of C_4H_9 – 1-Bromobutane



Nuclear Magnetic Resonance (NMR)

Isomer of C_4H_9 – 1-Bromo-2-methylpropane



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