Bonga university

Instrumental Analysis II

(Chem.2052)

Chapter 1. Introduction to Spectroscopy

2012 E.C

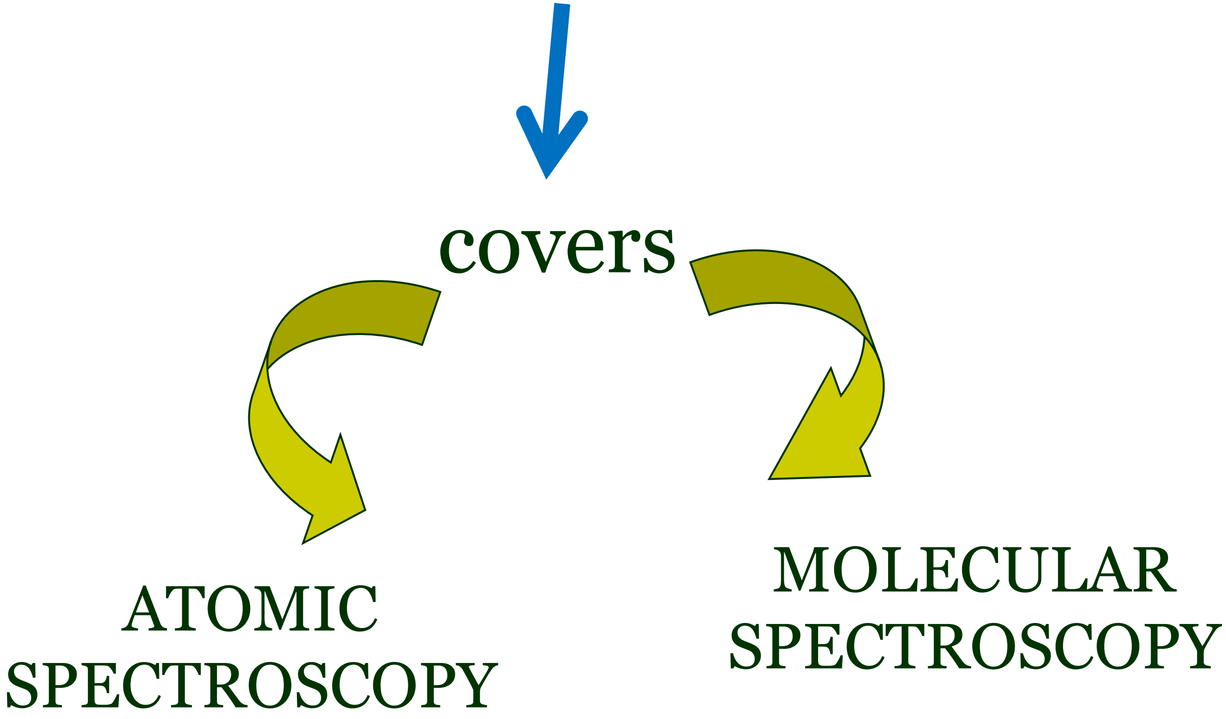
Introduction

- **Classical Methods**: Wet chemical methods such as precipitation, extraction, distillation, boiling or melting points, gravimetric and titrimetric measurements.

- **Instrumental Methods**: Analytical measurements (conductivity, electrode potential, light absorption or emission, mass-to-charge ratio, fluorescence etc.) are made using instrumentation.

Types of Instrumental Methods

1. Chromatographic methods (separations):
2. Electrochemistry:
3. Spectroscopic methods:



covers

ATOMIC SPECTROSCOPY

MOLECULAR SPECTROSCOPY

Introduction to Spectrochemical Methods

- The term Spectroscopy refers to a branch of science in which light (i.e. visible radiation) was resolved into its component wavelength to produce spectra.
- **Spectra** were plots of some function of radiant versus wavelength or frequency.
- In modern times, the meaning of Spectroscopy has been broaden to include studies not only with visible radiation but also with other types of EMR such as x-rays, ultraviolet, Infrared, Microwave and Radio frequency of radiations.

Examples:

- ✓ions (Mass spectroscopy)
- ✓electron (electron spectroscopy)
- ✓sound wave (Acoustic Spectroscopy)

i.e. Electromagnetic radiation requires no Supporting medium for its transition and passes readily through a vacuum.

- ➢The subject of spectroscopy is the study of the interaction of electromagnetic radiation and matter.

Classification

We can classify spectroscopic methods according to the region of the electromagnetic spectrum involved in the measurement. The regions include γ-ray, X-ray, ultraviolet (UV), visible, infrared (IR), microwave, and radio frequency (RF).

Spectrochemical methods have provided the most widely used tools for the elucidation of molecular structure as well as the quantitative and qualitative determination of both inorganic and organic compounds.

Cont….

Thus, Electromagnetic Radiation:

- is a form of energy that has both Wave and Particle Properties.

Electromagnetic Radiation

✓It is a type of energy that is transmitted through space at enormous velocity.

✓It is a type of energy that takes numerous form e.g. Visible light, γ-ray, X-rays, Ultraviolet, Microwave, Radio wave radiations.

✓It is a form of energy whose behavior is described by the properties of both waves and Particles

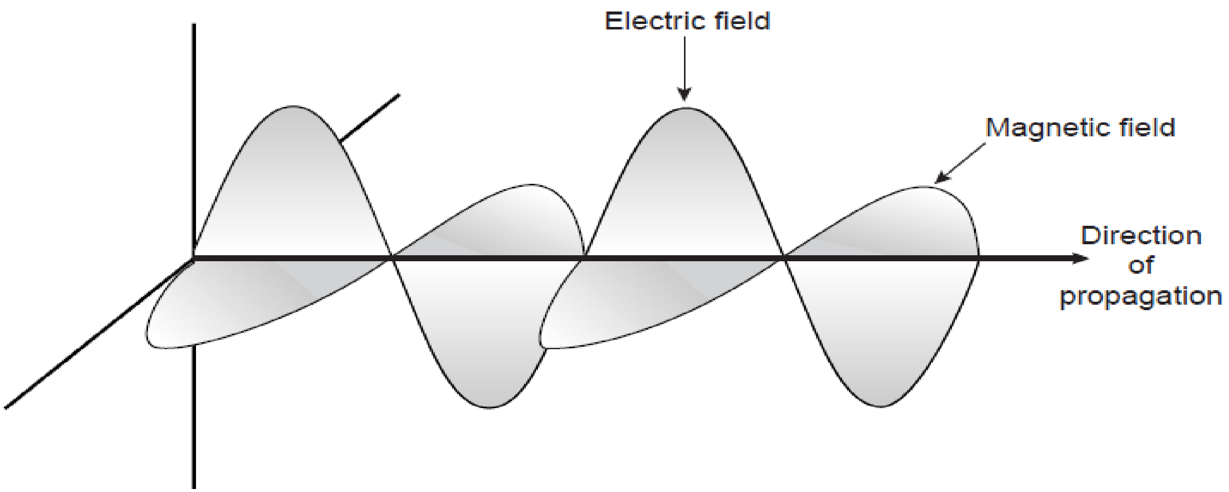
Properties of Electromagnetic Radiation

EMR have dual (both wave and particle nature of) properties.

- ✓The optical properties of electromagnetic radiation, such as diffraction, reflection, refraction and interference are explained best by describing EMR as a wave.
- ✓While absorption and emission, are better explained in terms of particulate or quantum nature.

i. Wave Properties of EMR

- ✓EMR as a wave is compose of two component: a) the electric field and b) the magnetic field
- ✓Each of the above components oscillates in plane perpendicular to both the direction of propagation and the other component.



❖If the direction of propagation is along X-axis then there will be the magnetic field along the Y-axis and the electric field along the Z-axis or the other way.

❖In a vacuum, electromagnetic radiation travels at the speed of light, *c*, which is 2.99792 ´ X 10^8 m/s.

❖Electromagnetic radiation moves through a medium other than a vacuum with a velocity, *v*, less than that of the speed of light in a vacuum. The difference between *v* and *c* is small enough (< 0.1%) that the speed of light to three significant figures, 3.00 X 10^8 m/s, is sufficiently accurate for most purposes.

❖An Electromagnetic wave, therefore is characterized by several fundamental properties including its: -

- Wave number
- Amplitude
- Frequency

- Velocity
- Wave length
-Phase angle

- Radiant Power
- Intensity

Definitions:

- **Period (p)** – the time required for one cycle to pass a fixed point in space.

- **Frequency (V)** – the number of cycles which pass a fixed point in space per second.

- **Amplitude (A)** – The maximum length of the electric vector in the wave (Maximum height of a wave).

- **Wavelength (λ)** – The distance between two identical adjacent points in a wave (usually maxima or minima).

- **Wavenumber (ν)** - The number of waves per cm in units of cm^{-1}.

Definitions:

- **Radiant Power (P)** - The amount of energy reaching a given area per second. Unit in watts (W)

- **Intensity (I)** - The radiant power per unit solid angle.

λ

Parameters that used to characterize wave Properties of EMR:

a) Wavelength(λ, Greek *lambda*):

✓It is defined as the distance between successive maxima, or successive minima.

✓It is the crest-to-crest distance between two successive maxima.

✓It is trough-to-trough distance between two successive maxima

The standard unit of wavelength is the SI unit of length, the meter (m), but smaller units such as the centimeter (cm), micrometer (mm), and nanometer (nm) are commonly used.

For example ultraviolet and visible electromagnetic radiation the wavelength is usually expressed in nanometers (nm, 10^{-9} m), and the wavelength for infrared radiation is given in microns (mm, 10^{-6} m).

N.B. Unlike frequency, wavelength depends on the electromagnetic wave’s velocity, where:

$$\lambda = \frac{v}{\nu} = \frac{c}{\nu} \qquad \text{(in vacuum)}$$

✓**Thus, for electromagnetic radiation of frequency, the wavelength in vacuum is longer than in other media.**

✓**Light of only one wavelength is called monochromatic light. Light that consists of more than one wavelength is called polychromatic light. White light is an example of polychromatic light.**

b)Wave number

It is the reciprocal of wavelength.

$$\bar{\nu} = \frac{1}{\lambda}$$

✓**Wave numbers are frequently used to characterize infrared radiation, with the units given in reciprocal centimeter (cm^{-1}).**

Example:

1. In 1817, Josef Fraunhofer (1787–1826) studied the spectrum of solar radiation, observing a continuous spectrum with numerous dark lines. Fraunhofer labeled the most prominent of the dark lines with letters. In 1859, Gustav Kirchhoff (1824–1887) showed that the "D" line in the solar spectrum was due to the absorption of solar radiation by sodium atoms. The wavelength of the sodium D line is 589 nm. What are the frequency and the wave number for this line?

SOLUTION

The frequency and wave number of the sodium D line are

Solution

$$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}\ \mathrm{m/s}}{589 \times 10^{-9}\ \mathrm{m}} = 5.09 \times 10^{14}\ \mathrm{s}^{-1}$$

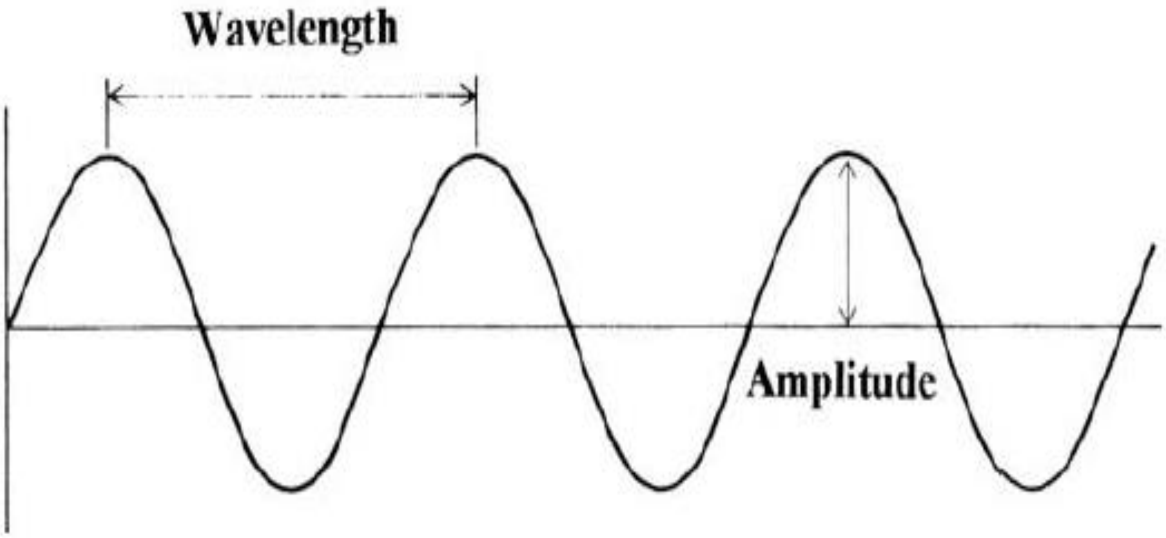
$$\bar{\nu} = \frac{1}{\lambda} = \frac{1}{589 \times 10^{-9}\ \mathrm{m}} \times \frac{1\ \mathrm{m}}{100\ \mathrm{cm}} = 1.70 \times 10^{4}\ \mathrm{cm}^{-1}$$

c) Frequency (υ)

- It is the number of crests passing a fixed point per second.
- One crest-to-crest oscillation of a wave is called a cycle.
- It is the number of complete cycles or wavelength passing through per unit time.
- The common unit of frequency is the hertz (Hz) or inverse second ; an older term for frequency is the cycle per second (s^{-1}). One hertz equals one cycle per second.

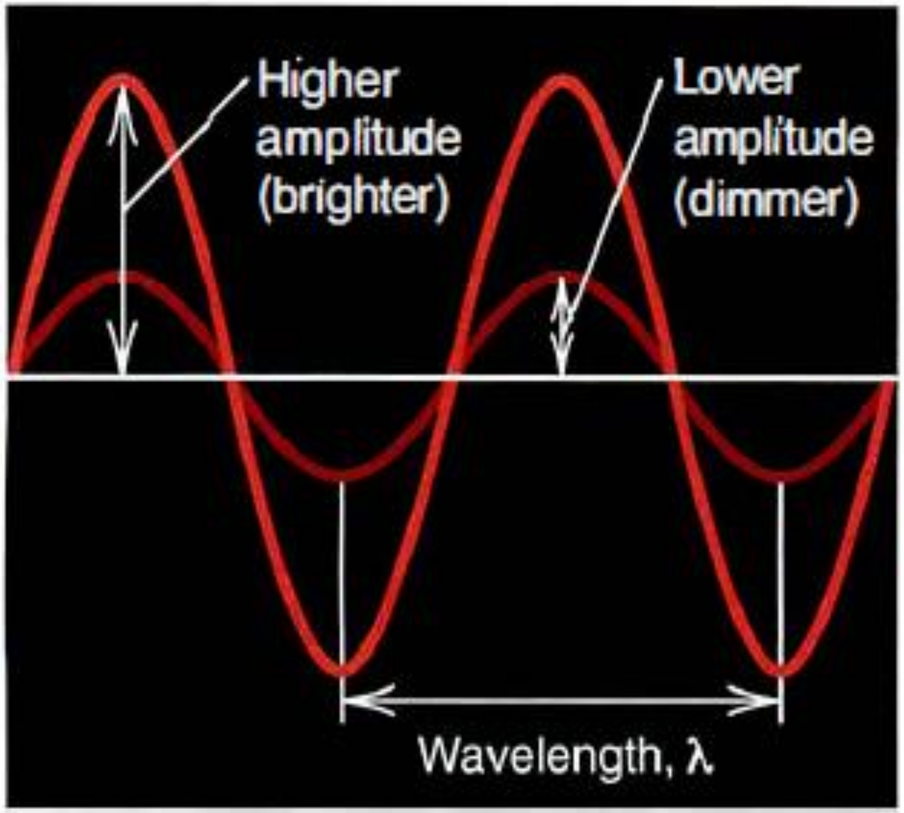
d) Amplitude (A)

- ✓It is the maximum of the vector from the origin to a point displacement of the oscillation.
- ✓It is the distance from the propagation line to the maximum.



Amplitude (A)

Is the height of the crest (or depth of the trough) of each wave



-is a measure of the strength of its electric and magnetic fields.

-is related to the **intensity** of the radiation, which we perceive as brightness in the case of visible light.

e) Speed (v)

✓It is the rate at which the wave front is propagated

Speed of light in vacuum is 2.99792 x 10^8 m/s: $v' =$ where, v' speed of light in medium, c speed of light in vacuum and n refractive index of a medium.

Speed of c > v'

λ decreases from vacuum to a medium and $\frac{\quad}{v}$

increases from vacuum to a medium.

Examples:

1)What is the frequency in MHz of a wave with wavelength of 5.6 m?

Given: $\lambda = 5.6$ m required: frequency?

$c = 3 \times 10^{8}$ m/s

Solution $\mathbf{c = \lambda v}$

$$v = c / \lambda = \frac{3 \text{ x } 10^{8} \text{ m/s}}{5.6\ m}$$

$= 53.6 \times 10^{6}\ s^{-1} = 53.6 \times 10^{6}$ Hz

$= 53.6$ MHz (because mega equals to 10^{6})

2) A radio operator broadcast at a frequency of 14.2 MHz (megahertz). What is the wavelength of the radio waves put out by the transmitter?

Given: $\boldsymbol{v}$ = 14.2 MHz c = 3 x 10 ^{8} m/s

Required: Wavelength?

Solution c = $\boldsymbol{\lambda v}$

$\boldsymbol{\lambda}$ = 21.1 m how?

- ***$E = h\nu$***

$h\nu$ is called energy of incident photon.

$\varnothing = h\,\nu_o$

$h\,\nu_o$ work function (minimum energy required to remove electron)

- If we use maximum frequency,

$KE = 1/2mv^2 = h\,\nu - h\,\nu_o$

v ***is speed of electron***

$KE = h\,(\nu - \nu_o)$

- ☐ Einstein also proposed a theory called relativity $E = mc^2$ which helps us to determine the mass of the photon

$$E = h\nu = \frac{hc}{\lambda}$$

$$E = mc^2$$

$$mc^2 = \frac{hc}{\lambda}$$

$$m_{photon} = \frac{h}{\lambda c}$$

$$E = h\nu$$

$$= \frac{hc}{\lambda}$$

$$= hc\bar{\nu}$$

But $E = mc^2$ thus $mc^2 = \frac{hc}{\lambda}$

$$\frac{1}{\lambda} = \frac{mc}{h}$$

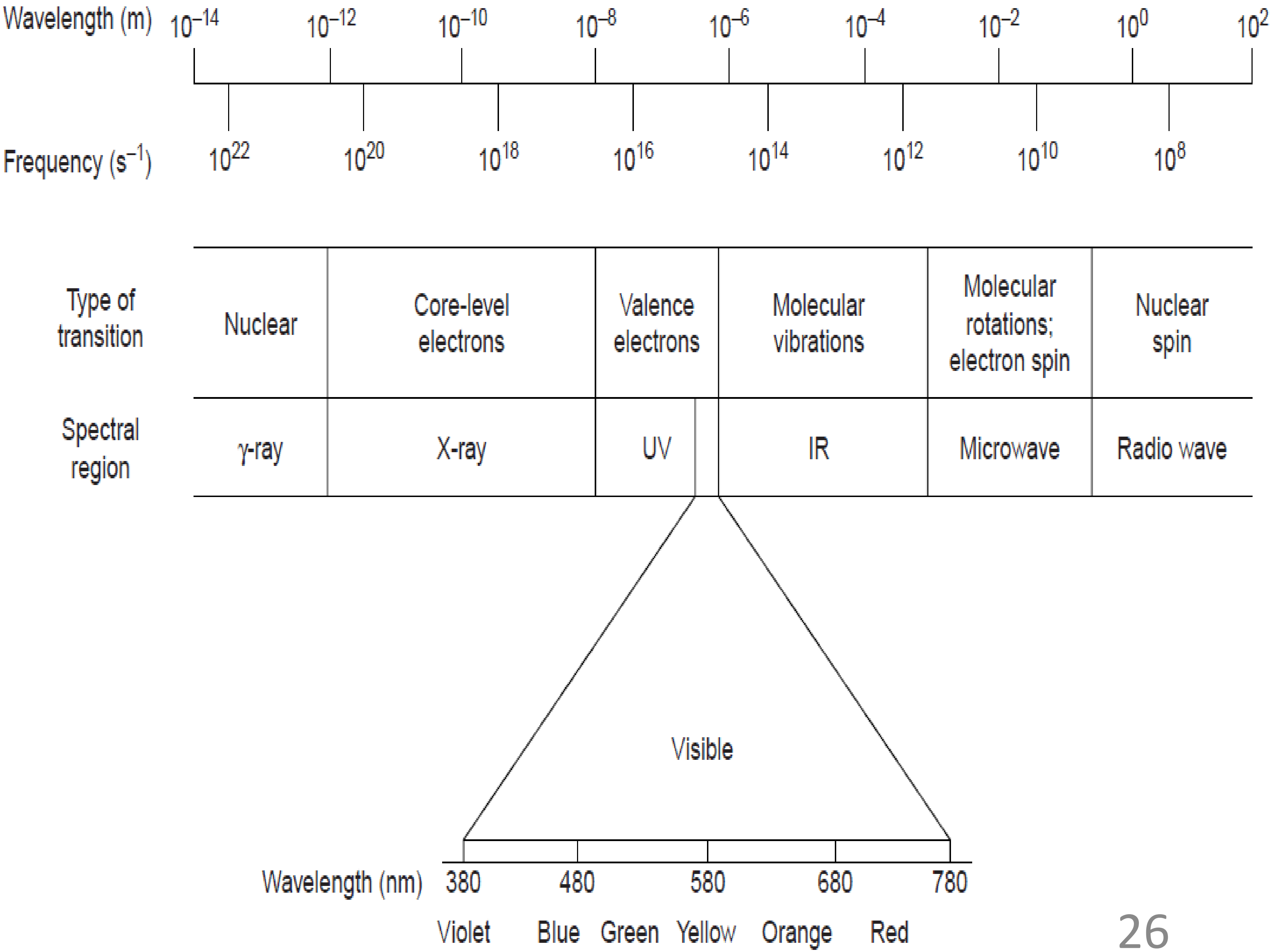
$$\lambda = \frac{h}{mc}$$

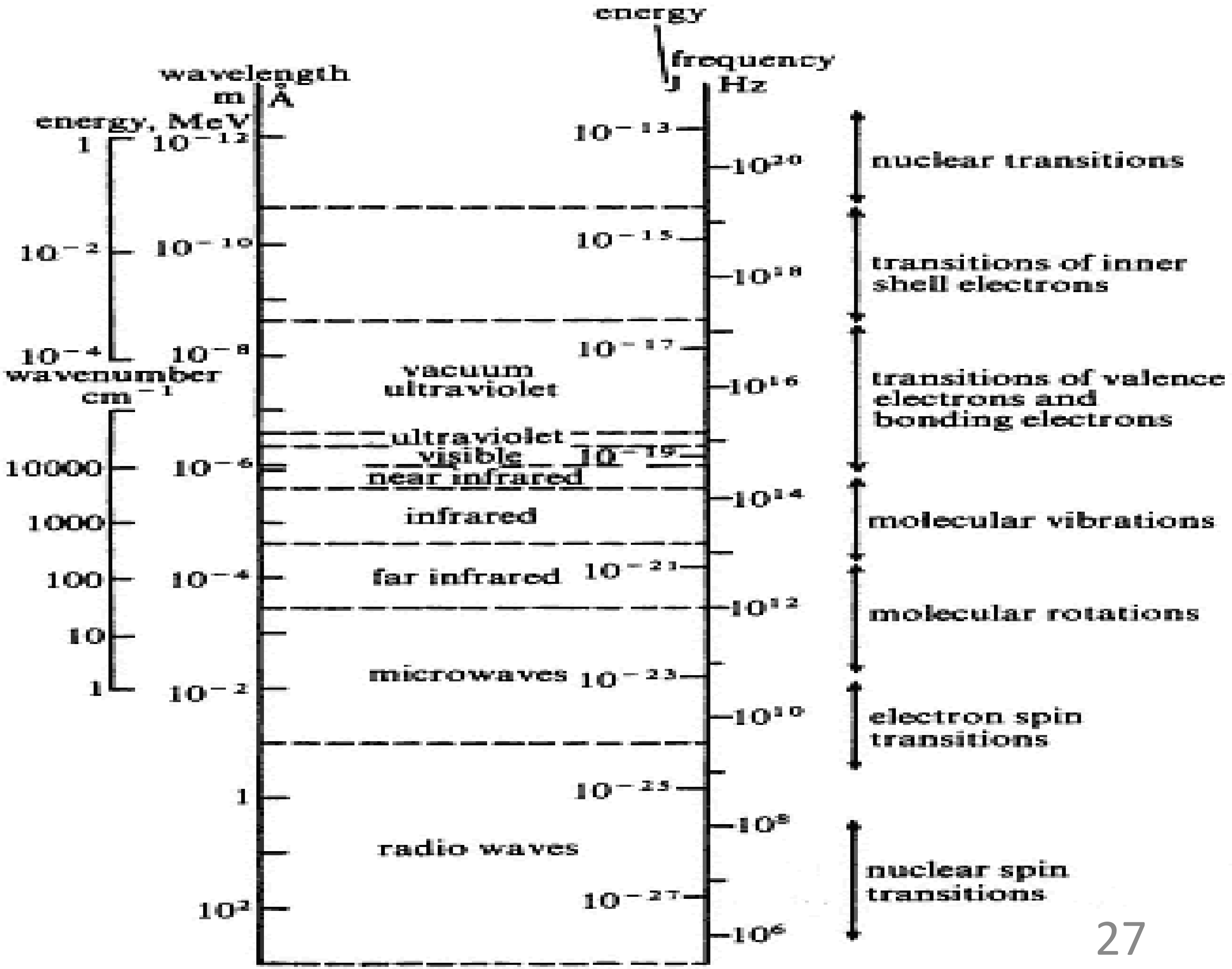
The Electromagnetic Spectrum

✓The frequency and wavelength of electromagnetic radiation varies from few angstrom to several meters. Hence, different units can be employed for different regions.

✓For convenience, electromagnetic radiation is divided into different regions based on the type of atomic or molecular transition that gives rise to the absorption or emission of photons (Figure 1.2).

✓The boundaries describing the **electromagnetic spectrum** are not rigid, and an overlap between spectral regions is possible.


Wavelength (m)
10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
10^{2}
Frequency (s^{-1})
10^{22}
10^{20}
10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
10^{8}
Type of transition
Nuclear
Core-level electrons
Valence electrons
Molecular vibrations
Molecular rotations; electron spin
Nuclear spin
Spectral region
γ-ray
X-ray
UV
IR
Microwave
Radio wave
Visible
Wavelength (nm)
380
480
580
680
780
Violet
Blue
Green
Yellow
Orange
Red


energy
frequency
J
Hz
wavelength
m
Å
energy, MeV
1
10^{-2}
10^{-4}
wavenumber
cm^{-1}
10000
1000
100
10
1
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
10^{2}
10^{-13}
10^{-15}
10^{-17}
10^{-19}
10^{-21}
10^{-23}
10^{-25}
10^{-27}
10^{20}
10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
10^{8}
10^{6}
vacuum ultraviolet
ultraviolet
visible
near infrared
infrared
far infrared
microwaves
radio waves
nuclear transitions
transitions of inner shell electrons
transitions of valence electrons and bonding electrons
molecular vibrations
molecular rotations
electron spin transitions
nuclear spin transitions

- ✓In the previous section we defined several characteristic properties of electromagnetic radiation, including its energy, velocity, amplitude, frequency, phase angle, and direction of propagation.
- ✓ Spectroscopy is possible only if the photon’s interaction with the sample leads to a change in one or more of these characteristic properties.

THANK YOU !

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Instrumental Analysis II

(Chem.2052)

Chapter 2. Absorption Laws (Quantitative Analysis)

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Atomic Spectroscopy

- ❖It studies the interaction of EMR with atoms.

  Atoms ⟶ Atoms

  (Ground state) (Exited state)

- ✓When a beam of polychromatic UV or Visible radiation passes through medium containing gaseous atoms, only a few frequencies are attenuated by absorption and the spectrum consists of a number of very narrow lines.

Examples:

✓These transition involves excitation of the single outer electron of Na from its room temperature or gaseous state 3s orbital to 3p, 4p and 5p orbital's.

✓This kind of movement is known as electronic movement. These excitations are brought on by absorption of photons of radiation whose energies exactly match the difference in energies between the exited states and the 3s orbital.

i.e. E = $\Delta E = h\upsilon$

Example:

1. The energy difference between the 3p and the 3s orbital is 2.107 eV. Calculate the wavelength of radiation that would be observed in exiting the 3s electrons to the 3p state (1eV = 1.6 x 10^{-19} J).

Solution: E = $\frac{hc}{\lambda}$ **= 590 nm**

Molecular Spectroscopy

- ✓Molecules undergo three types of quantized transitions when exited by Ultraviolet, Visible and infrared radiations
- ✓In addition to electronic transition, molecules exhibit two other types of transition namely Vibrational transition and Rotational transition.
- ✓ These rotational energy states are superimposed on each of the vibrational states shown in energy diagram (**figure 5**).
- ✓The energy difference among these states are smaller than those among vibrational states by an order of magnitude.
- ✓ The total energy E associated with a molecule is then given by:

$$E = E_{\text{electronic}} + E_{\text{vibrational}} + E_{\text{rotational}}$$

Where $E_{\text{electronic}}$ is the energy associated with the electros in the various outer orbitals of the molecule, $E_{\text{vibrational}}$ is the energy of the molecule as a whole due to interatomic vibrations, and $E_{\text{rotational}}$ accounts for the energy associated with rotation of the molecule about its center of gravity.

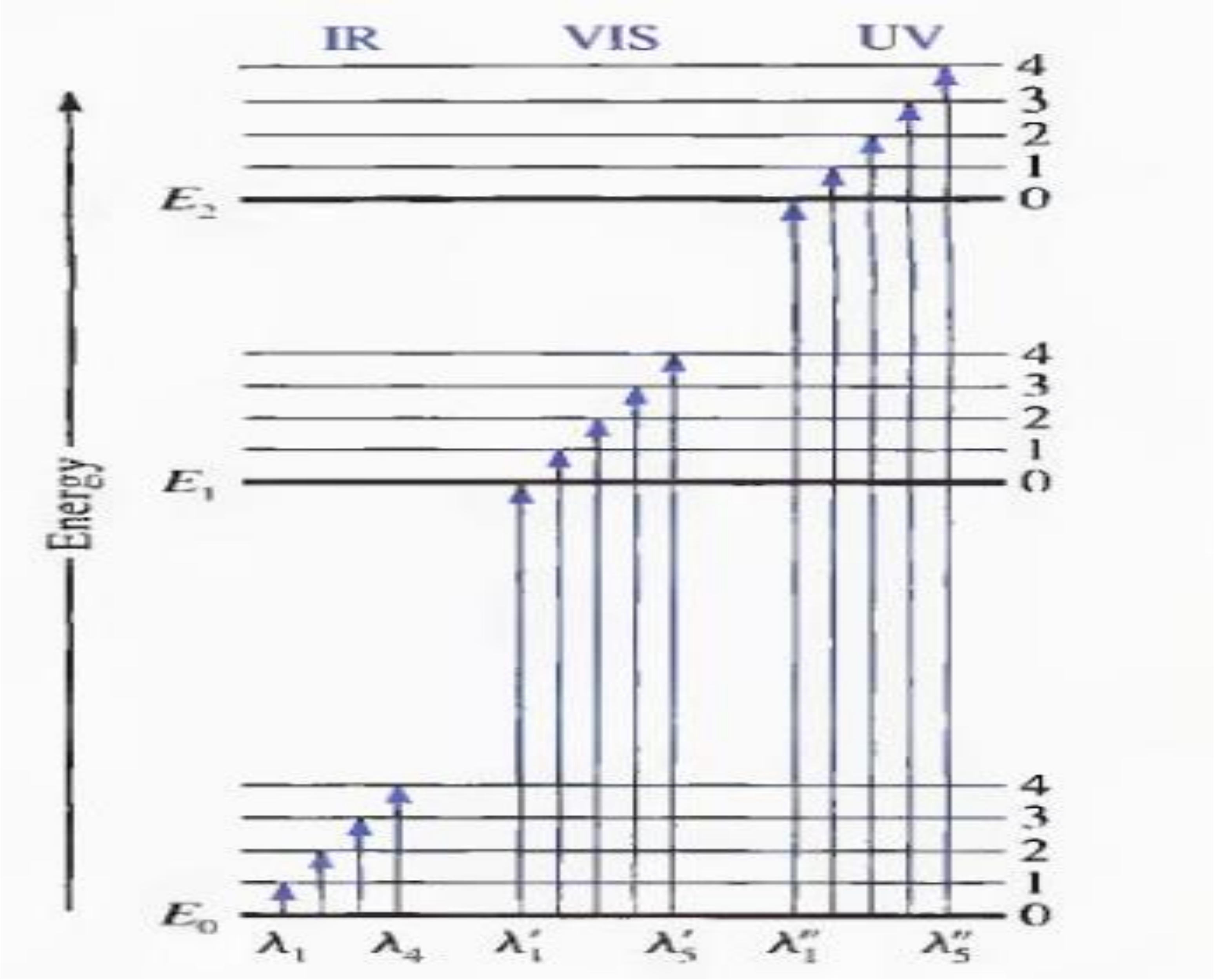

IR
VIS
UV
Energy
E_2
E_1
E_0
4
3
2
1
0
4
3
2
1
0
4
3
2
1
0
λ_1
λ_4
λ'_1
λ'_5
λ''_1
λ''_5

Figure 1

Note:

- **UV-Vs** – composes of both electronic, vibrational and rotational but IR composes of Only vibrational and rotational but not electronic because it is not energetic as UV-Vs.
- When an EMR is passed through a molecule a superimposed peaks of electronics, vibrational and and rotational is given in the spectrum (it will not be sharp).
- Generally, when EMR is interacted with matter at least one of the following occurs: absorption, emission, refraction, reflection, scattering etc.

Absorption and Emission Radiations

- ✓In absorption spectroscopy the energy carried by a photon is absorbed by the analyte, promoting the analyte from a lower-energy state to a higher-energy, or excited, state (**Figure 2**).

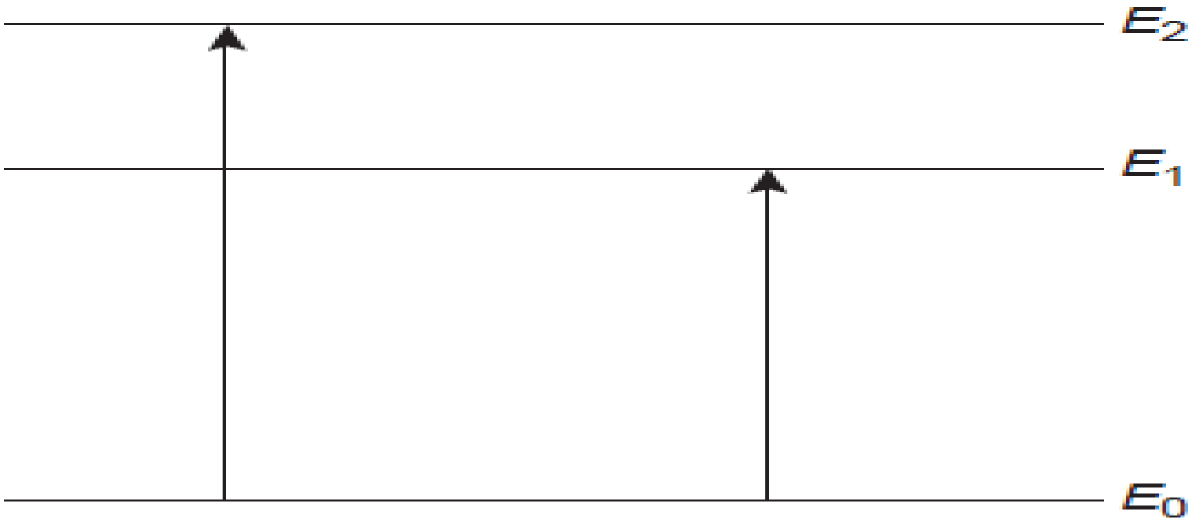


Figure 2

✓When light strikes a sample of matter, the light may be absorbed by the sample, transmitted through the sample, reflected off the surface of the sample, or scattered by the sample.

✓ Samples can also emit light after absorbing incident light; such a process is called **luminescence**.

✓ There are different kinds of luminescence, called **fluorescence** or **phosphorescence** depending on the specific process that occurs.

Emission of a photon occurs when an analyte in a higher-energy state returns to a lower-energy state (**Figure 3**).

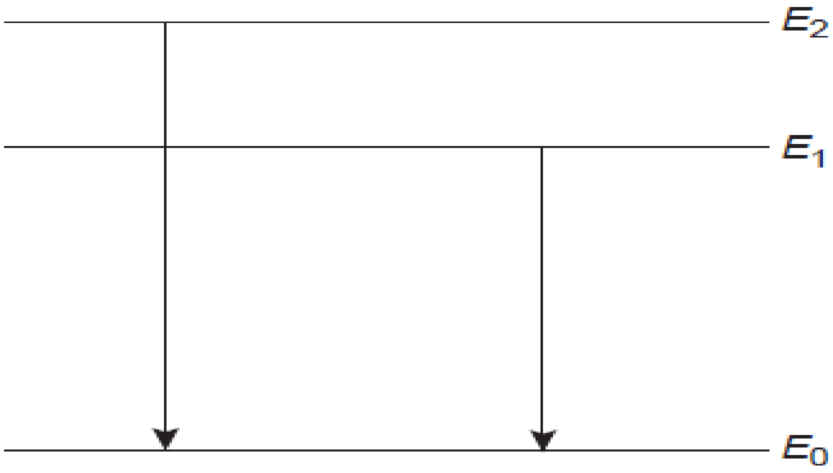


Figure 3

✓The higher-energy state can be achieved in several ways, including thermal energy, radiant energy from a photon, or by a chemical reaction.

✓Emission following the absorption of a photon is also called **photoluminescence,** and that following a chemical reaction is called **chemiluminescence.** i.e. in **chemiluminescence** the exited species is not the anayte but another form of it.

Photoluminescence,

Fluorescence	Phosphorescence
• When there is no change in spin	- There is change in spin
• Short lived	- Relatively long time (more or less stable)

- When the spin of exited state is the same as its initial one, then the spin is short lived i.e. comeback to its origin fastly called fluorescence.
- On the other hand, the spins are in the same direction carrying the same charge, they repel each other, so these electrons doesn’t prefer to comeback i.e. they take long time.

❑Summary:

- **Absorbance-** The attenuation of photons as they pass through a sample (*A*).
- **Absorbance spectrum-** A graph of a sample's absorbance of electromagnetic radiation versus Wavelength (or frequency or wavenumber).
- ***Example*****:** Ultraviolet/visible absorption spectrum for bromothymol blue.
- **Emission-** The release of a photon when an analyte

returns to a lower-energy state from a higher-energy state.

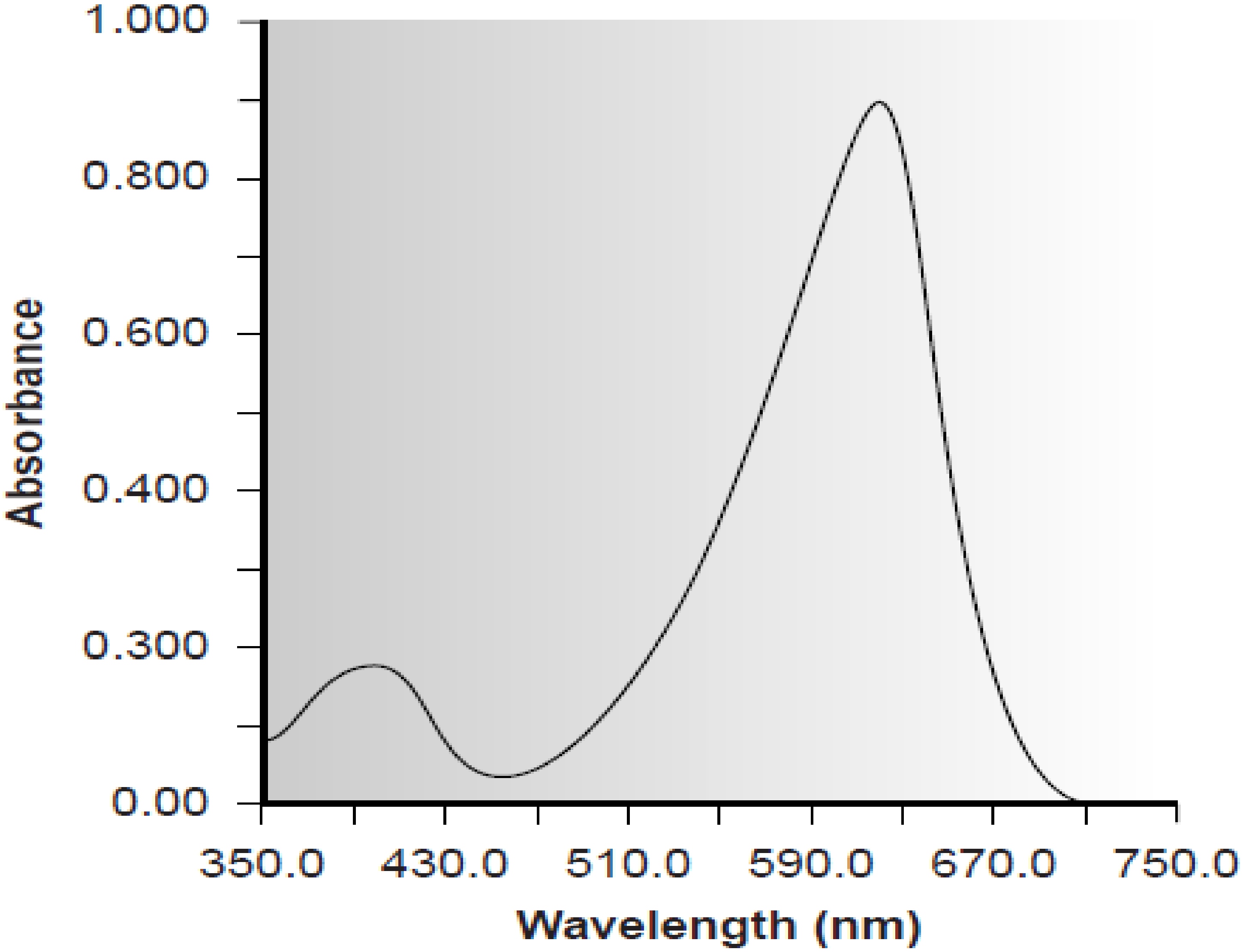

1.000
0.800
0.600
0.400
0.300
0.00
Absorbance
350.0
430.0
510.0
590.0
670.0
750.0
Wavelength (nm)

Figure 4

- **Photoluminescence-** Emission following absorption of a photon.
- **Chemiluminescence-** Emission induced by a chemical reaction.
- **Emission spectrum-** A graph of emission intensity versus wavelength (or frequency or wavenumber).

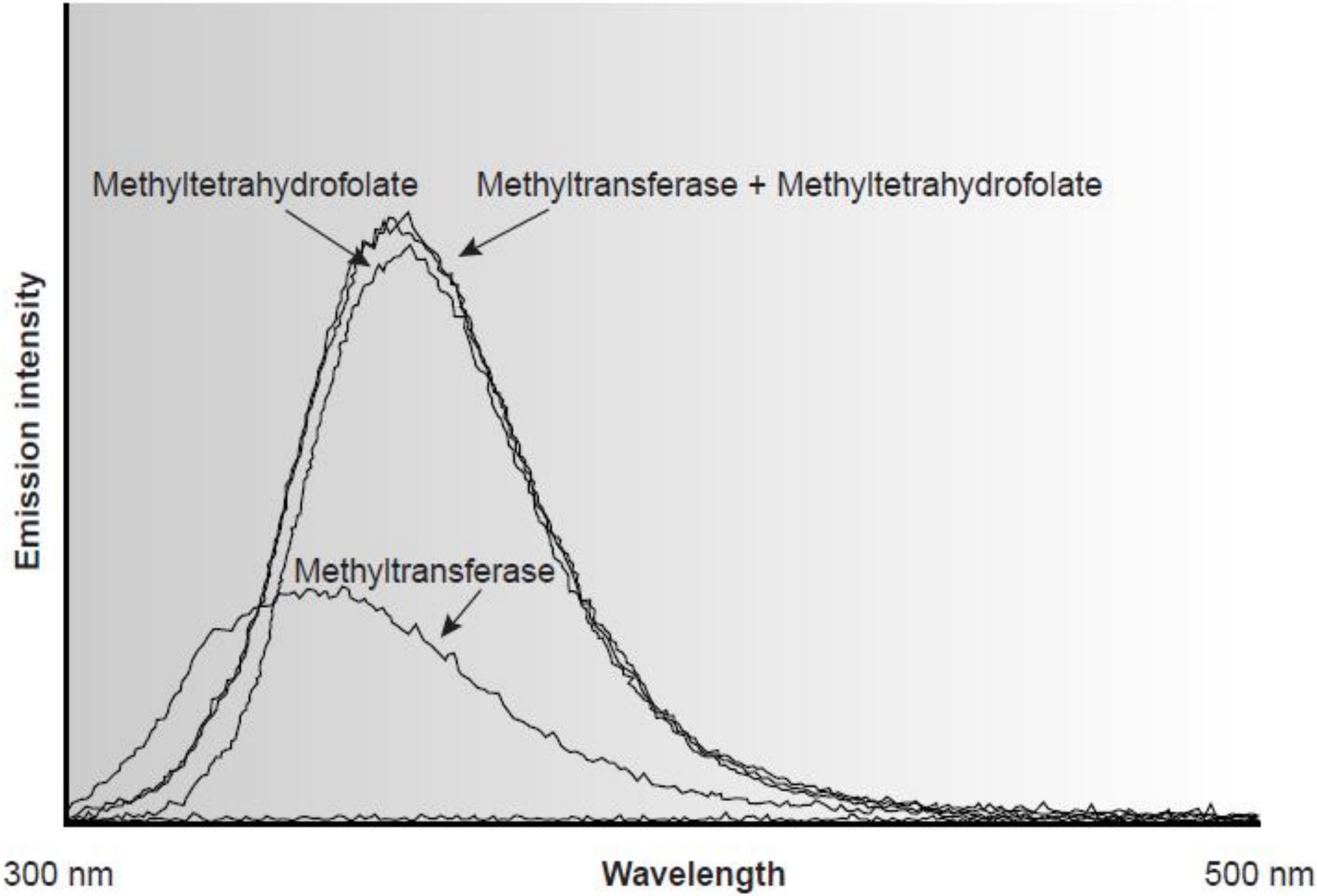
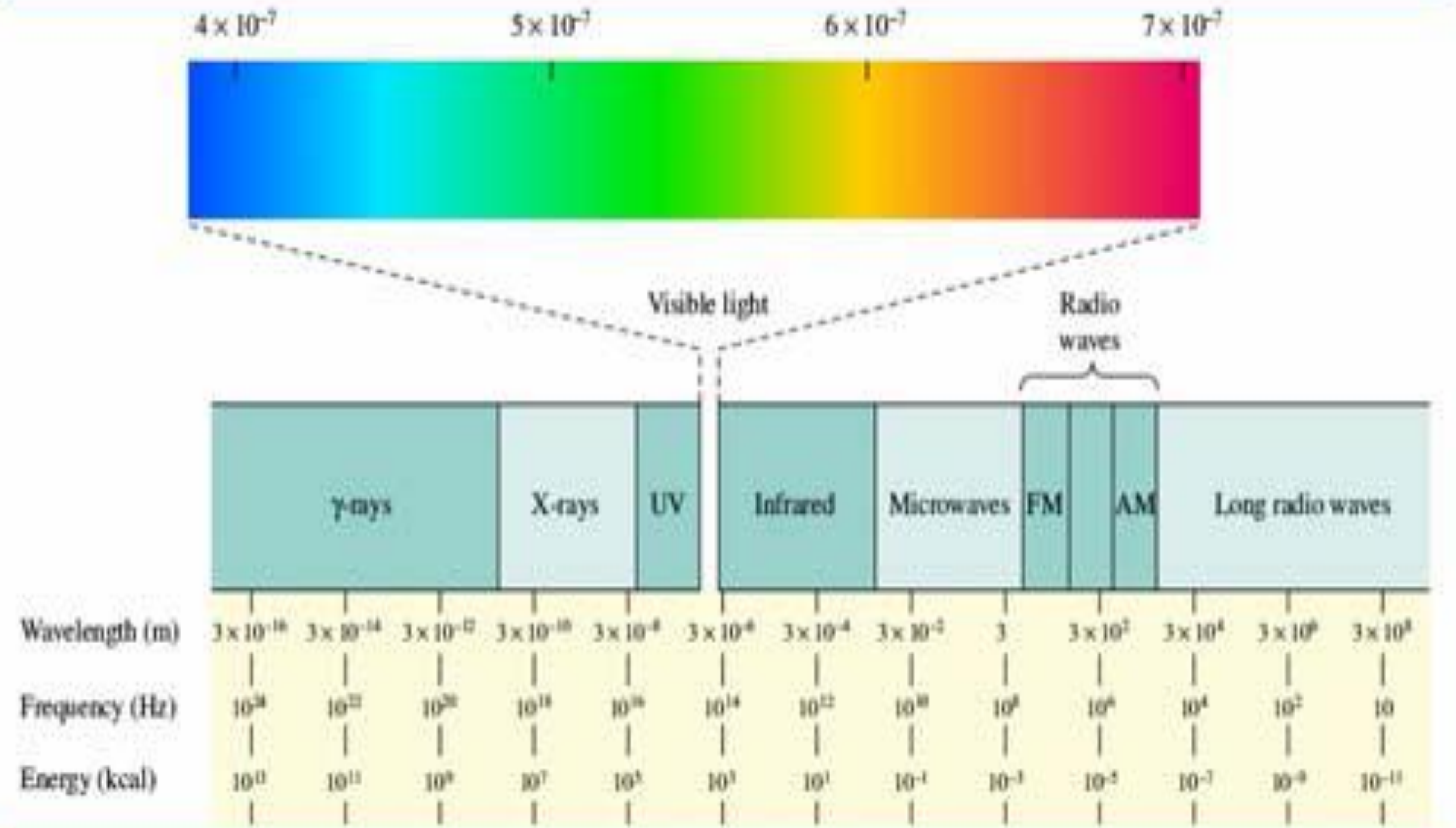

Methyltetrahydrofolate
Methyltransferase + Methyltetrahydrofolate
Methyltransferase
Emission intensity
300 nm
Wavelength
500 nm

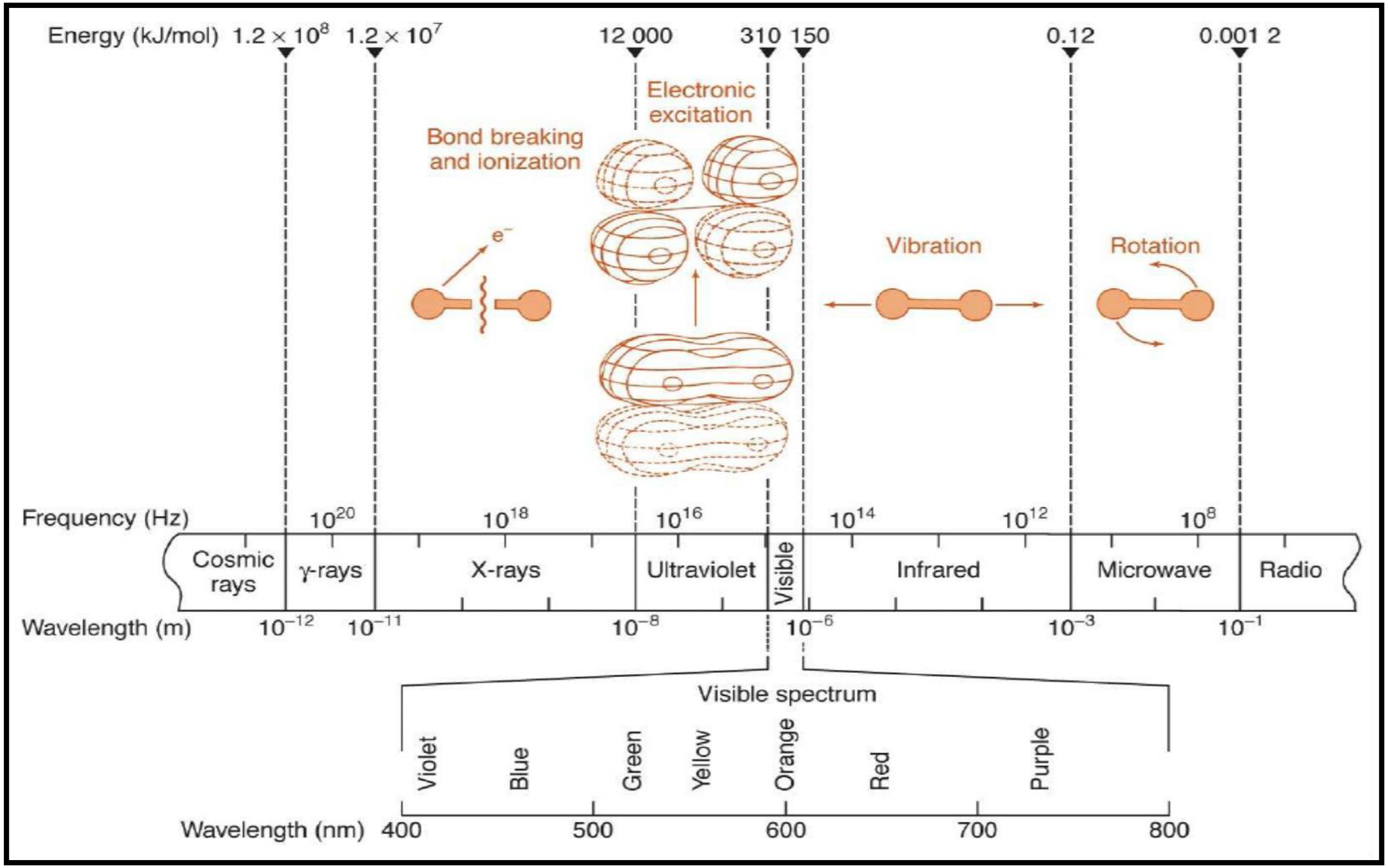
Figure 5

The Electromagnetic Spectrum

Table 12.1 Wavelengths, Frequencies, and Energies of Some Regions of the Electromagnetic Spectrum



INTERACTION OF ELECTROMAGNETIC RADIATION WITH MATTER



Infrared primarily acts to set molecules into vibration.

UV and visible light primarily acts to elevate electrons to higher energy levels.

INTERACTION OF ELECTROMAGNETIC RADIATION WITH MATTER

- The interaction of radiation with matter can cause redirection of the radiation and/or transitions between the energy levels of the atoms or molecules.

1. A transition from a lower level to a higher level with transfer of energy from the radiation field to the atom or molecule is called absorption.

2. A transition from a higher level to a lower level is called emission if energy is transferred to the radiation field, or nonradioactive decay if no radiation is emitted.

3. Redirection of light due to its interaction with matter is called scattering, and may or may not occur with transfer of energy, i.e., the scattered radiation has a slightly different or the same wavelength.

Types of spectra

1. Absorption spectrum
2. Emission spectrum

✓ Absorption spectrum

- A plot of the absorbance as a function of wavelength or frequency.

✓ Emission spectrum

- A plot of the relative power of the emitted radiation as a function of wavelength or frequency.

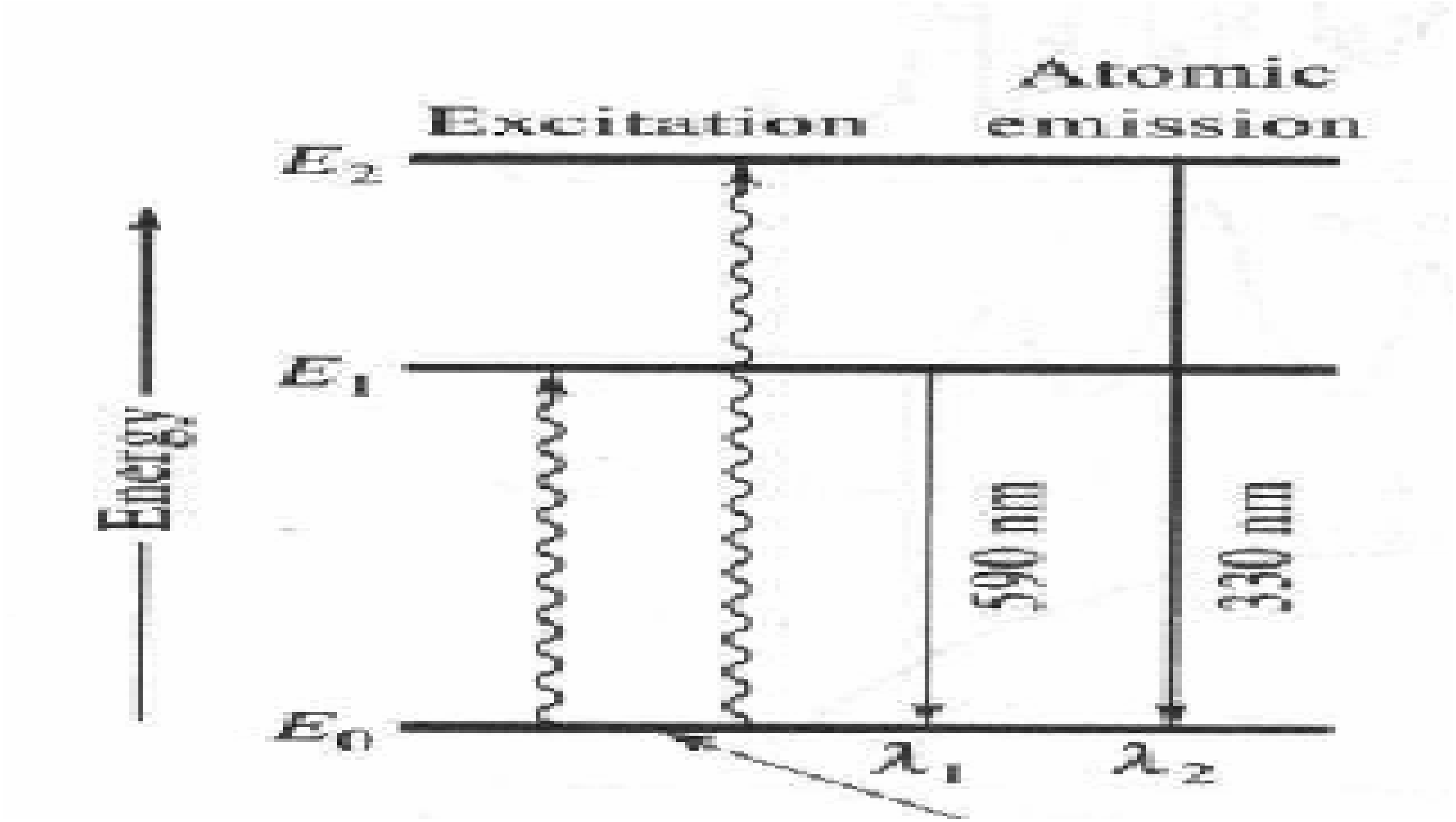
Atomic transition

- Atomic transitions are usually very discreet changes of electrons from one quantum state to another (energy levels, shells, spins, etc.).
- Only electronic transition is quantized.
- When an atom changes energy state, it absorbs or emits energy equal to the energy difference

$$\square E = E_1 - E_0$$

- The wavelength or frequency of radiation absorbed or emitted during a transition proportional to $\square E$
- Transitions between electronic levels produce *line spectra*.

Atomic transition



- E_0 – lowest energy electronic level or ground state
- E_1, E_2 – higher-energy electronic levels

Molecular transition

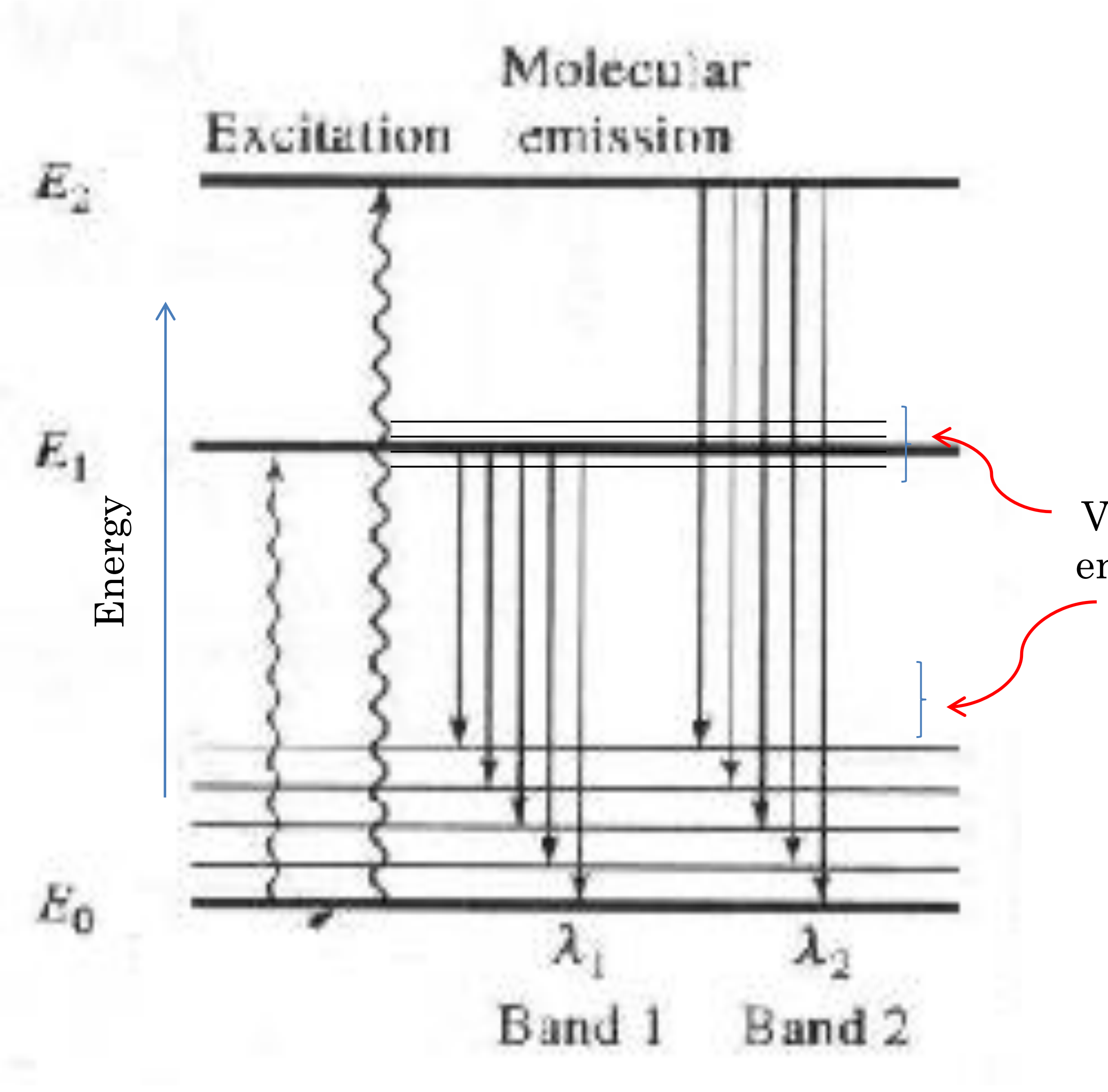
- In molecules the electronic states are subdivided into vibrational states.

- The energy of a band in a molecular absorption spectrum is the sum of three different energy components.

  $E = E_{\text{electronic}} + E_{\text{vibrational}} + E_{\text{rotational}}$

- Transitions between electronic-vibrational-rotational states give rise to spectra that appear to have bands.

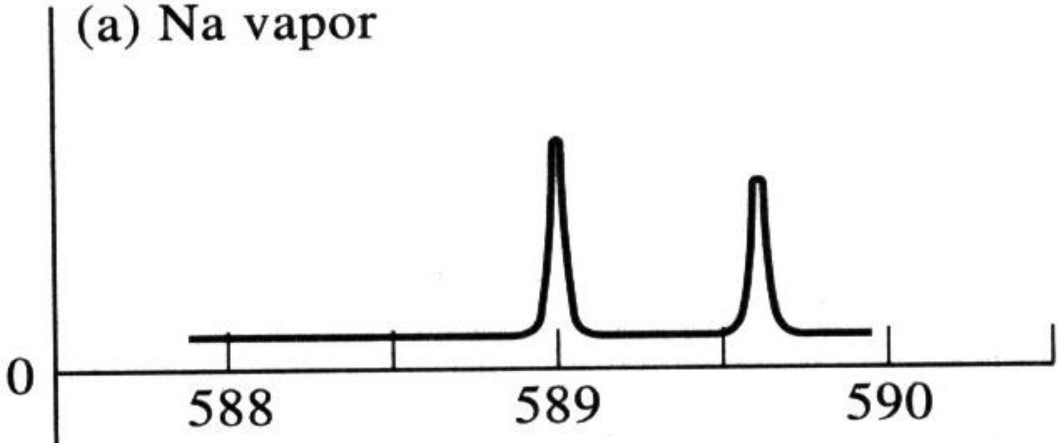
Molecular transition



Vibrational energy level

Atomic absorption spectrum

Absorption Spectrum of Na



- The two peaks arise from the promotion of a 3s electron to the two 3p states

The Absorption Process

The absorption law, also known as the Beer-Lambert law or just Beer’s law, tells us quantitatively how the amount of attenuation depends on the concentration of the absorbing molecules and the path length over which absorption occurs.

As light traverses a medium containing an absorbing analyte, decreases in intensity occur as the analyte becomes excited. Why?For an analyte solution of a given concentration, the longer the length of the medium through which the light passes (pathlength of light), the more absorbers are in the path and the greater the attenuation. Also for a given pathlength of light, the higher the concentration of absorbers, the stronger the attenuation.

The Absorption Process

Consider radiation as it passes through an absorbing solution of thickness b cm and concentration c moles per liter.

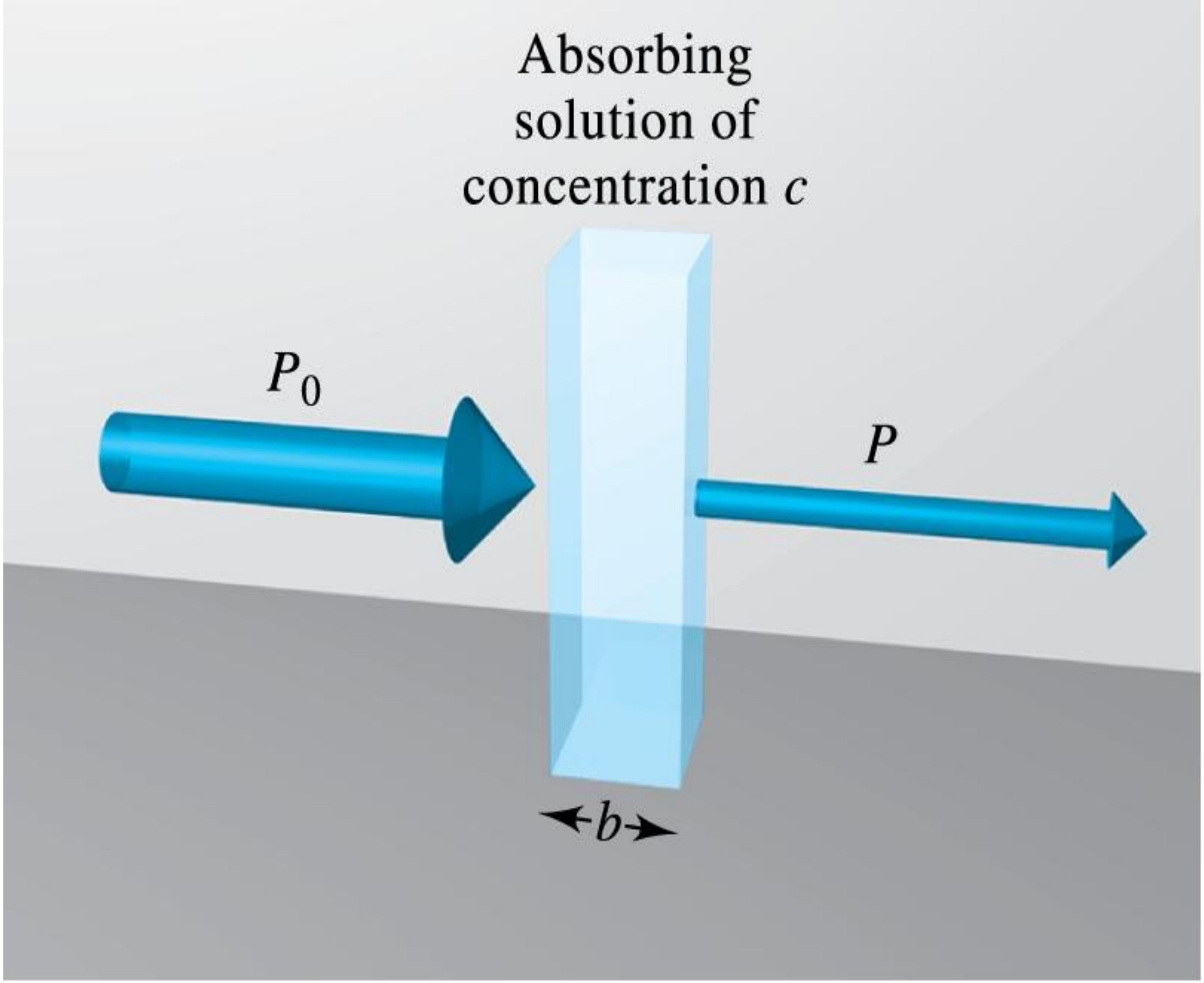
Because of interactions between the photons and absorbing particles, the radiant power of the beam decreases from P_0 to P.

The ***transmittance T*** of the solution is the fraction of incident radiation transmitted by the solution. Transmittance is often expressed as a percentage and called the ***percent transmittance***.

$$T = P / P_0 \quad (T = I/I_0)$$

The **absorbance** A of a solution is related to the transmittance in a logarithmic manner.

$$A= -\log T= \log(P_0/P)$$



$$T = \frac{P}{P_0}$$

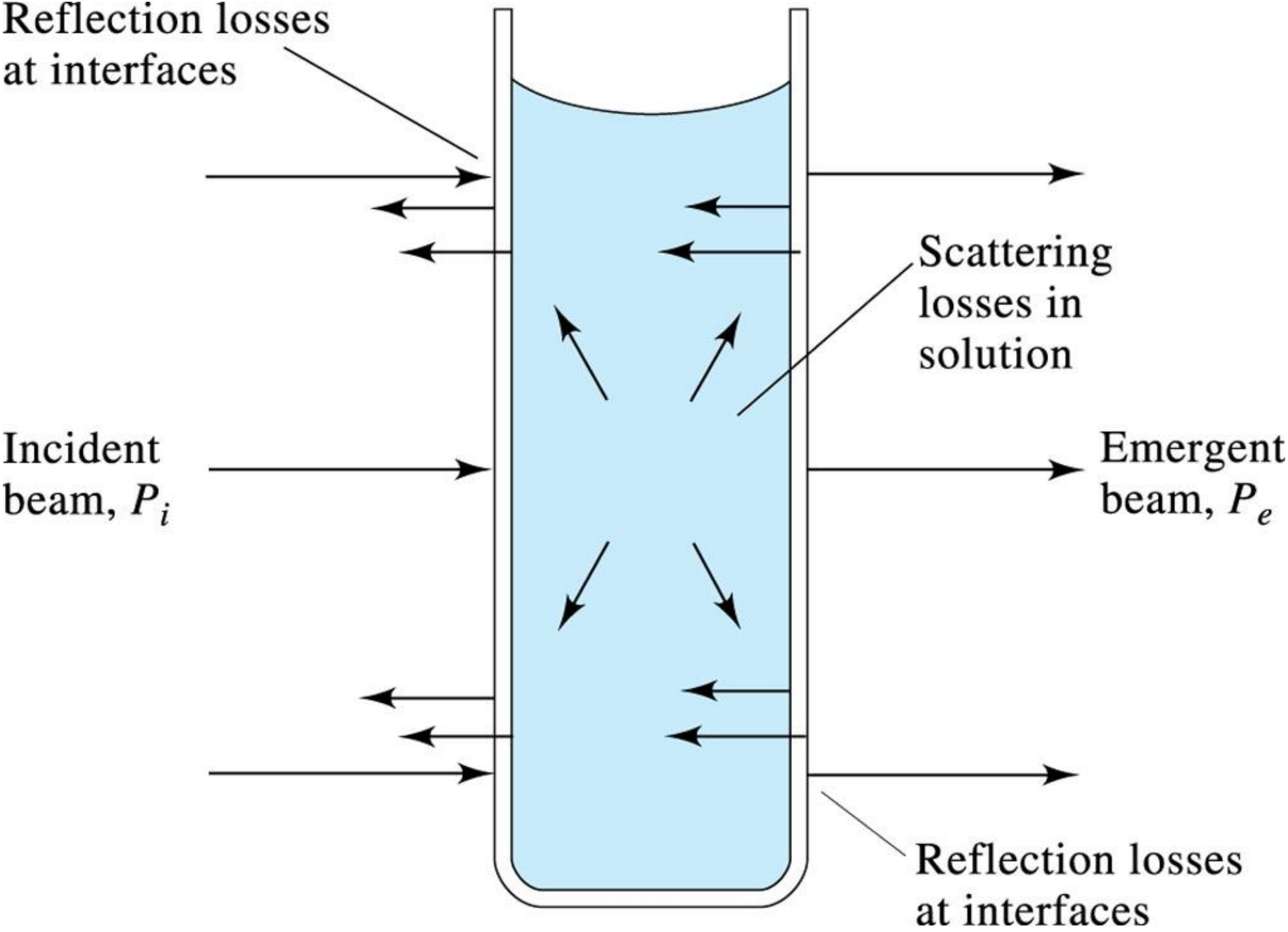
$$A = \log \frac{P_0}{P}$$

Measuring Transmittance and Absorbance

Ordinarily, transmittance and absorbance, cannot be measured as shown because the solution to be studied must be held in some sort of container (cell or cuvette).

Reflection and scattering losses can occur at the cell walls. These losses can be substantial.

Light can also be scattered in all directions from the surface of large molecules or particles, such as dust, in the solvent, and this can also cause further attenuation of the beam as it passes through the solution.


Reflection losses at interfaces
Scattering losses in solution
Incident beam, P_i
Emergent beam, P_e
Reflection losses at interfaces

Beer’s Law

According to Beer’s law, absorbance A is directly proportional to the concentration of the absorbing species c and the path length b of the absorbing medium

$$A = \log P_0 / P = abc$$

Here, a is a proportionality constant called the **absorptivity**. Because absorbance is a unitless quantity, the absorptivity must have units that cancel the units of b and c. If, for example, c has the units of grams per liter ($g\ L^{-1}$) and b has the units of centimeters (cm), absorptivity has the units of liters per gram centimeter ($L\ g^{-1}\ cm^{-1}$).

Cont….

When we express the concentration in moles per liter and b in centimeters, the proportionality constant, called the **molar absorptivity**, is given the special symbol ε. Thus,

$$A = \varepsilon bc$$

where, ε has the units of liters per mole centimeter (L mol^{-1} cm^{-1}).

Applying Beer’s Law to Mixture

Beer’s law also applies to solutions containing more than one kind of absorbing substance. Provided that there are no interactions among the various species, the total absorbance for a multicomponent system is the sum of the individual absorbances. In other words,

$$A_{total} = A_1 + A_2 + \ldots A_n$$

$$= \varepsilon_1 bc_1 + \varepsilon_2 bc_2 + \ldots + \varepsilon_n bc_n$$

where the subscripts refer to absorbing componets 1, 2, …, n.

Limits to Beer's Law

There are few exception to the linear relationship between absorbance and pathlength at afixed concentration.

We frequently observe deviations from the direct proportionality between absorbance and concentration where b is a constant.

Some of these deviations, called ***real deviations***, are fundamental and represent real limitations to the law.

Others occur as a consequence of the manner in which the absorbance measurements are made or as a result of chemical changes associated with concentration changes. This deviations is called ***chemical deviation***.

Real Limitations to Beer’s Law

Beer’s law describes the absorption behavior of dilute solutions only and is a limiting law.

At concentrations exceeding about 0.01 M, the average distances between ions or molecules are diminished to the point where each particle affects the charge distribution, and thus the extent of absorption of its neighbors.

The occurrence of this phenomenon causes deviations from the linear relationship between absorbance and concentration. When ions are in close proximity, the molar absorptivity of the analyte can be altered because of electrostatic interactions, which can lead to departures from Beer’s law.

Chemical Deviations

Deviations from Beer's law appear when the absorbing species undergoes association, dissociation, or reaction with the solvent to give products that absorb differently from the analyte.

- Chemical deviations are the apparent deviations from Beer's law that occur when an analyte changes in the presence of the solvent to form compounds that have a different light absorbing character from the parent species.
- The ionization reactions of acidic or basic indicators are examples of this behavior. As the indicator concentration increases so does its influence on the pH, and when the pH changes so do the proportions of the different ionized species which in tum changes the absorptivity of the solution

THANK YOU !

Bonga university

Instrumental Analysis II (Chem.2052)

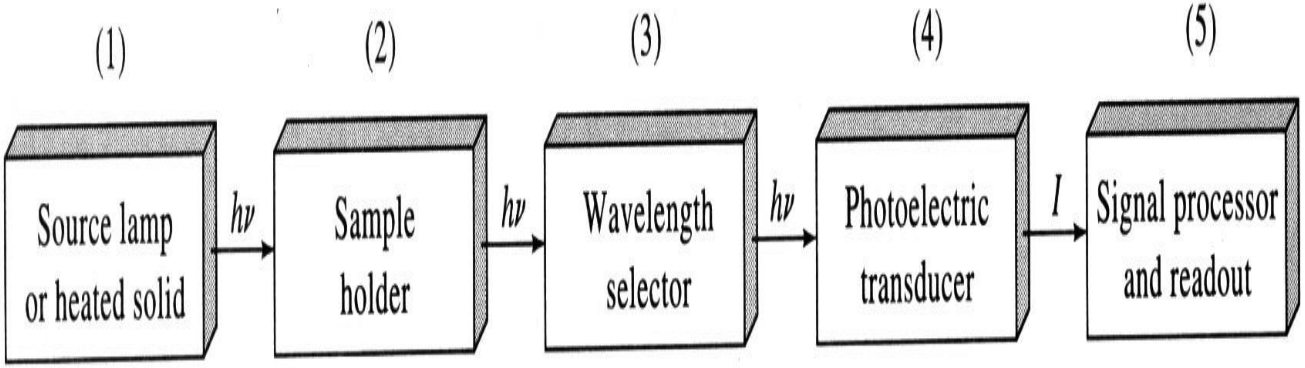
Chapter 3.

Instruments for optical spectroscopy

2012 E.C

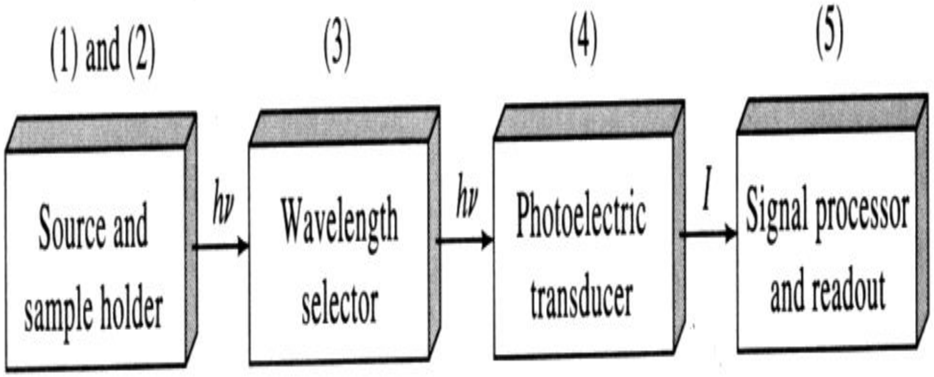
General Design of Optical Instruments

Absorption



(a)

Emission



(c)

Five Basic Optical Instrument Components

1)**Source** - A stable source of radiant energy at the desired wavelength (or λ range).

2)**Sample Holder** - A transparent container used to hold the sample (cells, cuvettes, etc.).

3)**Wavelength Selector** - A device that isolates a restricted region of the EM spectrum used for measurement (monochromators, prisms, & filters).

4)**Photoelectric Transducer** - (Detector) Converts the radiant energy into a useable signal (usually electrical).

5)**Signal Processor & Readout** - Amplifies or attenuates the transduced signal and sends it to a readout device such as a meter, digital readout, chart recorder, computer, etc.

I. Sources of Radiation

- Generate a beam of radiation that is stable and has sufficient power.

A. Continuum Sources

- emit radiation over a broad wavelength range and the intensity of the radiation changes slowly as a function of wavelength.

This type of source is commonly used in UV, visible and IR instruments.

- Deuterium lamp is the most common UV source.
- Tungsten lamp is the most common visible source.
- Glowing inert solids are common sources for IR instruments.

B. Line Sources

- Emit a limited number *lines* or bands of radiation at specific wavelengths.

- Used in atomic absorption spectroscopy

- Types of line sources:

1) Hollow cathode lamps
2) Electrodeless discharge lamps
3) Lasers - Light amplification by stimulated emission of radiation

II. Wavelength Selectors

- Wavelength selectors output a limited, narrow, continuous group of wavelengths called a *band*.

- Two types of wavelength selectors:

A) Filters
B) Monochromators

A. Filters

- Two types of filters:

1) Interference filters
2) Absorption Filters

B. Monochromators

- Wavelength selector that can continuously scan a broad range of wavelengths

- Used in most scanning spectrometers including UV, visible, and IR instruments.

III. Radiation Transducers (Detectors)

- Early detectors in spectroscopic instruments were the human eye, photographic plates or films. Modern instruments contain devices that convert the radiation to an electrical signal.

Two general types of radiation transducers:

a. Photon detectors

b. Thermal detectors

A. Photon Detectors

- Commonly useful in ultraviolet, visible, and near infrared instruments.
- Several types of photon detectors are available:

1. Vacuum phototubes
2. Photomultiplier tubes
3. Photovoltaic cells
4. Silicon photodiodes
5. Diode array transducers
6. Photoconductivity transducers

B. Thermal Detectors

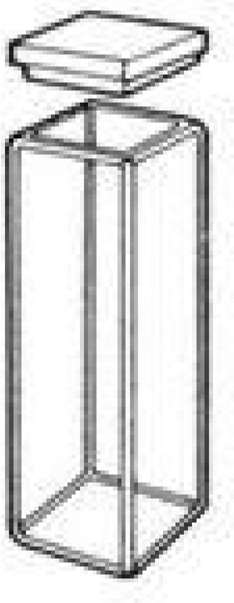
- Used for infrared spectroscopy because photons in the IR region lack the energy to cause photoemission of electrons.

- Three types of thermal detectors :

1. Thermocouples
2. Bolometers
3. Pyroelectric transducers

IV.Sample Holder (Container)

- Sample containers, usually called ***cells*** or ***cuvettes*** must have windows that are transparent in the spectral region of interest.
- There are few types of cuvettes:
  - quartz or fused silica
  - silicate glass
  - crystalline sodium chloride



cuvette

quartz or fused silica

- required for UV and may be used in visible reg

silicate glass

- cheaper compared to quartz. Used in UV

crystalline sodium chloride

- used in IR

- SPECTROMETER

- is an instrument that provides information about the intensity of radiation as a function of wavelength or frequency

- SPECTROPHOTOMETER

- is a spectrometer equipped with one or more exit slits and photoelectric transducers that permits the determination of the ratio of the radiant power of two beams as a function of wavelength as in absorption spectroscopy.

SUMMARY

Types of source, sample holder and detector for various EM region

REGION	SOURCE	SAMPLE HOLDER	DETECTOR
Ultraviolet	Deuterium lamp	Quartz/fused silica	Phototube, PM tube, diode array
Visible	Tungsten lamp	Glass/quartz	Phototube, PM tube, diode array
Infrared	Nernst glower (rare earth oxides or silicon carbide glowers)	Salt crystals e.g. crystalline sodium chloride	Thermocouples, bolometers

THANK YOU!!!