Electrochemical Technology in Pollution Control
Dr. J. R. Mudakavi
Department of Chemical Engineering
Indian Institute of Science, Bangalore

Lecture – 03
Atomic Structure – 2

Welcome back, we will continue our discussion on the Atomic Structure as part of our Electrochemical Technology for Pollution monitoring.

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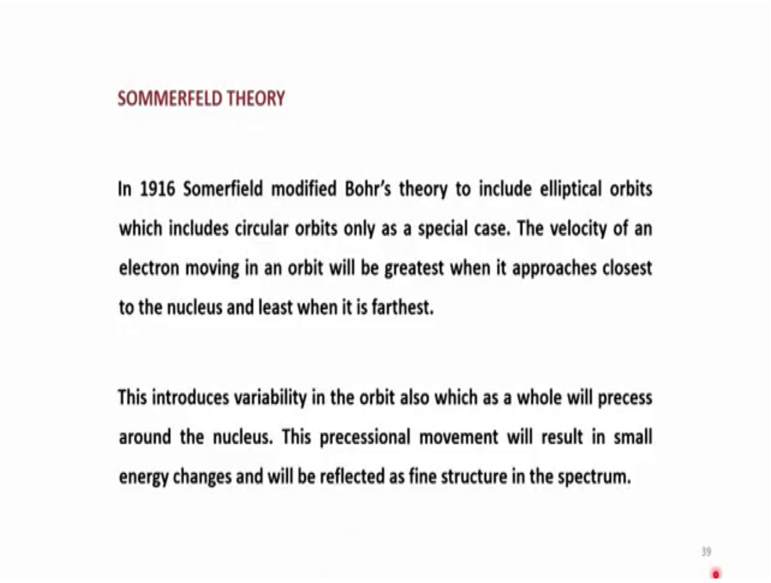

SOMMERFELD THEORY

In 1916 Somerfield modified Bohr's theory to include elliptical orbits which includes circular orbits only as a special case. The velocity of an electron moving in an orbit will be greatest when it approaches closest to the nucleus and least when it is farthest.

This introduces variability in the orbit also which as a whole will precess around the nucleus. This precessional movement will result in small energy changes and will be reflected as fine structure in the spectrum.

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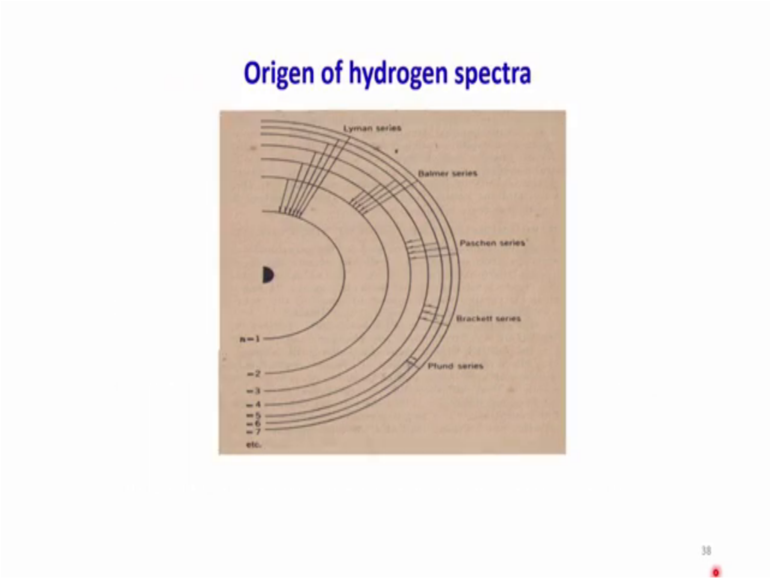

Origen of hydrogen spectra

Yesterday we had seen this figure, where we had I had explained to you that the origin of the hydrogen spectra arises from the fact that electrons from higher energy levels will fall on the fall to the lower energy levels after excitation.

So, we have a Lyman series, we have Balmer series when the transition takes place from n is equal to 2 and then Paschen series n is equal to 3; 3, 4, 5, 6 etcetera excitation can take place. And then we have brackett series and pfund series. Now, we also want to know a little bit about the Sommerfeld theory. In 1916 Sommerfeld modified Bohr’s theory to include elliptical orbits instead of stationary orbits circular orbits. So, circular orbits form only a part of a special case of elliptical orbits because the elliptical orbits have two axis a and b, when a is equal to b we have a circular orbit.

So, the velocity of an electron moving in an orbit will be greatest when it approaches closest to the object that is nucleus and least when it is farthest. So, this introduces variability in the orbit also which as a whole will process around the nucleus ok. This precessional movement will result in small energy changes and that will be reflected as fine structure in the spectrum. So, this is how the spectrum of hydrogen could be explained at that time.

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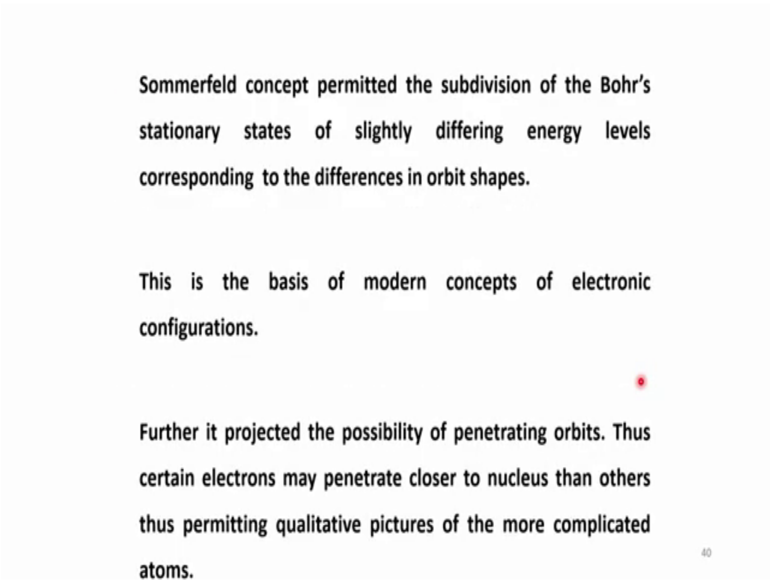

Sommerfeld concept permitted the subdivision of the Bohr's stationary states of slightly differing energy levels corresponding to the differences in orbit shapes.

This is the basis of modern concepts of electronic configurations.

Further it projected the possibility of penetrating orbits. Thus certain electrons may penetrate closer to nucleus than others thus permitting qualitative pictures of the more complicated atoms.

And Sommerfeld concept permitted the subdivision of the Bohr's stationary states of slightly differing energy levels corresponding to differences in orbital shapes. So, this is the basics of modern concepts of electronic configurations further it projected the possibility of penetrating orbits. Because most of the orbits are spaces you know the one orbit if it is empty space, an orbit can occupy another one into one another and then the spaces can also electron can be win any of these orbits.

So, the probability of electron being in a particular space around the nucleus is always positive and it projected the possibility of penetrating orbits therefore, certain electrons may penetrate closer to the nucleus than others, then permitting qualitative pictures of the more complicated atoms can be visualized so, that was the idea.

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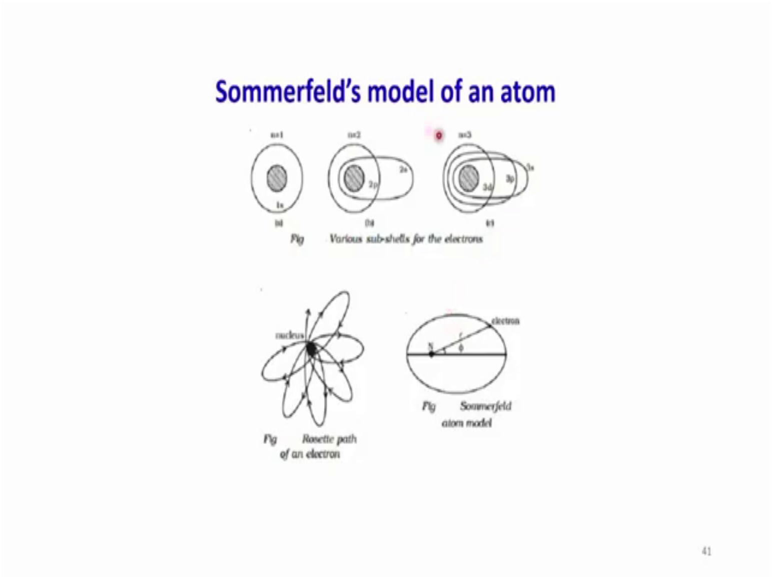

Sommerfeld's model of an atom

Fig *Various sub-shells for the electrons*

Fig *Rosette path of an electron*

Fig *Sommerfeld atom model*

Now, look at this figure, this is the first one that is circular orbit there is a Bohr's orbit special case of elliptical orbit. And this is 2 s and 2 p see how the orbits can be overlapping one another in this case. And here you can see there is lot of overlapping various sub shells for the electrons are there and then this is rosette path of an electron, electron can be moving in different orbits, in different angles, different speeds, but only around the nucleus and this is the Sommerfeld atomic model.

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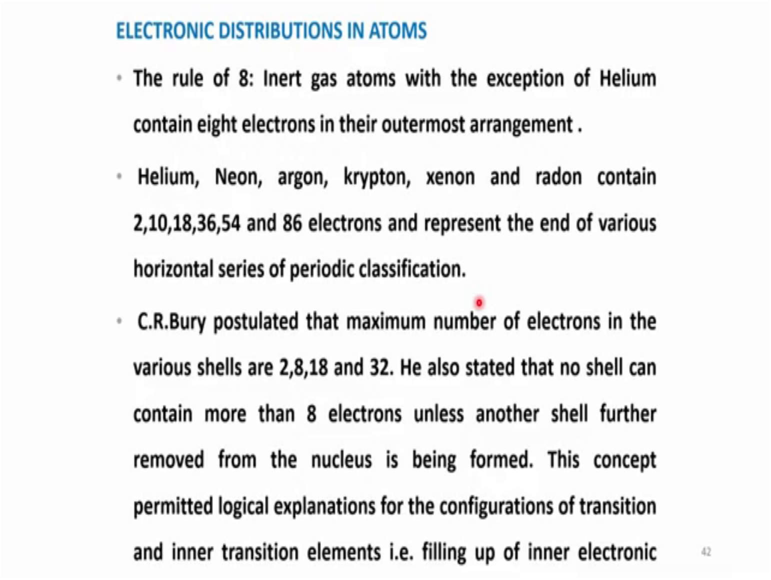

ELECTRONIC DISTRIBUTIONS IN ATOMS

- The rule of 8: Inert gas atoms with the exception of Helium contain eight electrons in their outermost arrangement .
- Helium, Neon, argon, krypton, xenon and radon contain 2,10,18,36,54 and 86 electrons and represent the end of various horizontal series of periodic classification.
- C.R.Bury postulated that maximum number of electrons in the various shells are 2,8,18 and 32. He also stated that no shell can contain more than 8 electrons unless another shell further removed from the nucleus is being formed. This concept permitted logical explanations for the configurations of transition and inner transition elements i.e. filling up of inner electronic

So electronic how do the electrons, then move around the nucleus because if the electrons are orbiting around one another, then their problem is how do you visualize an electron moving around a nucleus in different orbits at all. So, we have certain rules, which were have observed and which have been formulated for our better understanding.

So, one is the rule of 8 that is inert gas atoms with the exception of helium they contain eight electrons in the outer most orbit. So, that is the rule of 8 except helium. Then helium, neon, argon, krypton, xenon and radon they contain 2, 10, 18, 36, 54, 86 electrons and represent the end of various horizontal series of the periodic classification.

C R Bury postulated that maximum number of electrons in the various shells are 2 8 18 and 32 not more than that; obviously, the total number of electrons will exceed the known elements the maximum we have electrons in any element is about 108 elements are there, 108 electrons in a maximum.

So, he also stated that no shell can contain more than 8 electrons unless another shell further removed from the nucleus is being formed. So, this concept permitted logical explanation for the configuration of the transition and inner transition elements that is filling up of inner electronic configurations of the electron.

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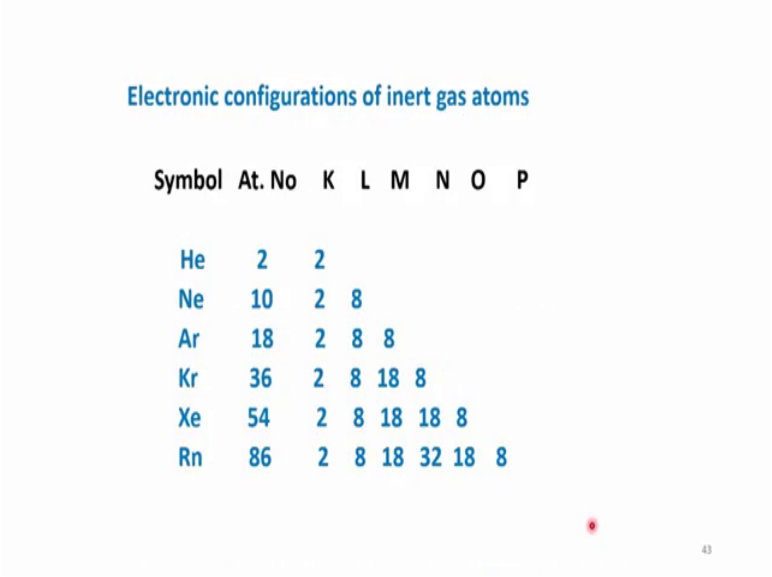

Electronic configurations of inert gas atoms

Symbol	At. No	K	L	M	N	O	P
He	2	2					
Ne	10	2	8				
Ar	18	2	8	8			
Kr	36	2	8	18	8		
Xe	54	2	8	18	18	8	
Rn	86	2	8	18	32	18	8

So, for example, here you can see that helium has got two electrons atomic number is 2 and it has got two electrons in the K shell and next is neon it has got 10. So, 2 go into K shell and 8 goes into L shell similarly Ar got 2 8 8 and krypton 2 8 18 8 and the xenon is 2 8 18 18 8 and radon is 2 8 18 32 18 8 like that the electronic configurations of the electrons in the inert gas ok.

Now, suppose there is one element which is lower than radon. So, it will have 7 electrons in the last outer outermost orbit. So, that would be something like halogen group ok. So, we can understand the periodic tables very easily.

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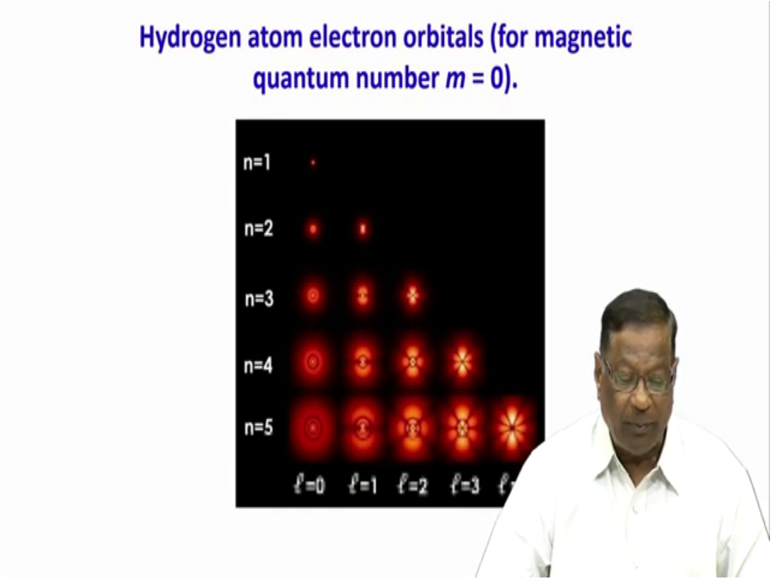

Hydrogen atom electron orbitals (for magnetic quantum number *m* = 0).

So, here is hydrogen atom electron orbital’s for magnetic number m is equal to 0 and n is equal to 1, n is equal to 2, n is equal to 3 we have and this is a pictorial representation and quantum designations.

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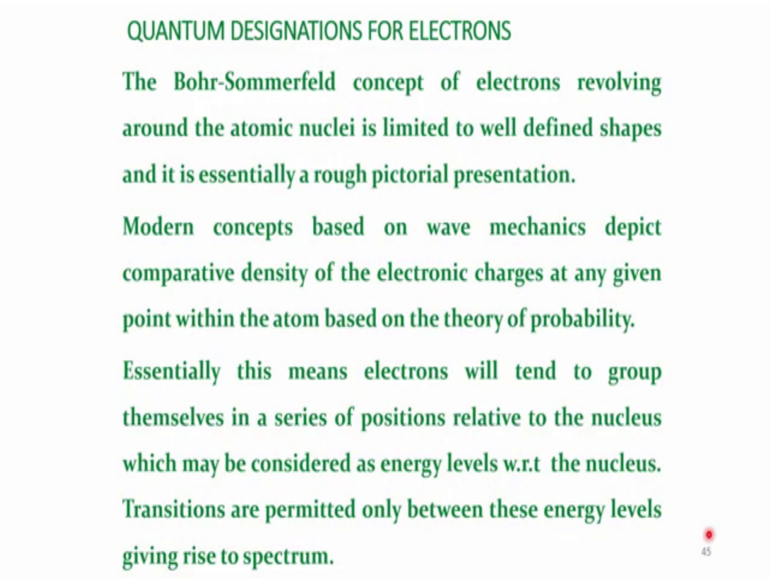

QUANTUM DESIGNATIONS FOR ELECTRONS

The Bohr-Sommerfeld concept of electrons revolving around the atomic nuclei is limited to well defined shapes and it is essentially a rough pictorial presentation.

Modern concepts based on wave mechanics depict comparative density of the electronic charges at any given point within the atom based on the theory of probability.

Essentially this means electrons will tend to group themselves in a series of positions relative to the nucleus which may be considered as energy levels w.r.t the nucleus. Transitions are permitted only between these energy levels giving rise to spectrum.

So, if there are only so, many electrons, we should be able to designate every electron by its own description. So, how do we do that? The Bohr Sommerfeld concept of electrons revolving around the nucleus atomic nuclei, he is limited to well defined shapes only. It is essentially a rough pictorial presentation.

Modern concepts based on the wave mechanics depict quantitative comparative density of the electronic charges at any given point within the atom based on the theory of probability. So, we essentially say that the electron remains maximum in this space of space around the nucleus. If it is K shell or if it is S orbital it will be in a space around the nucleus in the circular orbit space.

So, similarly if it is a p orbital electron in a p orbital the object will be something like a dumbbell shape. So, this dumbbell shape also we can say the electron probability of electron being present in that dumbbell shape is maximum at any time like that we can continue.

So, essentially this means that electrons will tend to group themselves in a series of positions relative to the nucleus, which may be considered as energy levels with respect to nucleus. If it is nearer the nucleus, energy level will be very high if it is a removed further away energy level will be lower. So, we have a series of energy levels which does not mean that the electrons are further away, you know in the space no it will be in the same area, but grouping is more charge density will be more.

So, transitions can be permitted only between these energy levels giving rise to a spectrum that is what is spectroscopy is all about. So, the electrons are best described in terms of four quantum numbers that is principal quantum number n, orbital quantum number is l, magnetic quantum number is m, spin quantum number is s.

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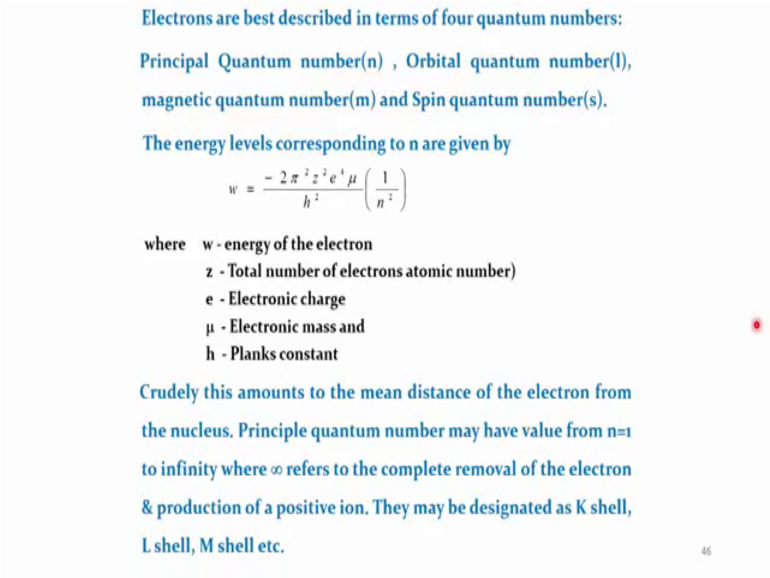

Electrons are best described in terms of four quantum numbers:

Principal Quantum number(n) , Orbital quantum number(l), magnetic quantum number(m) and Spin quantum number(s).

The energy levels corresponding to n are given by

$$w = \frac{-2\pi^2 z^2 e^4 \mu}{h^2}\left(\frac{1}{n^2}\right)$$

where w - energy of the electron
z - Total number of electrons atomic number)
e - Electronic charge
μ - Electronic mass and
h - Planks constant

Crudely this amounts to the mean distance of the electron from the nucleus. Principle quantum number may have value from n=1 to infinity where ∞ refers to the complete removal of the electron & production of a positive ion. They may be designated as K shell, L shell, M shell etc.

So, with these four orbital magnetic quantum numbers, we can define any electron in a given system that is in any element. So, the energy levels corresponding to different orbital levels n orbital different orbits are given by this equation and w is equal to 2 pi square z square this is all puc stuff puc chemistry stuff, I am not going into details because this is only to remind you of the things as they are with respect to understanding of the atomic structure.

We do not need many of these information, but it is for the sake of brevity we are doing it. So, here this equation represents the energy in a at any particular this thing here we have w is energy of the electron and z is the total number of electrons or atomic number e is the electronic charge and mu is the electronic mass h is Planck’s all those things are very well known and the energy of a particular level can be calculated simply by putting n. All other things have constant this is known as rate Birks constant.

So, basically what does it mean? w represents the mean distance of the electron from the nucleus. So, the principal quantum number may have value from n is equal to 1 to infinity where infinity refers to the complete removal of the electron from the system. Suppose you have one nucleus have one electron take it to higher energy levels and then when it is completely removed, n it becomes infinity. So, production with that results in the production of an ion because the electron is completely gone.

So, they may be designated. So, the electrons may be designated as being in K shell, L shell M shell etcetera. So, the last electron that can be transferred to higher energy levels until it is produces an positive ion.

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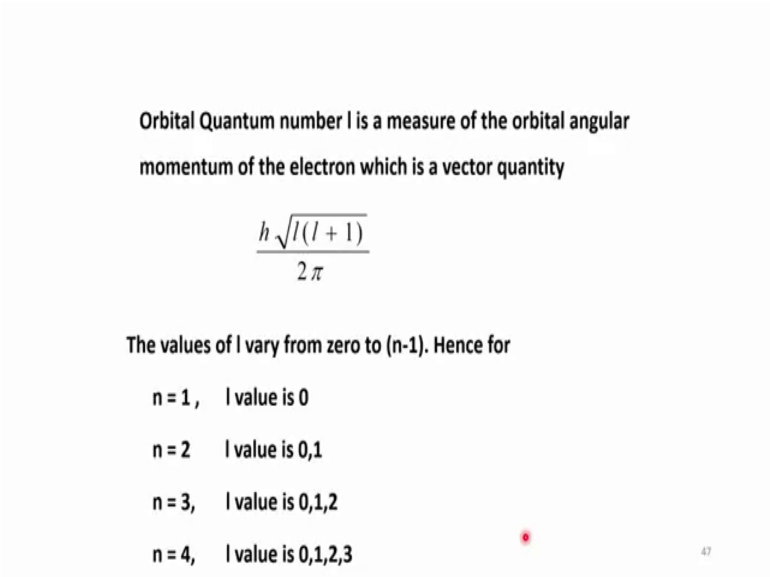

Orbital Quantum number l is a measure of the orbital angular momentum of the electron which is a vector quantity

$$\frac{h\sqrt{l(l+1)}}{2\pi}$$

The values of l vary from zero to (n-1). Hence for

n = 1 , l value is 0

n = 2 l value is 0,1

n = 3, l value is 0,1,2

n = 4, l value is 0,1,2,3

So, the orbital quantum number l is a measure of the orbital angular momentum of the electron, this is another way of describing the electron. So, there are l values of l varies from

0 to l n minus 1. So, when n is 1 l value is 0, n is equal to 2 l will be 0 and 1. The n is equal to 3 again the n minus 1 means it should become 0 1 and 2 like that there will be orbital angular momentum that also can be described as the described for determining the energy of an electron. So, one is principal quantum number, it says where the electron is next is its angular orbital angular momentum l.

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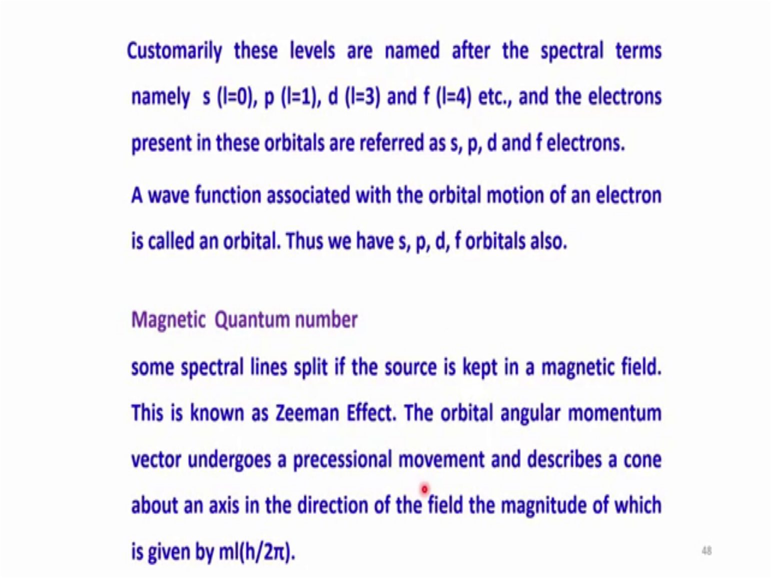

Customarily these levels are named after the spectral terms namely s (l=0), p (l=1), d (l=3) and f (l=4) etc., and the electrons present in these orbitals are referred as s, p, d and f electrons.

A wave function associated with the orbital motion of an electron is called an orbital. Thus we have s, p, d, f orbitals also.

Magnetic Quantum number

some spectral lines split if the source is kept in a magnetic field. This is known as Zeeman Effect. The orbital angular momentum vector undergoes a precessional movement and describes a cone about an axis in the direction of the field the magnitude of which is given by ml(h/2π).

In quantum number then we these things are customarily named after spectral terms namely s, p, d and f. So, electrons present in these orbital's are referred as s, p, d f electrons also and the orbit all are also called as s, p, d, f orbital. So, we have a third quantum number that is magnetic quantum number. So, what happens is when some spectral lines are there, you put the sample in a magnetic field the spectral line split.

So, the orbital angular momentum undergoes a processional movement and describes a cone about an axis in the direction of the field of the magnitude of which is given by ml into h by 2 pi. Here you can see in the slide I written it in the last line the orbital angular momentum is ml h by 2 pi.

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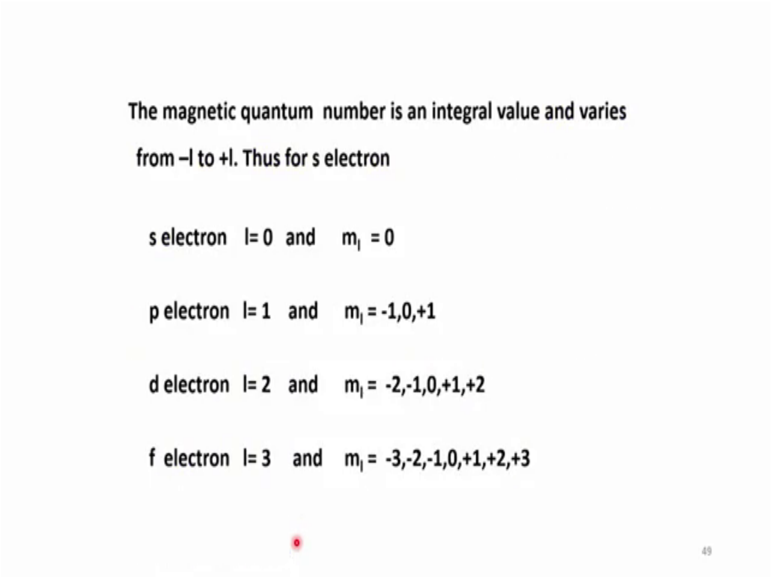

The magnetic quantum number is an integral value and varies from –l to +l. Thus for s electron

s electron l= 0 and m_l = 0

p electron l= 1 and m_l = -1,0,+1

d electron l= 2 and m_l = -2,-1,0,+1,+2

f electron l= 3 and m_l = -3,-2,-1,0,+1,+2,+3

So, we have magnetic number quantum number, it can be from l to minus l to plus l. So, for a s electron l should be 0 and m should be 0 and p for a p electron l is equal to 1 and the m should be magnetic quantum numbers should be minus 1 to plus 1 that is plus minus 1, 0 n plus 1. Similarly, l is equal to 2 will result in minus 2, minus 1, 0 and plus 1, n plus 2 for f electrons again we have about six magnetic quantum numbers 7 l is equal to 3.

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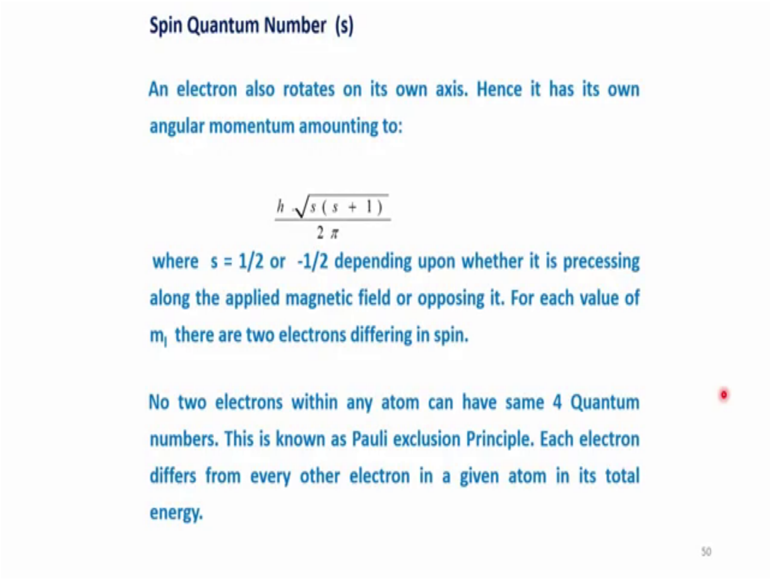

Spin Quantum Number (s)

An electron also rotates on its own axis. Hence it has its own angular momentum amounting to:

$$\frac{h\sqrt{s(s+1)}}{2\pi}$$

where $s = 1/2$ or $-1/2$ depending upon whether it is precessing along the applied magnetic field or opposing it. For each value of m_l there are two electrons differing in spin.

No two electrons within any atom can have same 4 Quantum numbers. This is known as Pauli exclusion Principle. Each electron differs from every other electron in a given atom in its total energy.

Then we have a spin quantum number this refers only to the spin of the electron whether the electron goes at clockwise or anti clockwise. Just like any planet electron is also supposed to process around itself while it is going around the nucleus. So, that spin quantum number is given by this expression h s into h into square root of s into s plus 1 divided by 2 pi where s is equal to half or minus half. This is a sort of arbitrary number and it depends upon whether it is processing along the magnetic field or opposing way.

So, it is for each value of mi there are only two different s quantum numbers. So, no two electrons within any atom can have all the same four quantum numbers this is known as Pauli exclusion Principle. So, each electron differs from every other electron in a given atom in its total energy.

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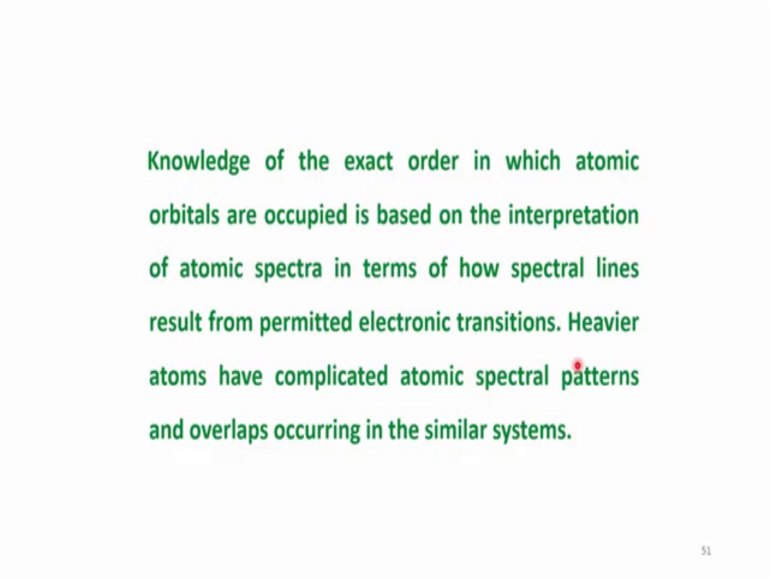

Knowledge of the exact order in which atomic orbitals are occupied is based on the interpretation of atomic spectra in terms of how spectral lines result from permitted electronic transitions. Heavier atoms have complicated atomic spectral patterns and overlaps occurring in the similar systems.

So, knowledge of the exact order in which atomic orbitals are occupied is based on the interpretation of atomic spectra, in terms of how the spectral lines result from the permitted electronic transitions. So, what we are essentially saying is, how the electrons are occupied will reflect on the spectral lines.

So, you inspect the spectrum, you will know how the electrons are occupying different energy levels. Heavier atoms have very complicated spectral patterns and overlaps occurring in similar systems. This is expected, is not it?

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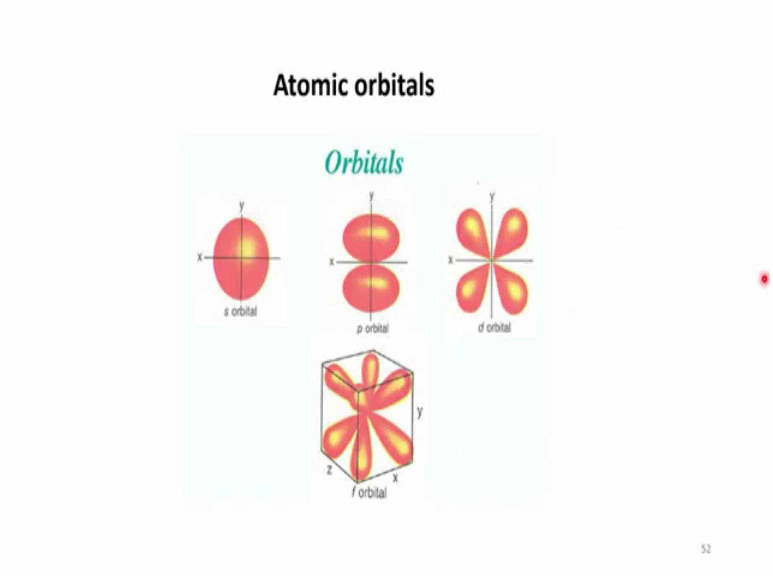

Atomic orbitals

So, here is a small pictorial representation of the orbitals, this is s orbitals completely spherical, p orbital dumbbell shaped, the this will be in x y direction and then one may be y z and x z. Three different p orbitals can be there and d orbitals are two dumbbell shaped in x y plane and other planes also.

So, f orbital is something you can imagine a hexagon like you can imagine a cube and nuclease at the center for at the top occupying the four corners and four orbitals at the bottom all are dumbbell shaped only ok. So, except spherical the s orbitals.

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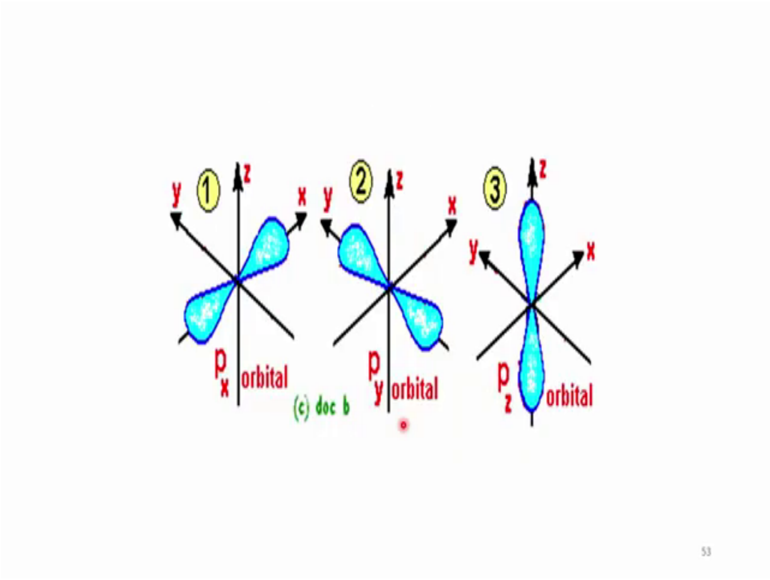

So, this is px py and pz orbital, these are all very simple stuff.

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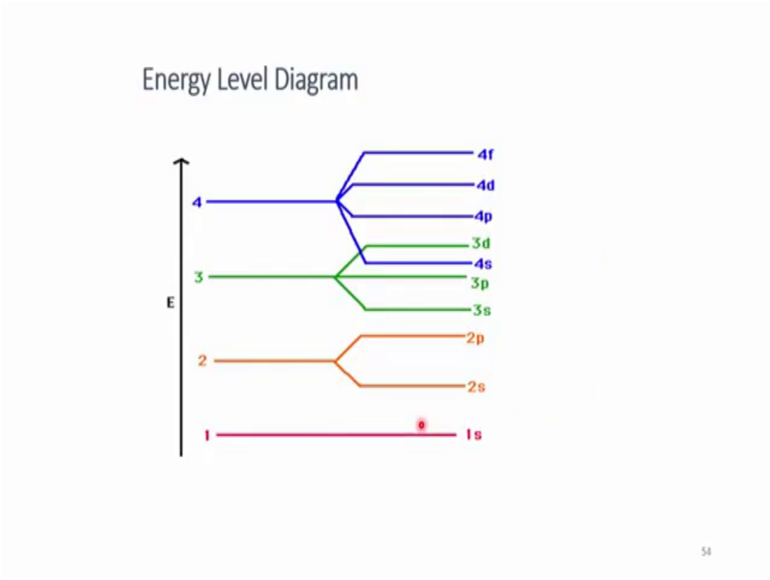

Energy Level Diagram

And the actual energy level diagram will tell us that first one is whenever we want to put the electrons in the atomic structure, if I want to write down first I have to fill 1 s and then 2 s, 2 p, 3 s, 3 p and then 4 s afterwards 3 d. See there is a slight this thing energy level of 3 d is higher than 4 s and then 4 p, 4 d, 4 f etcetera this is the typical energy level diagram of an elector of the electron filling in the nucleus.

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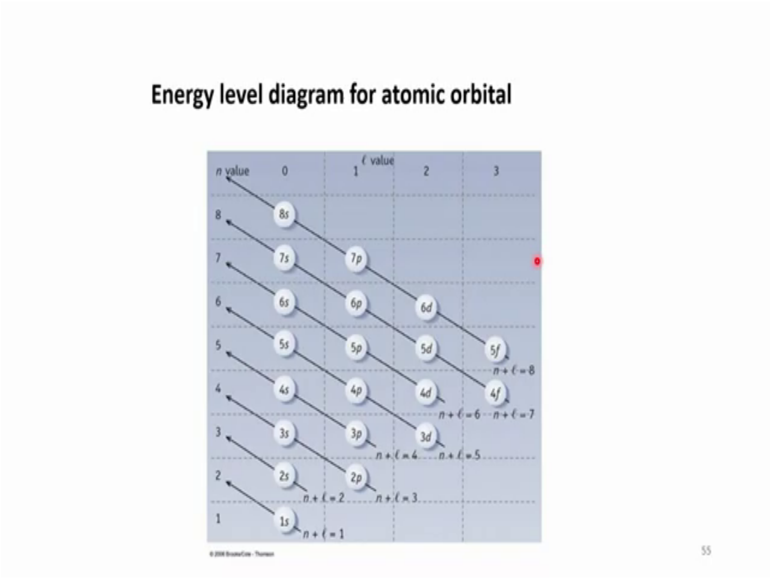

Energy level diagram for atomic orbital

So, if I use this a spiral figure you will get n l 1 s 2 s etcetera this is how the electrons are filled. This is this is part of the PUC textbook only you will find this figure in explanation etcetera in the PUC this thing.

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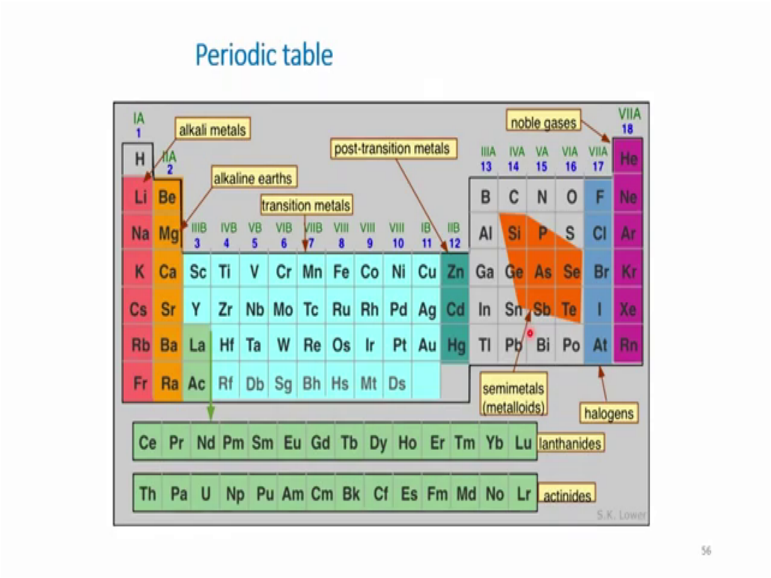

Periodic table

IA 1	IIA 2	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	VIII 8	VIII 9	VIII 10	IB 11	IIB 12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	VIIA 18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Cs	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Rb	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds								

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	lanthanides
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	actinides

With the based on this type of electron filling we have the modern periodic table and here we have the hydrogen is here and then helium is here, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine and then neon and then we have the second a periodic second period these are all red ones are called here, their alkali metals, here it is transition metals, here it is alkaline earth metals, beryllium, magnesium, calcium, strontium, barium the (Refer Time: 19:43) ones are all alkaline earth metals, here we have a couple of post transition metals and they are cadmium zinc mercury.

And here we have noble gases on the right hand side and then the things depicted in blue are halogens, all others are these are all non metals and some of them are metals and nonmetals together. So, these are all poster transition, these are all semi metals metalloids they are called and then we have where two 3 d and 3 f 4 d etcetera those things are filled. We have the transition metals and 4 f and 5 f are called lanthanides and actinides.

So, this is how so, many elements we have up to the whole periodic table has been organized and it is easy for us to work on this understanding of the current level of the arrangement of the electrons and neutrons and neutrons in the elements and how the elements can be organized in the different fashions ok. So, that completes our discussion about the basic structure of the atom.

So, what we have said essentially is an atom is composed of protons neutrons and electrons there are other subdivision of particles smaller than electrons, they are all known as positrons, masons etcetera some of them have independent existence, some of them do not have, they are all existing momentarily maybe in nuclear reactors and stars.

So, what we need from this introduction is that we need the outer electrons for our discussion in the electrochemical technology that is why I have given you this. So, that will enable us to proceed for the next module that is properties of solutions.

So, why do we do properties of solutions first? The idea is most of the electrochemical systems are all equation non equation systems containing water and non equi solvents also methanol, ethanol etcetera and we should know how the ions or metals metal ions behave in the aqueous systems and non aqueous systems ok.

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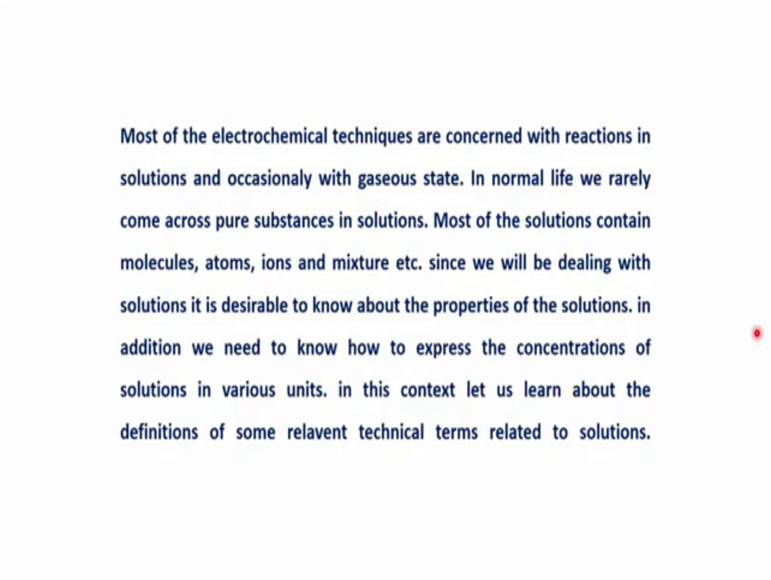

Most of the electrochemical techniques are concerned with reactions in solutions and occasionaly with gaseous state. In normal life we rarely come across pure substances in solutions. Most of the solutions contain molecules, atoms, ions and mixture etc. since we will be dealing with solutions it is desirable to know about the properties of the solutions. in addition we need to know how to express the concentrations of solutions in various units. in this context let us learn about the definitions of some relavent technical terms related to solutions.

So, here we have most of the this is sort of introduction, most of the electrochemical techniques are concerned with reactions in solutions. Occasionally gaseous state definitely yes and in normal life we rarely come across very pure substances in solutions. Most of the solutions contain molecules, atoms, ions and mixtures etcetera.

Since we will be dealing with solutions it is desirable to know about the properties of the solutions. In addition we need to know how to express the concentrations of solutions in various units because without no express capability to express the concentrations, we will be nowhere. In this context let us learn about the definitions of some relevant terms related to solutions. So, what are the terms?

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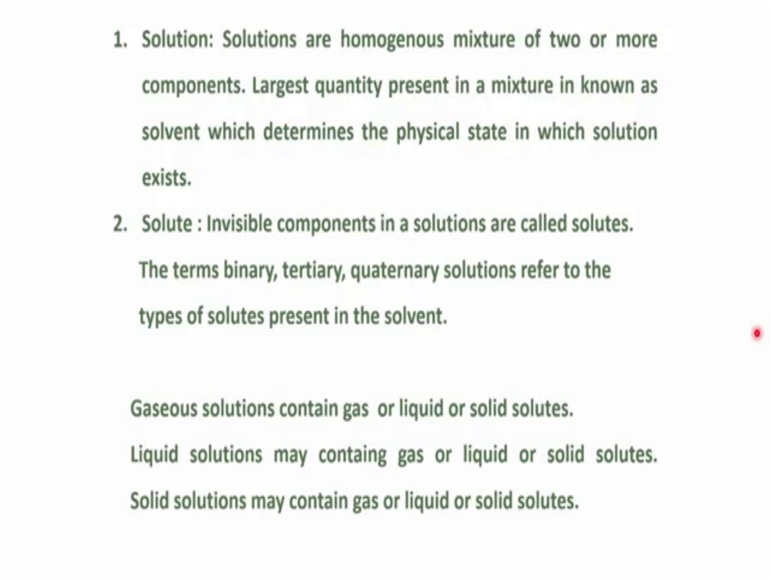

1. Solution: Solutions are homogenous mixture of two or more components. Largest quantity present in a mixture in known as solvent which determines the physical state in which solution exists.
2. Solute : Invisible components in a solutions are called solutes.

The terms binary, tertiary, quaternary solutions refer to the types of solutes present in the solvent.

Gaseous solutions contain gas or liquid or solid solutes.
Liquid solutions may containg gas or liquid or solid solutes.
Solid solutions may contain gas or liquid or solid solutes.

Here first I defined a solution what is the solution? Solutions are homogeneous mixtures of two or more components largest quantity present in a mixture is known in a known a solvent, which determines the physical state in which solution exists. So, we know what a solutions, what is a solvent which define solute.

So, what is a solute? In the solute is an indivisible component in a solution that is resolved not visible to us, they are called as solutes. We can call binary solute, tertiary solute, quaternary solutions and they all types refer to the different types of solutes present in the given solvent.

So, one solvent can contain number of solutes giving rise to binary tertiary or ternary and several other mixtures also. So, that is a solute. They should be dissolved they should not be visible to naked eye. And then we have gaseous solutions they contain gas or liquid or solid solutes. So, liquid solutions may contain gas or liquids or solute solid solutes this we understand very easily is not it; liquid solutions may contain gas, gas may be dissolved all our fishes in the rivers live because there is oxygen gas in the water in the river, in the lakes, in the sea.

So, liquid solutions may contain gas, it may we contain another liquid or it may contain a solid also. Solid solutions may contain gas or liquids or solid solutes other way around also is possible. So, what do we call them solid solutions. If a solid contains another solid then it is a solid solution, if it contains gas a solid solution, if it contains liquid again solid solution and the solid solutes it may contain also.

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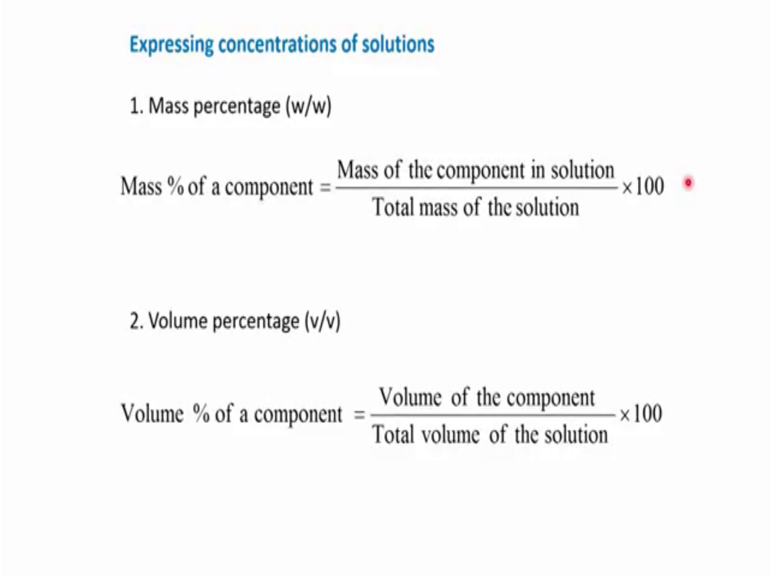

Expressing concentrations of solutions

1. Mass percentage (w/w)

$$\text{Mass \% of a component} = \frac{\text{Mass of the component in solution}}{\text{Total mass of the solution}} \times 100$$

2. Volume percentage (v/v)

$$\text{Volume \% of a component} = \frac{\text{Volume of the component}}{\text{Total volume of the solution}} \times 100$$

So, how do I express the concentration of the solution? Here is a very simple way of expressing mass percentage. So, what is mass percentage? Mass of the component in the solution divided by total mass of the solution into 100. Very simple explanation where I say 5 gram is dissolved in 100 gram of the solution multiplied by 100 you can call it mass percentage.

Total mass present in a solution divided by total mass of the solution and component means solutes. 5 gram of sugar in 100 gram of water or 50 gram of sugar in 10 ml 10 gram of water that is also the. So, we can have any number of expressing expressions, but standard expression would be per in percentage multiplied by 100 that will give us mass component of a mass of a component.

I can also say a volume component; volume of the compass if it is a liquid I cannot say so, many grams of the liquid is present in so, many grams of the solution. I can I instead as well say that we can it contains 10 ml of the component a and 10 ml of the component b in 100 ml of solution or 10 ml of solution.

So, multiply it by 100 we have a volume percentage of a component, this is another simple way of explain. We can we come across in electrochemical technology all these terms very regularly that is why I wanted to remind you.

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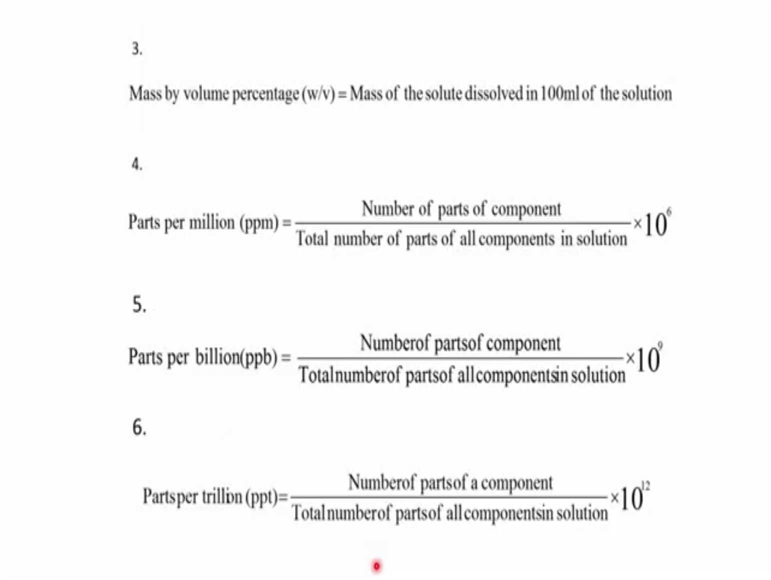

3.

Mass by volume percentage (w/v) = Mass of the solute dissolved in 100ml of the solution

4.

$$\text{Parts per million (ppm)} = \frac{\text{Number of parts of component}}{\text{Total number of parts of all components in solution}} \times 10^6$$

5.

$$\text{Parts per billion(ppb)} = \frac{\text{Numberof partsof component}}{\text{Totalnumberof partsof allcomponentsin solution}} \times 10^9$$

6.

$$\text{Partsper trillion (ppt)} = \frac{\text{Numberof partsof a component}}{\text{Totalnumberof partsof allcomponentsin solution}} \times 10^{12}$$

Then 3rd is mass by volume percentage that is number of parts, number of the mass by volume percentage, mass of the solute dissolved in 100 ml of solution that is the mass by volume percentage third one. So, 4th one is parts per million; number of parts of component divided by total number of all components in solution multiplied by 10 raise to 6; that means, if there is one part in 10 raise to 6 part of the all the components then it is known as 1 ppm.

1 micro gram per milliliter or 1 milligram per liter they are also equivalent concentrations. So, I can say either 1 ppm or 1 microgram per liter or 1 milligram 1 microgram per ml or 1 milligram per liter. You can say 1 kg in 1 ton or something like that that is also possible. So, parts per billion level is another word very specific term people use that represents parts number of parts of component divided by total number of parts of all components in solution multiplied by 10 raised to 9.

So, if there is one part in 10 raised to 9 solution, then you call it 1 nanogram ok. So, 1 ppb parts per billion; 1 ppb is 1 nanogram per ml of the solution. So, we also have parts per trillion ppt. So, we express many of our pollutants in these terms number of parts of a component divided by total number of parts of all components multiplied by 10 raised to 12.

Below that also is possible that is known as femto gram, but we will not worry about it because most of the time we will be using either percentage, mass by volume, mass by mass, moles number of moles per liter, parts per million, parts per billion or parts per trillion not more than that.

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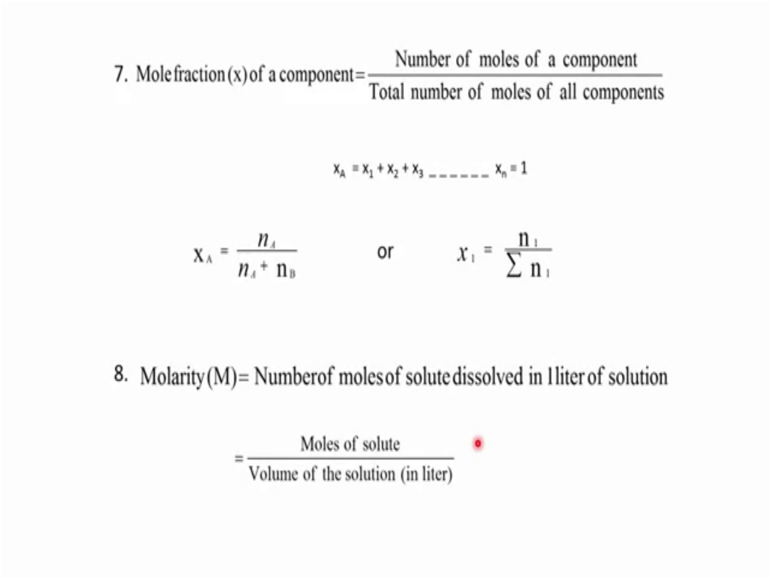

7. Mole fraction (x) of a component $= \dfrac{\text{Number of moles of a component}}{\text{Total number of moles of all components}}$

$$x_A = x_1 + x_2 + x_3 \text{------} x_n = 1$$

$$x_A = \frac{n_A}{n_A + n_B} \quad \text{or} \quad x_1 = \frac{n_1}{\sum n_1}$$

8. Molarity (M) = Numberof molesof solutedissolved in 1liter of solution

$$= \frac{\text{Moles of solute}}{\text{Volume of the solution (in liter)}}$$

So, we also should know what is known as mole fraction of a component. So, what is mole fraction? It is defined as x we can call it anything there is nothing sacred about x. So, a number of moles of a component divided by total number of moles of all components that is x

A you should be referring to the number of components of a divided by number of other components n A plus n B plus n C if there are more number of components more. So, we can write we normally write it either like this n A over n A plus nB or simply mole fraction x 1 or chi 1 is equal to n 1 divided by sigma n 1 total number of components at the bottom.

So, we also have another one that is molarity. So, molarity is number of moles of the solute dissolved in 1 liter of the solution. So, what is a mole? It is a molecular weight of a substance dissolved in 1 liter. So, if I take sodium chloride it a sodium is 23, atomic weight and chloride is 35. So, 58 grams of sodium chloride dissolved in 1 liter of water gives you 1 mole of sodium chloride.

So, in terms of expression, if I want to write an equation then I should say moles of the solute divided by volume of the solution and that should be in liters, it cannot be in milliliters or something this is another way.

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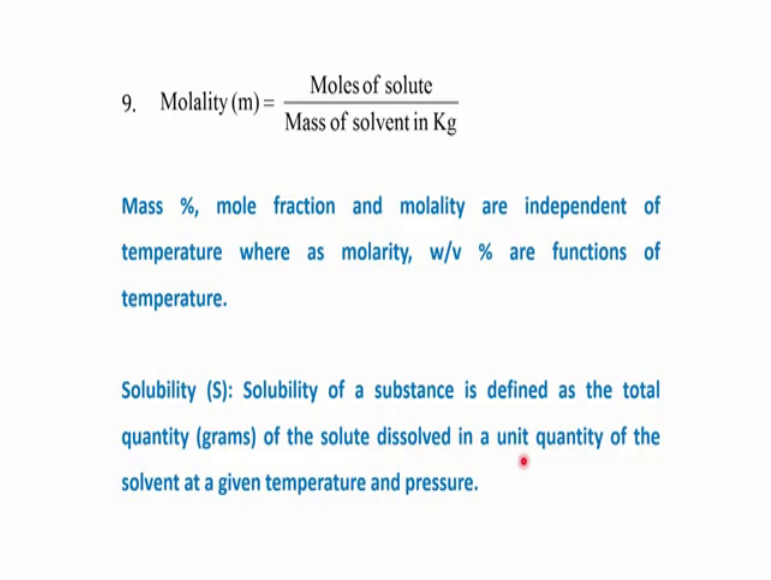

9. $$\text{Molality (m)} = \frac{\text{Moles of solute}}{\text{Mass of solvent in Kg}}$$

Mass %, mole fraction and molality are independent of temperature where as molarity, w/v % are functions of temperature.

Solubility (S): Solubility of a substance is defined as the total quantity (grams) of the solute dissolved in a unit quantity of the solvent at a given temperature and pressure.

Then we define another term that is known as molality. In molality what we do is moles of the solute divided by mass of the solvent in kg. The only difference between this and previous one is volume of the solution here, volume of the solution in 1 liter correct.

So, the next one is molality refers to moles of solute, here also it is moles of solute only in the molarity, but here denominator differs volume of the solution in gives you molarity and mass of the solvent in kg gives you molality. So, mass percent, mole fraction and molality are independent of temperature whereas, molarity weight by volume percent are all functions of temperature ok.

So, you can see that as the temperature increases solubility also increases sometimes. So, they are all functions of temperature. Whereas, mass percent mole fraction and molality they have no influence by temperature pressure of course, it does not arise, because 99 percent of these solvents are not in compressible they are incompressible. And then we define another term that is known as solubility; solubility of a substance is defined as the total quantity of grams of the solute dissolved in a unit quantity of the solvent at a given temperature and pressure.

Essentially what if the definition may look very big, but actually what it means is, the quantity dissolved in a unit quantity of the solvent at a pressure given temperature that is how we define the solubility because solubility is a function of temperature and pressure.

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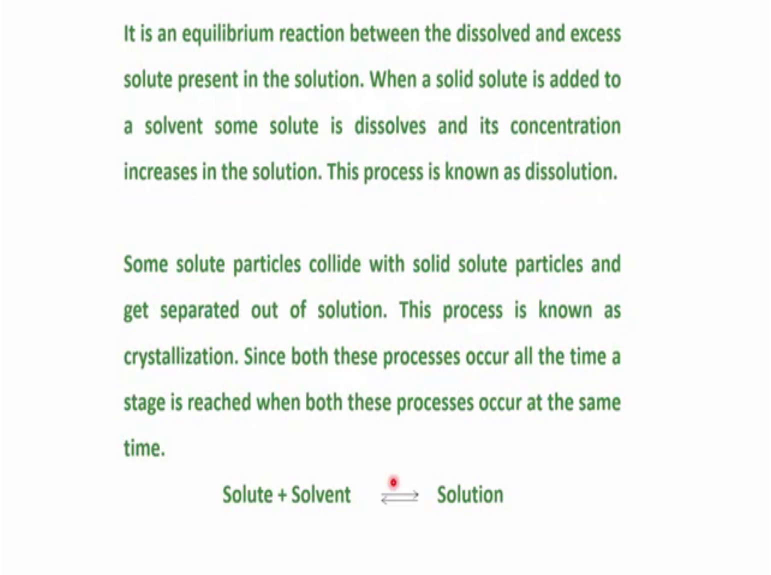

It is an equilibrium reaction between the dissolved and excess solute present in the solution. When a solid solute is added to a solvent some solute is dissolves and its concentration increases in the solution. This process is known as dissolution.

Some solute particles collide with solid solute particles and get separated out of solution. This process is known as crystallization. Since both these processes occur all the time a stage is reached when both these processes occur at the same time.

Solute + Solvent $\rightleftharpoons$ Solution

Especially, if it involves gases, it involves pressure also. So, a solubility is something like an equilibrium reaction, here I am showing here solute plus solvent is equal to solution I have written it at the bottom. So, it is an equilibrium reaction between the dissolved salts and excess solute present in the solution.

So, when a solid solute is added to a solvent, some solute is dissolves and its concentration increases in the solution this process is known as the dissolution everybody knows this. Some solute particles collide with solute solid particles and get separated out of crystal solution this process is known as crystallization. Since both these processes occur all the time, a stage is reached when both these processes occur at the same speed at the same time, then we have an equilibrium described a solvent plus solute is going to solution.

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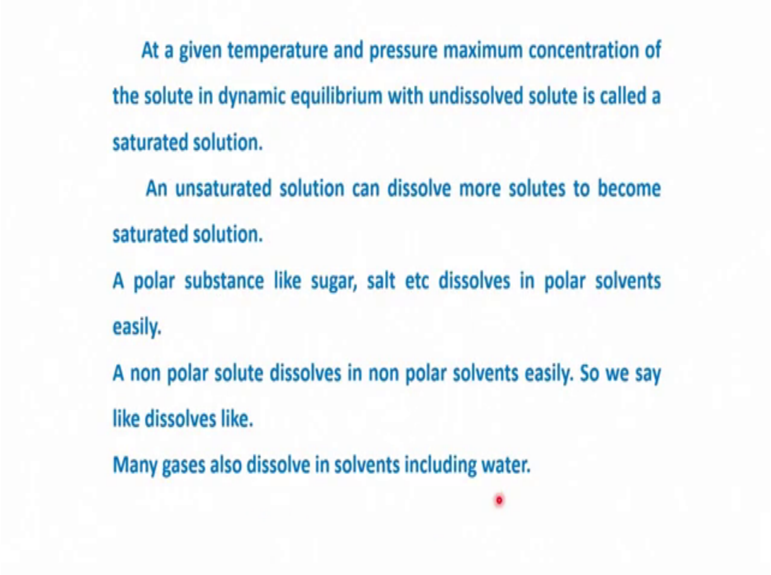

At a given temperature and pressure maximum concentration of the solute in dynamic equilibrium with undissolved solute is called a saturated solution.

An unsaturated solution can dissolve more solutes to become saturated solution.

A polar substance like sugar, salt etc dissolves in polar solvents easily.

A non polar solute dissolves in non polar solvents easily. So we say like dissolves like.

Many gases also dissolve in solvents including water.

At a given temperature pressure and pressure and pressure maximum concentration of the solute is in dynamic equilibrium with undissolved solute that is called a saturated solution maximum dissolved. And you add a keep on adding sugar to water it keeps on dissolving and after some time the sugar will not dissolve. So, sugar will remain excess as solid only at the bottom of the beaker.

So, let me we call it saturated do you take it cannot dissolve any more. So, an unsaturated solution can dissolve more solutes to become saturated solution. A polar substance like sugar salt etcetera they dissolve in polar solvents easily, a non polar substance dissolves in nonpolar solvents. So, we say like dissolves like and many gases also dissolve in solvents including water. We will continue our discussion in the next class.

Thank you.