Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) for Pollution Monitoring

Dr. J R Mudakavi
Department of Chemical Engineering
Indian Institute of Science, Bangalore

Lecture – 09
Interaction of EM radiation with matter-II

Greetings to you we will continue our discussion on the electromagnetic radiation and it is interaction with the matter in the last slide, we have the seen.

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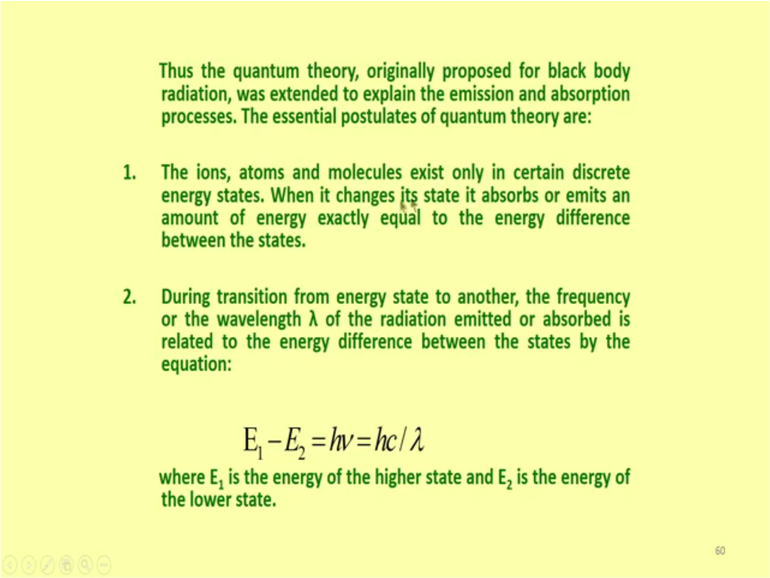

Thus the quantum theory, originally proposed for black body radiation, was extended to explain the emission and absorption processes. The essential postulates of quantum theory are:

1. The ions, atoms and molecules exist only in certain discrete energy states. When it changes its state it absorbs or emits an amount of energy exactly equal to the energy difference between the states.
2. During transition from energy state to another, the frequency or the wavelength λ of the radiation emitted or absorbed is related to the energy difference between the states by the equation:

$$E_1 - E_2 = h\nu = hc/\lambda$$

where E_1 is the energy of the higher state and E_2 is the energy of the lower state.

How we can calculate the energy of the electron here, I we had stopped at this slide, but I want to go back and spend a few seconds and their previous slide.

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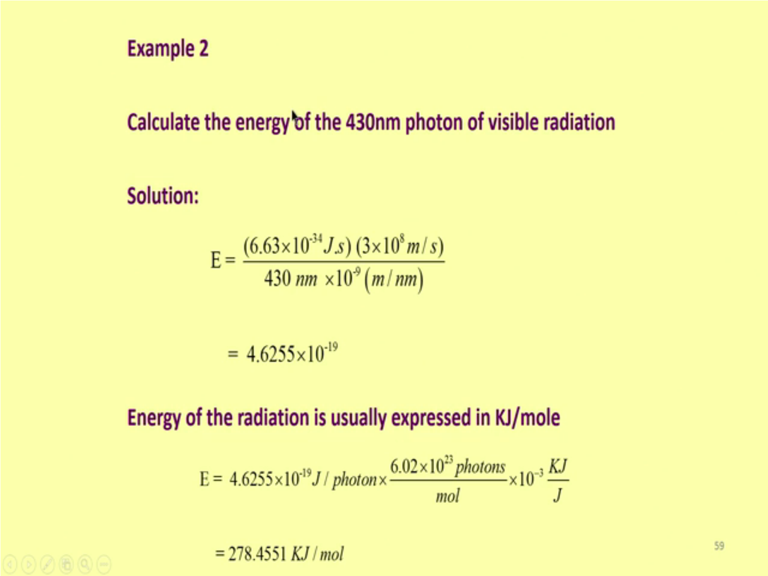

Example 2

Calculate the energy of the 430nm photon of visible radiation

Solution:

$$E = \frac{(6.63\times10^{-34} J.s)\,(3\times10^{8} m/s)}{430\ nm\ \times10^{-9}\,(m/nm)}$$

$$= 4.6255\times10^{-19}$$

Energy of the radiation is usually expressed in KJ/mole

$$E = 4.6255\times10^{-19} J/photon \times \frac{6.02\times10^{23} photons}{mol} \times 10^{-3}\frac{KJ}{J}$$

$$= 278.4551\ KJ/mol$$

So, what we did was aftercare, looking at most of the electron electromagnetic radiation properties, we have decided, how to characterize the electromagnetic radiation.

So, we did two examples and the second one is this, I did not spend much time on this. So, the idea is to calculate the energy of the 430 nanometer photon of visible radiation, this 430 nanometer is sort of a reddish orange color, orange color. So, if you see color, any color in the sky. For example, 430 nanometers in the orange color, you can actually calculate what is the energy of that radiation. So, you use a prism and then pass the radiation, collect the radiation at collect the radiation of the orange color, you can calculate what is the energy of that radiation similarly, you can calculate for blue color, violet color etcetera.

So, the information formula is very simple E is equal to h c by lambda. This is planks constant this is velocity of the electro velocity of the light, in vacuum 3 into 10 raise to 10 meters per second, I have put otherwise 3 into 10 raise to 10 meter centimeters per second, also we can put here.

I have put Joules in and the planks constant in joules seconds and then you have to divide it by wave length that is orange color. So, orange color wave length corresponds to 430 and nanometer that you have to convert it into meters again. So, meters by nanometers. So, the energy comes to 4.6255 into 10 raise to minus 9 Hertz. So, that, but that is expressed in kilojoules per mole.

So, the energy of each one will correspond to each photon, would correspond to 4.6255 into 10 raise to minus 19 Joules per photon and that is the. So, many photons per mole per mole that is if a mole one molecular this substance is giving out radiation how many radiation atoms are there will be 6 into avgas address number 6 into 10 raise to 23, so many photons, so many molecules, so many atoms. So, many photons per molecule multiply it by convert it into kilojoules. So, that you will get 278.4551 kilojoules per mole, that is how you can calculate the energy of any wavelength corresponding to electromagnetic radiation.

So, I can ask you in the test to calculate the energy of a photon per mole corresponding to different colors. So, be prepared for such small surprise in the tests, if you plan to take the test, but even otherwise the information is very useful. So, now, after having studies all these, I had put on this slide stating that the quantum theory originally proposed for black body radiation etcetera. This I already given you enough introduction. So, it was extended to explain the emission and absorption processes. This emission and absorption processes are closely related to our topic of interest that is ICP Inductive Coupled Plasma, atomic emission and absorption. So, the rules remain the same with respective of whether it is UV visible I R, whatever it is.

So, what are the essential postulates? The essential postulates of the quantum theory are ions, atoms, molecules; exists only in certain discreet energy levels and when it changes it is state. It absorbs or emits the radiation exactly equal to the amount of energy difference between that two states. So, if T gets excited, it absorbs the radiation, if it gets emission, comes back to ground state, it emits that radiation, but it will be exact quantity. So, if we know the energy, we can calculate the amount of the radiation that comes up and vice versa.

So, during the transition from one energy state to another frequency or the wavelength of the radiation is related to the energy difference, this we already covered and E1 minus E2 is equal to h c by lambda.

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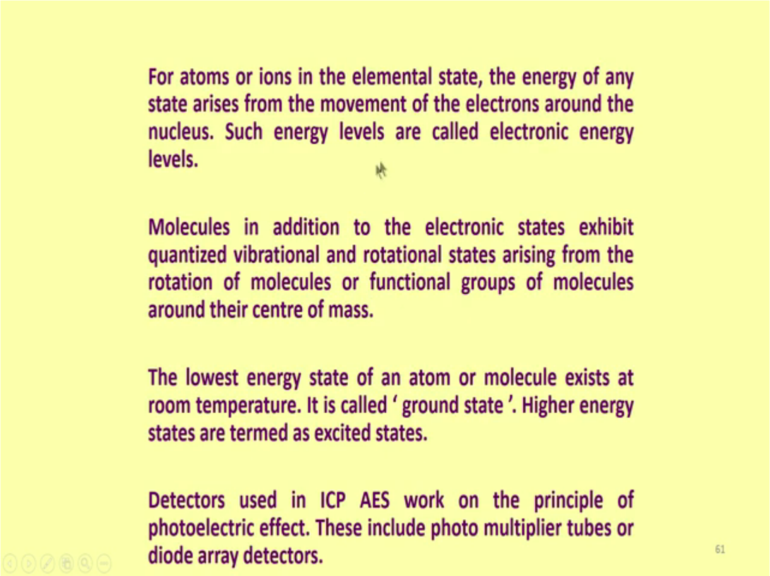

For atoms or ions in the elemental state, the energy of any state arises from the movement of the electrons around the nucleus. Such energy levels are called electronic energy levels.

Molecules in addition to the electronic states exhibit quantized vibrational and rotational states arising from the rotation of molecules or functional groups of molecules around their centre of mass.

The lowest energy state of an atom or molecule exists at room temperature. It is called ' ground state '. Higher energy states are termed as excited states.

Detectors used in ICP AES work on the principle of photoelectric effect. These include photo multiplier tubes or diode array detectors.

So, for atoms are ions in the elemental state that is uncombined atoms or atoms in from which electrons have been removed, they are known as ions. The energy of any state arises from the moment of electrons around the nucleus. Such energy levels are called electronic energy levels. Molecules exhibit apart from electronic energy levels vibrational and rotational energy level that is each electronic energy level is associated with number of vibrational energy. We can imagine a big building with, from the ground floor, first floor, second floor, third floor.

So, each floor represents some sort of an electronic level, but each floor to reach, each floor you have to clime number of steps those steps, you can imagine as made up of vibrational energy levels. Now, suppose you divide each step again into still smaller steps. So, that smaller people or and say other things, small animals can go through stage by stage, they are know something like rotational animal, rotational vibrations.

So, each vibrational and rotational energy level corresponds to a particular electronic energy level. So, the lowest energy state or a molecule of an atom, or a molecule exists at room temperature that is all molecules and atoms contain the electrons at the lowest energy level at room temperature; this is called as ground state.

Higher energy states are termed as excited states. So, detectors used in ICP AES work AES work on the principle of photo electric effects, these include photo multiplier tubes and diode array photo detectors. So, the job of the detector is to convert the photons that fall on the photo multiplier tube, or photo electric effect, or photo diode. Array is to convert the photon back into an electrical signal and that signal can be recorded, it will be in the voltage or ampere or whatever, it is or resistance, any of the electrical properties.

So, the use of photo detectors are part and parcel of all instruments, which work on the photo on the electromagnetic radiation, we will come to that again, when we describe about the instrumentation for ICP, AES in particular, because there is lot of theory to be learnt about it, but I have already covered most of it in my previous course that is on atomic absorption.

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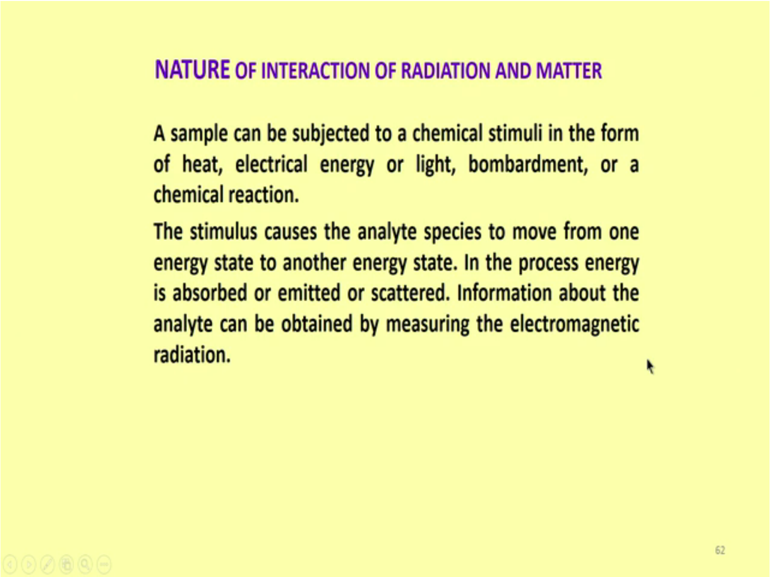

NATURE OF INTERACTION OF RADIATION AND MATTER

A sample can be subjected to a chemical stimuli in the form of heat, electrical energy or light, bombardment, or a chemical reaction.

The stimulus causes the analyte species to move from one energy state to another energy state. In the process energy is absorbed or emitted or scattered. Information about the analyte can be obtained by measuring the electromagnetic radiation.

Now, what I want to do is I want to shift again your attention to the nature of interaction of radiation and matter. So, radiation passing through a matter, passing through on it's own in vacuum or in air, or in this, thing is different, but interaction, how does it really affect the matter?

We have already seen that refraction, reflection, refraction and scattering. They are all part and parcel of the interaction only. So, now, I want to tell you about the interaction of electromagnetic radiation with a sample, which we want to analyze, because apart from the optics, the radiation also has to react with the sample to generate spectra graphic data. So, what we need to do is, we take a sample subject it to a chemical stimuli in the form of heat electrical energy, or light, or bombardment, or a chemical reaction, we can contain, we can carry out. So, this stimulus, any temperature heating or chemical reaction etcetera, it causes the enlighten spices to move from one energy state to another state.

See now, I am talking about the sample. So, in the process the sample absorbs energy, or it emits, or scatters.

So, information about this can be obtained by measuring, the electromagnetic radiation, that is incoming radiation matter and outgoing radiation. I have three parts; imagine, my head as a sample incoming radiation is on my left and outgoing radiation is on my right. So, the radiation comes here, passes through my head and then undergoes on some certain amount of transformation comes out on the other side. So, my sample interacts with the matter and undergoes changes in it is energy states.

So, that is what we are talking about.

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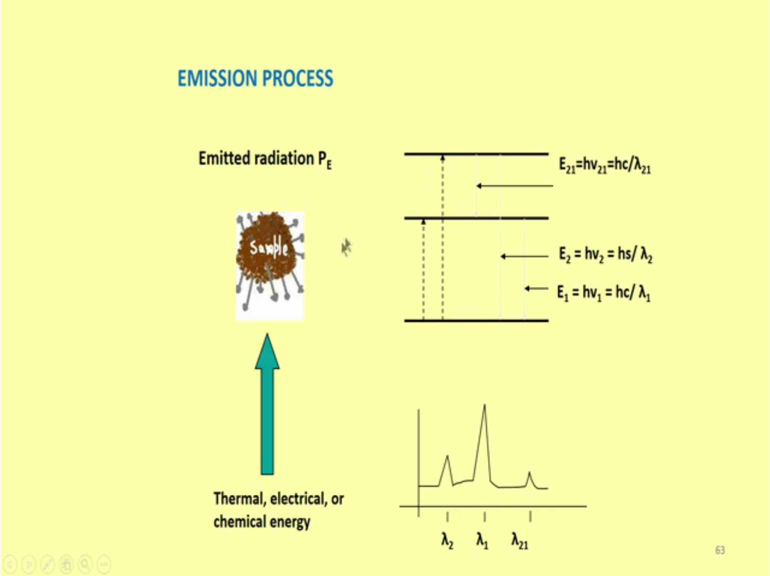

EMISSION PROCESS

Emitted radiation P_E

Thermal, electrical, or chemical energy

$E_{21}=hv_{21}=hc/\lambda_{21}$

$E_2 = hv_2 = hs/ \lambda_2$

$E_1 = hv_1 = hc/ \lambda_1$

So, now look at this figure. There are two processes; one is emission, another is absorption, basically that is what we have been discussing, I have the sample here, I am putting the, I am exciting the sample into a suitable state, where electromagnetic can be interact with the electromagnetic radiation. So, it may be thermal electrical or chemical energy, the sample is here.

So, the radiation, the emitted radiation is collected here, my radiation also comes here. Electromagnetic radiation reacts with the sample and the energy comes out that is photonic energy. So, here what is the difference between sample or here the sample, this arrow, green arrow, what you are seeing, represents a transformation of the sample into a state, where electromagnetic radiation interacts with the atoms and molecules and ions, that is why I have written thermal electrical or chemical energy and then electromagnetic radiation also passes through that and then emitted radiation comes out, this is the emission. So, what happens here? I have put it in terms of energy levels, this is E1 h mu 1 h mi 2 E1 to E2 and then E2 1 is here. So, for each transaction that takes place here.

I have a peak corresponding to absorption at the dotted lines, represent absorption and the lines pointing down are emissions. So, the emission wavelength, I can calculate or measure by using photo detectors. So, this is the whole process of spectroscopic application, how a spectroscopy is generated etcetera, and what is recorded is a response of the wavelength versus it is energy. We know how to calculate the energy and how to determine the energy that is coming out. So, I know the incoming energy of the electromagnetic radiation, I know the out coming energy of the electromagnetic radiation.

I can generate a figure like this by plotting lambda versus energy.

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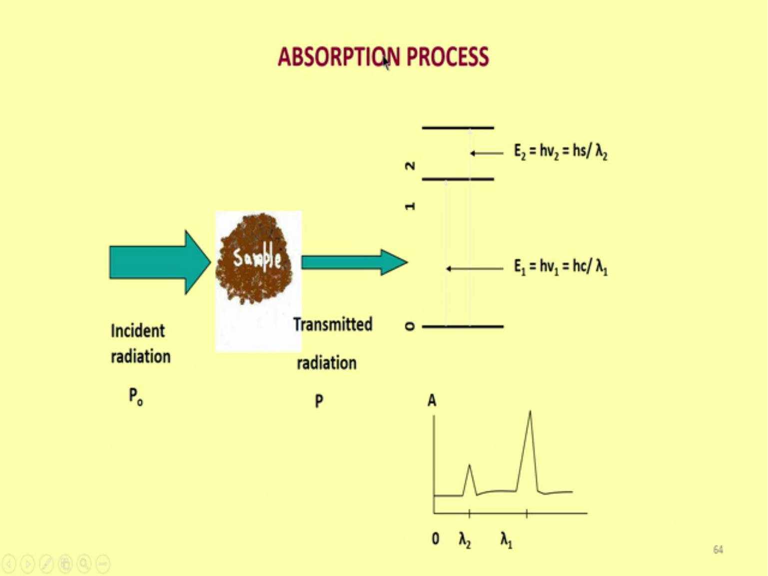

ABSORPTION PROCESS

So, this is absorption process, I have the sample here again I am sub, I am changing it into a measurable formed by supplying heat, or temperature, or making into small molecules and then I have the incident radiation coming from the left here and then it passes through the sample undergoes transformation and what comes out is transmitted radiation. So, here the energy is absorbed. So, even the absorbed energy, the same parameters can be calculated. This here, the excess is absorption Y axis and then the X axis is wavelength.

So, these are the two basic principles absorption and emission that take place here.

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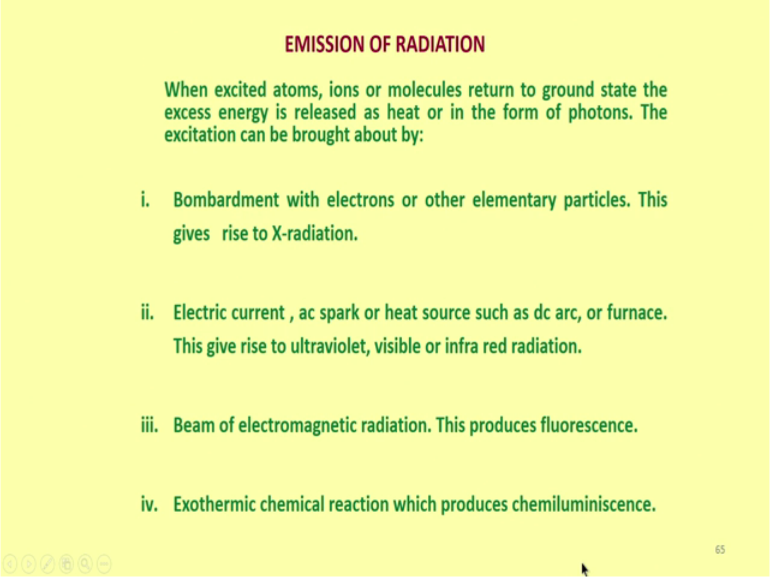

EMISSION OF RADIATION

When excited atoms, ions or molecules return to ground state the excess energy is released as heat or in the form of photons. The excitation can be brought about by:

i. Bombardment with electrons or other elementary particles. This gives rise to X-radiation.

ii. Electric current , ac spark or heat source such as dc arc, or furnace. This give rise to ultraviolet, visible or infra red radiation.

iii. Beam of electromagnetic radiation. This produces fluorescence.

iv. Exothermic chemical reaction which produces chemiluminiscence.

So, we will talk about emission, this course is all about atomic emission spectroscopy. So, when excited atoms, ions or molecules return into the ground state, the excess energy is released as heat or in the form of photons, if the energy is released as heat you cannot measure the amount of radiation by photo detectors, but if it is photons that is coming out then it can be measured. So, the excitation can be brought about by bombardment with electrons or some other elementary particles. This gives raise to X-radiation, X-ray. So, I can use electric current, a c spark, heat source, a c arc, d c arc, farness etcetera, to give rise to UV visible infrared radiation.

Now, I can also use for excitation a beam of electromagnetic radiation. This produces florescence, why? Because they sometimes, the wavelength coming out is at higher wave length and lower energy after excitation so, that produces florescence. So, exothermal chemical reactions also produces what is known as chemiluminiscence, both these systems I have addressed in my MOS course on spectrophotometry, you can look up the details in that course.

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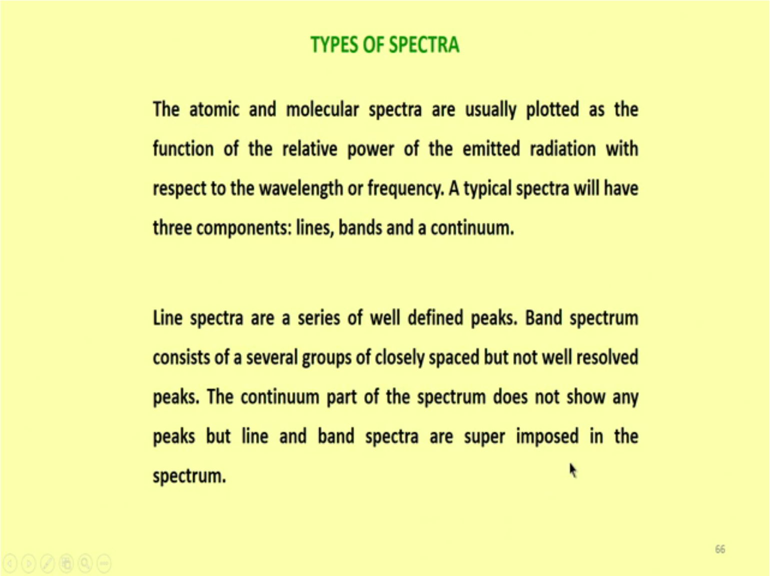

TYPES OF SPECTRA

The atomic and molecular spectra are usually plotted as the function of the relative power of the emitted radiation with respect to the wavelength or frequency. A typical spectra will have three components: lines, bands and a continuum.

Line spectra are a series of well defined peaks. Band spectrum consists of a several groups of closely spaced but not well resolved peaks. The continuum part of the spectrum does not show any peaks but line and band spectra are super imposed in the spectrum.

Now, there are different types of spectra, the response what I have, I was talking to you about the response of the electromagnetic radiation with respect to wavelength that is what is spectrograph, we will do and what is a spectrometer? We will produce and a plot is known as spectrum or spectra number of plots, those things the atomic and molecular spectra are usually plotted as the function of the relative power of the emitted radiation. So, that is with respect to wave length or frequency a typical spectra. We will have three components; one is, it can be a simple sharp line, or it can be a band, or it can be a continuum, you cannot make out a specific part of the spectrum.

This is an absorption or this is an emission, you will see a bright light somewhere or a peak with a simple with no maxima or minima. So, that is known as continuum spectrum. I had shown you in Fraunhofer lines, their lines and bands and continuum spectra earlier you can look it up again. So, what is the line spectra then line spectra are a series of well defined peaks, but they are. So, sharp that you cannot really think, it is a curve with a maximum or a minimum.

So, it just goes like this. So, our human eye is not capable of distinguishing the rising part or falling part of these of a peak that is known as line spectrum. Now, band spectrum is another one. So, there you can see, it contains a number of several groups closely spaced, but not well resolved peaks.

I have told you about the small energy difference between using spectral, using vibrational and rotational energy levels, those things if they are visible in the spectrometry in the spectrum, then it looks like a nice gaseous curve you can, I have shown you such curves earlier also, but we will see them more and more and such spectrums are very common in we, in UV visible spectrometry and atomic absorption spectrometry also.

So, the continuum part of the spectrum does not show any peaks. So, they, but line spectra and band spectra, they are all both super imposed in the spectrum, in the continuum area.

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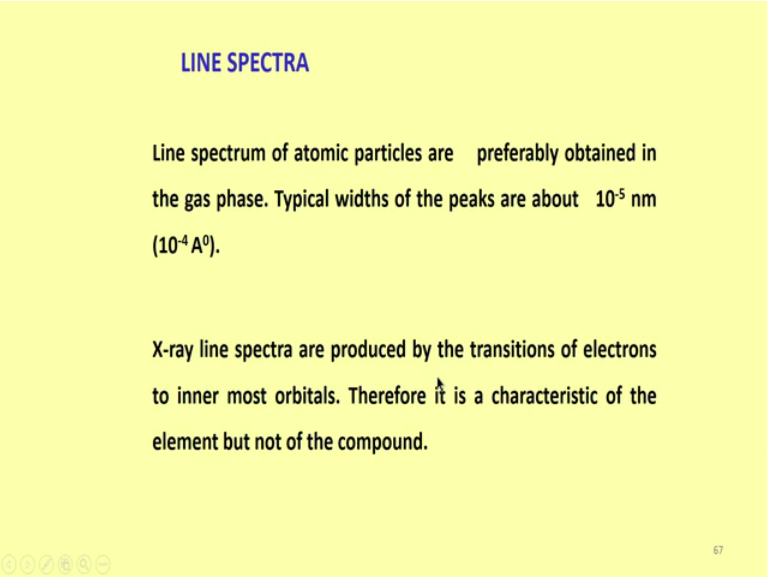

LINE SPECTRA

Line spectrum of atomic particles are preferably obtained in the gas phase. Typical widths of the peaks are about 10^{-5} nm (10^{-4} A^0).

X-ray line spectra are produced by the transitions of electrons to inner most orbitals. Therefore it is a characteristic of the element but not of the compound.

So, what is we will spend a little bit about line spectra line spectrum of atomic particles are preferably obtained in the gas phase; that means, the particles atoms must be well separated in the gaseous space any substance has got three states one is liquid state another is gaseous state another is solid state in the solid state all the atoms are compacted together in the liquid state they are in a state of motion and in the gaseous state they are in the they occupy the volume that we give.

Where the total volume is our occupied by the gas by the sample; that means, each atom or molecule is free to move around in a given volume. So, the gas phase, because they are so free, the spectrum particulars become clearly visible. So, line spectra are maximum seen in gaseous samples.

So, typical widths of these peaks are of the order of 10 raise to minus 5 millimeter; that means, we can see only 1 millimeter difference in our scales right in if you take your compass at home look at the scales 1 centimeter you can see 1 millimeter you can see less than 1 millimeter you can see with difference with a good eye and if you take a magnifying glass you can still see 1 millimeter nicely, but that is 0.1 of 1 10,000 times thinner than that 1 millimeter, you divide 1 millimeter into 10,000 parts that is 10 raise to minus 5 millimeter and that you cannot see with our necked eye each margin.

So, we need some space for marking also you know the markings themselves will be thicker than the peaks. So, 10 raise to minus 5 nanometer would be approximately equal to 10 raise to minus 4 Armstrong.

So, the line spectra are more maximum obtained by X-ray and they are produced by the transitions of electrons to inner most orbitals. Therefore, it is a characteristic of the element, but not of the compound, why? Imagine, I have a substance sodium chloride. Now, sodium chloride is a molecule, you know crystal it has got sodium ions and chloride ions suppose, I have molybdenum then it has got only molybdenum, but it is a solid, because it is a metal you all know it now when an electron in a molybdenum metal fall down from higher energy level to a lower energy level.

It is the characteristic of the molybdenum that we see in terms of a spectra, a spectrum, because it contains nothing else similarly, several molecules if they are subjected to X-rays, there will be line spectra, but the line spectra correspond to the characteristic of the elements that are contained in them. So, it is a characteristic of the element, but not of the compound.

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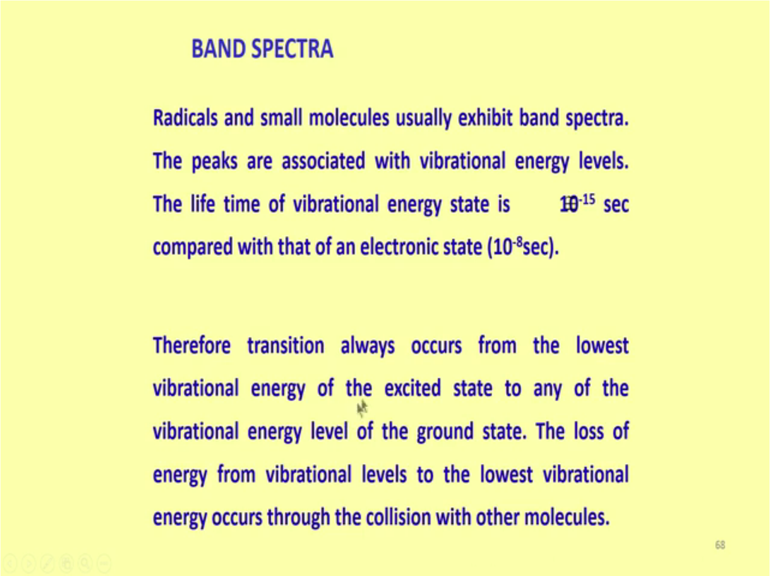

BAND SPECTRA

Radicals and small molecules usually exhibit band spectra. The peaks are associated with vibrational energy levels. The life time of vibrational energy state is 10^{-15} sec compared with that of an electronic state (10^{-8}sec).

Therefore transition always occurs from the lowest vibrational energy of the excited state to any of the vibrational energy level of the ground state. The loss of energy from vibrational levels to the lowest vibrational energy occurs through the collision with other molecules.

So, similarly in UV visible region, we do get line spectra for gases, but there the transition will be from electronic energy levels from one electronic energy level to another electronic energy level that is the transition and then we have, what is known as band spectrum. So, where do band spectra come from radicals and small molecules line carbon monoxide, carbon dioxide, nitrogen, molecules, small molecules, you know containing 2 or 3 atoms.

You can imagine many of them like water; it has got only 3 atoms H2O ammonia. So, many small molecules exist and such radicals and small molecules usually exhibit band spectra, these peaks are associated with vibrational energy levels. So, the life time of the vibrational energy level is also approximately 10 raise to minus 15 seconds, but this is very short compared to 10 raise to minus 8 seconds for the electronic an energy change. So, the transition always occurs from the lowest vibrational energy level of the excited state to any of the vibrational energy level of the ground state now imagine.

I have number of vibrational energy levels initially transition from excited state starts from vibrational energy level to lower and lower vibrational energy level and then the electronic transition will take place, when it falls to the lowest vibrational energy state of the excited electronic state. So, how does it happen it happens by collagen in the gaseous space lot of gases gas molecules are moving here, there, everywhere, in random directions. So, they may hit each other and during that time, the vibrational energy they lose energy in the form of heat or something and then they come to the lower vibrational energy levels. So, once they reach the ground excite electronic energy level.

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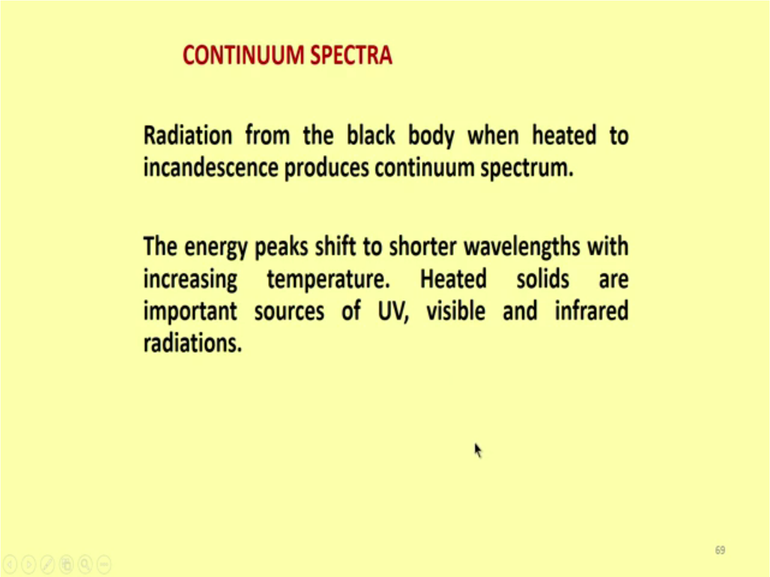

CONTINUUM SPECTRA

Radiation from the black body when heated to incandescence produces continuum spectrum.

The energy peaks shift to shorter wavelengths with increasing temperature. Heated solids are important sources of UV, visible and infrared radiations.

Then only the emission will take place in the continuum spectra, you do not see anything, you will just see a bright beam of light for example, radiation from a black body, when heated to incandescence; you can imagine a normal light bulb. Now a days, everybody using C F L and L ED lights etcetera, just a few years back people where using tungsten lamps that is Thomas Alva Addison’s discovery tungsten lamp, carbon lamp, etcetera, and there whenever you pass through, pass the current, the resistance go around, it gets heated up and you will see only a bright light like what you see in C F L or something, but tungsten lamp would give you some what yellowish light.

But you do not see any other light. So, it is a continuum light radiation, containing several wavelengths of the electromagnetic radiation belonging to the vibrational belonging to the visible range. So, the black body radiation produces a continuous light, bright light, yellow light or something like that and distinguishable from each other. So, the energy peaks, shift to shorter wavelengths with increasing temperature.

I keep on increasing to a higher temperature, the energy peak will come like this and then it shifts to shorter temperature. So, heated solids are important sources of UV visible and I R radiation.

So, if I want to produce ultraviolet range, I need to take a substance and heat it to.high temperature similarly, for I R similarly for visible range. So, these are the sources of UV visible and I R ranges.

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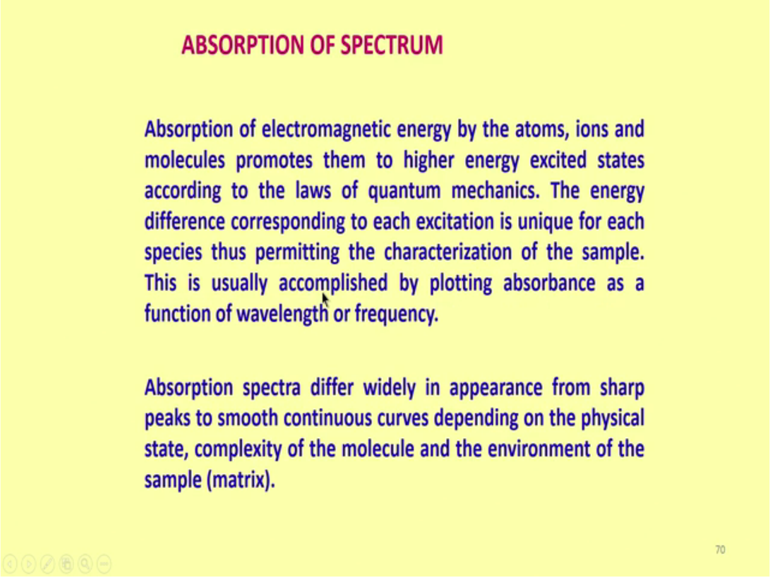

ABSORPTION OF SPECTRUM

Absorption of electromagnetic energy by the atoms, ions and molecules promotes them to higher energy excited states according to the laws of quantum mechanics. The energy difference corresponding to each excitation is unique for each species thus permitting the characterization of the sample. This is usually accomplished by plotting absorbance as a function of wavelength or frequency.

Absorption spectra differ widely in appearance from sharp peaks to smooth continuous curves depending on the physical state, complexity of the molecule and the environment of the sample (matrix).

So, I can, when I build a spectrometer. I need a source of electromagnetic radiation then what I do? I take a small amount of sample tungsten lamp heat. It gives out continuum background radiation cores containing several electrons. So, that is my source. So, I need a source while building, a spectrometer.

So, we do not have to, it is the building a spectrometer or something like that is not rocket science we just have to understand the different phenomenon of electromagnetic radiation and choose wisely that is the beauty of spectrometer.

So, now absorption of spectrum, we will discuss about it for a very short time. So, absorption of electromagnetic energy by atoms ions and molecules some what seems to higher energy? This we already seen and then we already also seen the spectrum, how it generates, but absorption spectra differ widely in appearance from sharp peaks to smooth continues curve in this also we have covered earlier. So, it all depend the nature of the curve, depends upon the physical state complexity of the molecule and the environment of the sample, that is whether it is heated or whether it is molecules or drop laid or error zone, whatever it is. So, that is that depends upon as to convert the sample into a suitable measuring state.

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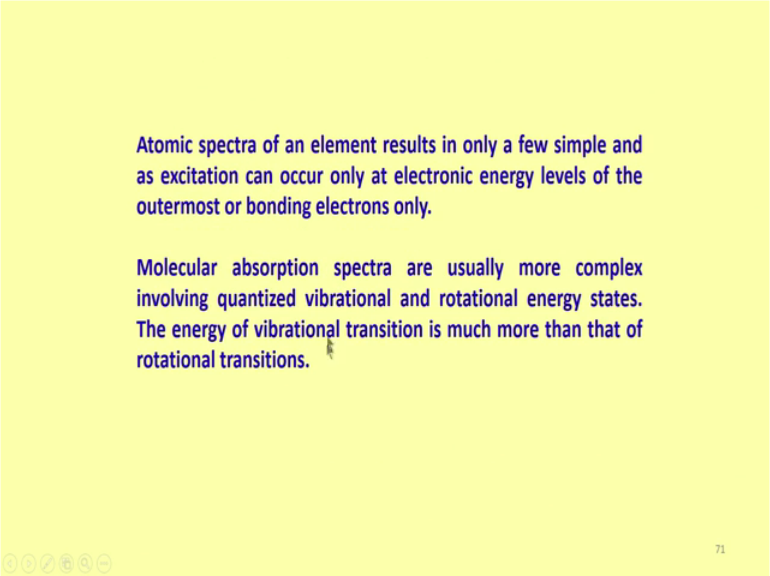

Atomic spectra of an element results in only a few simple and as excitation can occur only at electronic energy levels of the outermost or bonding electrons only.

Molecular absorption spectra are usually more complex involving quantized vibrational and rotational energy states. The energy of vibrational transition is much more than that of rotational transitions.

So, an atomic spectra of an element results in only a few simple lines and as excitation can occur only at electronic levels so, or the outer most and bonding electrons only.

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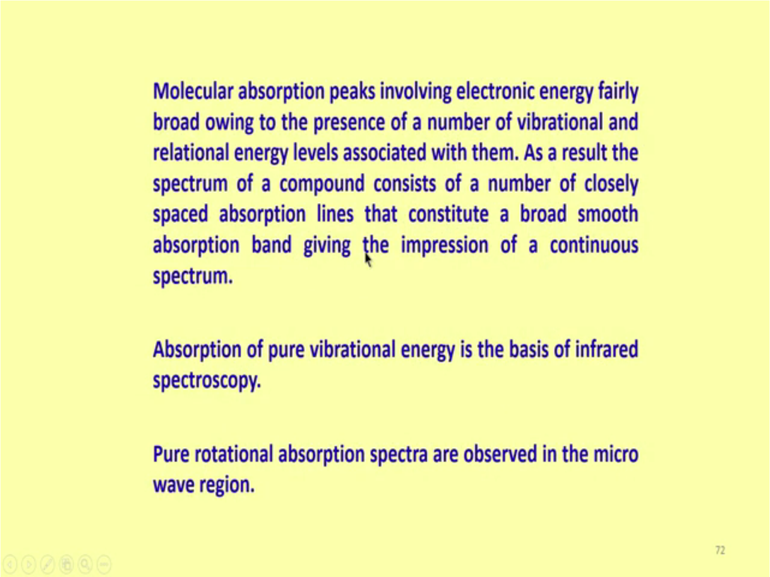

Molecular absorption peaks involving electronic energy fairly broad owing to the presence of a number of vibrational and relational energy levels associated with them. As a result the spectrum of a compound consists of a number of closely spaced absorption lines that constitute a broad smooth absorption band giving the impression of a continuous spectrum.

Absorption of pure vibrational energy is the basis of infrared spectroscopy.

Pure rotational absorption spectra are observed in the micro wave region.

So, molecular absorption spectra are more complex. This we have already covered number of times. Now, see the idea is the same phenomena, when they occur, they can be used as different aspects of a generating a molecular or atomic spectra.

So, that what we are discussing now; so, gases we can generate UV visible, we can generate infrared, we can generate molecular absorption peaks and so many other peaks.

So, molecular absorption peaks involving electronic energy are fairly broad, because molecular this thing going to the presence of vibrational and rotational energy levels, I keep on repeating these things. So, that it must remain embedded in your memory, as a result the spectrum of the compound consists of number of closely spaced absorption lines that constitute a broad smooth absorption band, giving the impression of a continues spectrum.

So, pure vibrational energy, if I have to measure, I can see it in the infrared spectroscopy only vibrational energy, not rotational or electronic, you will see it in the visible range or UV, but if you wish to see the absorption vibrational energy levels, then that energy level is reflected in the I R spectrum.

So, pure rotational absorption spectra are absorbed in microwave region that is not even I R I R is too much energetic with respect to rotational energy level. So, if you wish to see pure rotational energy level, you should go to a microwave region, examine this spectrum in microwave region. So, we are discussing about the absorption spectra obtained in different regions, one is UV visible in vacuum ultraviolet and X-ray. We will get only the line spectra and in UV visible. We get band spectra; that means, you will see a nice quotient curves one after another, depending upon the intensity and type of transitions and third one is the, where the energy differences are still less.

So, that is next energy level in after the electronic is vibrational. So, vibrational energy level means you do not see them in the visible range, you will see them in the infrared that is a next range of electromagnetic radiation. So, this is the vibrational energy level changes are the basis of infrared spectroscopy that we will study later in some other course not now and then there are pure rotational spectra still lower energy levels, then higher, then vibrational, they are obtained in the observed in the microwave region.

So, these things are all fairly is simple, but require different spectroscopy, different optics, different sources, different optics and then different detectors, different recording systems, everything changes in each and every system. So, electronic spectral transitions give rise to spectrophotometry UV visible. So, wavelength of the energy source does not change here, what comes in I measure, send in an electromagnetic radiation, pass it through the sample collect, the radiation that comes out after the sample is greeted. So, that total amount of energy corresponding to the molecular bond, which is characteristic of the element, is measured; that means incoming energy is so much, outgoing energy is so much difference is what is absorbed.

So, that is you visa UV visible spectrophotometry. So, the only changes in the intensity of the incident beam, in transmitted radiations are measured in UV visible spectrometry.

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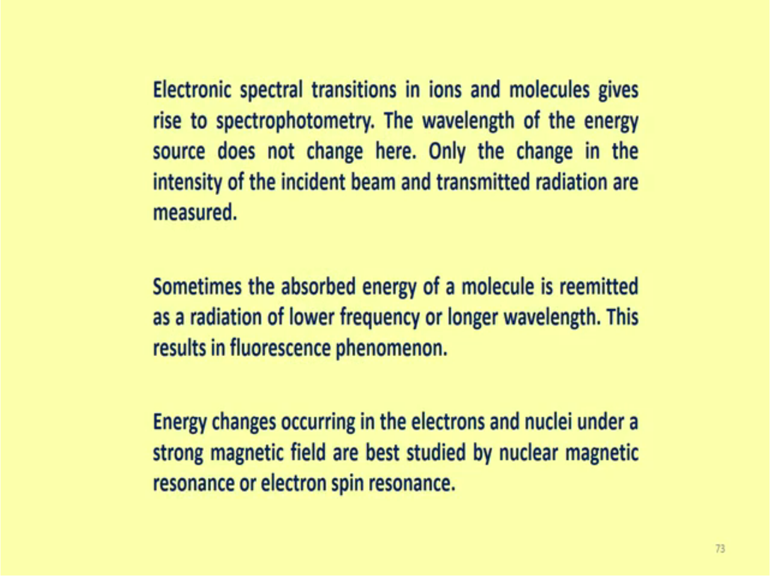

Electronic spectral transitions in ions and molecules gives rise to spectrophotometry. The wavelength of the energy source does not change here. Only the change in the intensity of the incident beam and transmitted radiation are measured.

Sometimes the absorbed energy of a molecule is reemitted as a radiation of lower frequency or longer wavelength. This results in fluorescence phenomenon.

Energy changes occurring in the electrons and nuclei under a strong magnetic field are best studied by nuclear magnetic resonance or electron spin resonance.

Sometimes the absorbed energy of a molecule is re emitted as a radiation of lower frequency or longer wavelength. This I have already referred in my last class and this is results in the florescence phenomenon. So, energy changes occurring in electrons and nuclei under a strong magnetic field are best studied by nuclear magnetic resonance spectra or electron spin resonance technique. So, these two are again a specialized techniques.

Not really useful for routine analysis, but for research purposes, they are very useful, which one? That is N M R nuclear magnetic resonance or electron spin resonance both of them, address different aspects naturally.

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So, UV visible spectrophotometry that time frame of absorption is 10 raise to minus 15 energy exchange occurs by the interaction of potential energy components of the molecules via the moment of electrons, which can be separated represented as single vertical line in the energy diagram this and all we have covered here, briefly and detailed in more, detailed in the earlier courses. So, the absorption bands occur only at definite values, corresponding to energy differences quantum mechanics.

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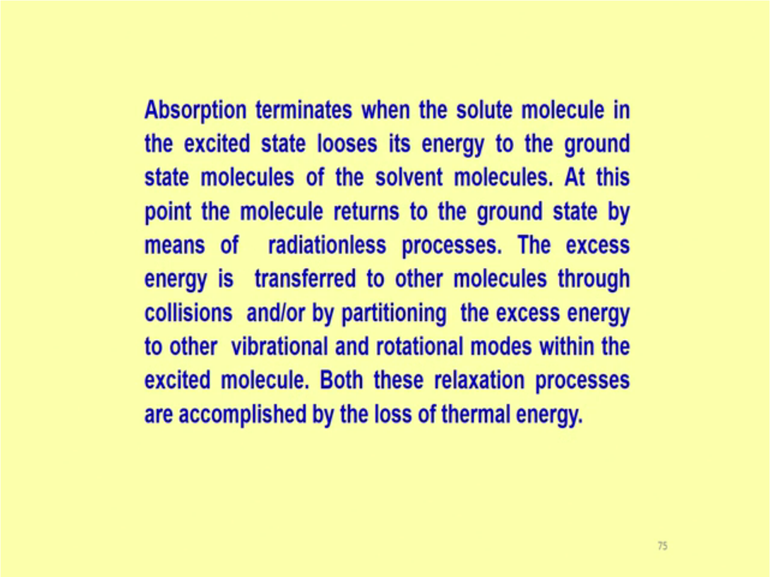

Absorption terminates when the solute molecule in the excited state looses its energy to the ground state molecules of the solvent molecules. At this point the molecule returns to the ground state by means of radiationless processes. The excess energy is transferred to other molecules through collisions and/or by partitioning the excess energy to other vibrational and rotational modes within the excited molecule. Both these relaxation processes are accomplished by the loss of thermal energy.

So, absorption terminates, when the solute molecule loses it's energy to the ground state molecules by, of the solvent molecules, once the elect, once the molecules get excited using electro electronic levels some time or the other whatever goes up should come down. So, when they come down to the ground state, the excess energy must be lost, the excess energy is lost to the solvent molecules or to the same molecules, but it is not, it is not lost in different quantities, exact quantities, but it is not as electromagnetic radiation. Electromagnetic radiation can get converted into a, it is form of energy. It can get converted into kinetic energy, potential energy, and then the heat energy.

So, many other ways it can get lost, collegial energy like that. So, by radiation these are known as radiation less process. So, the excess energy is transferred to the other molecules, through collisions and or vibrational and rotational modes, within the excited molecule. It can be through other molecules or it is own molecules. So, these both, these relaxation processes are accomplished by loss of thermal energy that is a mechanism.

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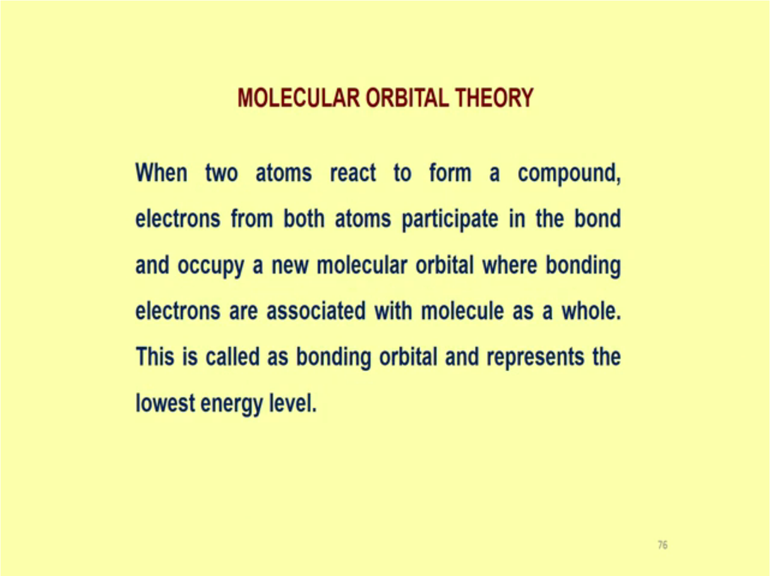

MOLECULAR ORBITAL THEORY

When two atoms react to form a compound, electrons from both atoms participate in the bond and occupy a new molecular orbital where bonding electrons are associated with molecule as a whole. This is called as bonding orbital and represents the lowest energy level.

So, there is a molecular orbital theory, which explains these things. I will try to attempt with respect to this course in a very short manner that is when two atoms react to form a compound electrons of both atoms participate in the bond formation.

This we have discussed earlier and occupy a new molecular orbital where bonding electrons are associated with molecule as a whole. So, this is called as bonding orbital and in bonding orbital, the energy of the molecule is at it is lowest levels. So, when I excite electrons, excite the molecule, the energy of the electron goes from lowest to next highest, next higher energy levels. So, during bonding, most of the molecules are stable at room temperature that is the bottom line. For example, water at room temperature is very stable, it will not go away right. So, similarly carbon monoxide, sulfur dioxide, nitrogen oxides, ammonia all these elements, carbon monoxide, carbon dioxide, all these elements are very stable at room temperature, because they are all bond by, bound by bonding orbitals sigma, bonds pi, bonds etcetera.

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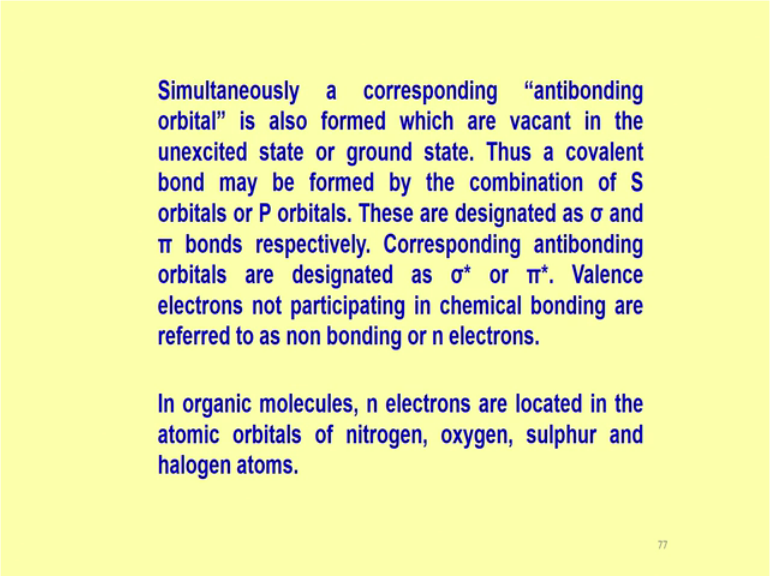

Simultaneously a corresponding “antibonding orbital” is also formed which are vacant in the unexcited state or ground state. Thus a covalent bond may be formed by the combination of S orbitals or P orbitals. These are designated as σ and π bonds respectively. Corresponding antibonding orbitals are designated as σ* or π*. Valence electrons not participating in chemical bonding are referred to as non bonding or n electrons.

In organic molecules, n electrons are located in the atomic orbitals of nitrogen, oxygen, sulphur and halogen atoms.

So, simultaneously whenever a bonding orbital is formed, there will be a some sort of a anti-bonding corresponding, anti orbital automatically generated. It is just like having a note one 10 rupee note or by you pick up one side, other side also, you automatically pick up. So, it is like in the moment, you have a bonding orbital there will be another bonding orbital. It may be occupied or need not be occupied, depends upon the state of the atom, so, but it is there all the time. So, anti-bonding orbital is also formed, which are usually vacant in the unexcited state or in the ground state.

So, a co valiant bond may be formed by the combination of S orbital or P orbitals, because most of the electrons are contained in the most of the electrons are contained in the using or formed using S orbital or P orbitals, A S and S orbital of 2 hydrogen atoms combines to give you a molecular orbital. Similar bond S and P orbital will give you a pi bond P and P are sorry. P and P orbital will give you a pi bond.

So, S and P orbital will give you bond which is ground state, but oriented in space between S orbital and P orbital, something like this, in tumble shape.

S orbital is round P orbital is tumble shape X Y and Z is direction. So, a combination of S orbital electrons from S orbital and P orbital will give you a bond in between these space of the, it is neither in S, nor in P, but it is a vector combination. So, the corresponding antibonding orbitals also will be there, at higher temperature. They are designated as sigma star or pi star. So, valance electrons not participating in chemical electrons, chemical bonding are there in almost several compounds, we deal come across.

For example, oxygen in water is having only two bonds H 2 O H O H H. Now, oxygen has got another 4 electrons extra. They are known as non-bonding electrons, they are not bond with any other element. So, such non boding electrons are there, present in nitrogen, chlorine, sulfur, phosphorous, and many other elements, they are known as n electrons nonbonding. So, organic molecules nonbonding electrons are located in the atomic orbitals of these elements nitrogen, oxygen, sulfur (Refer Time: 45:37) etcetera.

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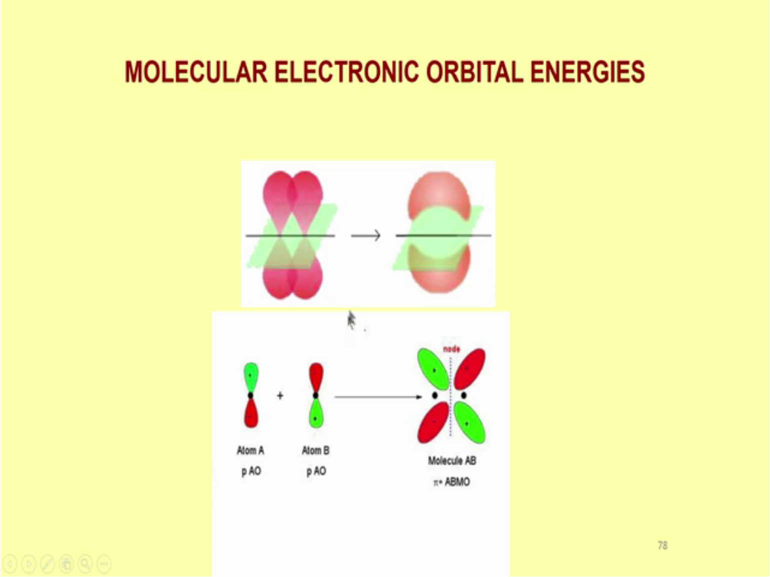

MOLECULAR ELECTRONIC ORBITAL ENERGIES

So, here is a typical presentation of bonding and nonbonding orbitals for example, here I have an atom A here, I have an atom B and when both of these are combined to give you pi orbitals.

What I that is something like this the bonding orbitals are like this and anti-bonding orbitals are like this. So, I am lower in, lower once represent, the ground state higher, once represents excited state. So, this is sigma, star pi and pi star similarly, this is again another type.

This you can see, this is a plane of the atom, there is tumble shape, one above the plane, one below the plane, another P orbital of another compound in the same. This thing when they are bound together, when they form a compound, they are, they come very close to each other, that closeness is controlled by the electronic properties of the atoms that is, if they come too close, electrons will start rippling, they come still closer, nucleus will start rippling.

So, it has to be some sort of equilibrium distance and as the electrons, as the atoms come nearer to form a bond, the energy comes down.

So, the compound energy of the compound, a molecule is always like this. So, the combination of these two logs of the top, we will give you shape, something like this and this is another shape, which Si a below the axis, the axis is represented by X X green color. So, far we have discussed introduction atomic structure and electromagnetic radiation.

The electromagnetic radiation has two parts; one is the definition and parts of electromagnetic radiation and their interaction with natural materials, with matter that is air glass prism diffraction, with a gratings and all that and then we have also discussed about the interaction of the electromagnetic radiation, with the sample, which we want to take this spectrum. So, far whatever we had discussed will form the basis of the instrumentation of the ICP Inductive Coupled Plasma. So, we are going to do sort of Ranga Pravehsam for the actual hard core part of the matter now. So, what now; I want to correlate everything to the ICP that is in our next model.