hello in the last class we discussed the
postulates of quantum mechanics we discussed   the solution of hydrogen atom the solution of
schrodinger equation we saw the solution of   schrodinger equation gave the wave functions
and these wave functions can be described in   terms of some quantum numbers we discussed about
two quantum numbers the principal quantum number   and the azimuthal quantum number or the orbital
quantum number in today's class we will continue   our discussion and we will talk about the
remaining quantum numbers the next quantum   number that we will discuss will be magnetic
quantum number the magnetic quantum number which is ah signified with letter m now what
is ah we saw that principle quantum number n   talked about the size azimuthal
quantum number talked about the shape   and magnetic quantum number talks
about the orientation of this orbital and at the moment we will say that this
orientation by this orientation we mean   orientation in space what what kind of orientation does it have
so this   signifies the orientation of the orbital we saw
that the value of l the azimuthal quantum number   was determined by the value of n the principal
quantum number that was the leading quantum number   and then was the azimuthal quantum number now the
value of magnetic quantum number m
so value of m is decided by depends on the value of l
so what values of l have we
seen we have seen l is 0 when l is 0 its   s orbital when l a or l is 1 then it is p
orbital l is 2 this is d orbital l is 3 this is   f of orbital and
so on
so forth now when l is 0 it
is s orbital and the shape is sphere let us say i   draw my ah x axis y axis z axis and i am showing
you a sphere
so how many ways can i orient this   sphere the answer is one there is nothing
called reorienting the sphere because it is ah   symmetric in along all direction
so there is only
one way then that this s orbital can be oriented
so the number of ways that ah this can orient is one
so this is number of orientations possible for s orbital it is one what about p
orbital p orbitals looks like a dumbbell
so it has got two lobes
so if i draw
my cartesian axis i can have this as x   these as y and ah the plane ah above and below
the plane of sorry the axis above and below the   plane of paper let us call that c
so you see that
the way i have drawn this particular dumbbell   it is oriented along y axis but

i can orient i can
twist it by a 90 degree and then reorient it along x axis
so this is my y this is x and
this is the z axis
so this is another orientation and then i can also orient along
z axis which is above and below the plane
so this is the z axis
so i
can orient it in this way
so the the this slope actually goes
below the plane of the paper
so you saw i can orient this p orbital in three different
ways either along y axis or this one along x axis or this one along z axis
so i have got now
three orientations this number of orientation for p orbital is is three now
similarly d
orbital actually has a double dumbbell shape ah let us draw this way it has
got ah two
different ah two dumbbells and i can reorient it ah in five different ways i
am not trying to
draw that you see these are five different orientation orientations that this
d orbitals
can show
so you see that in this picture the the two dumbbells
so this is one dumbbell in
in silver colored another in orange color both the dumbbells are actually on
the x y plane
so this is
z is going uh coming out of the plane up ah plane of paper and this dumbbells
are actually on the x
y plane
so i call that d x y or i can also arrange the dumbbells along the x z plane
or i can arrange
these dumbbells along y z plane or along the in all these three cases you saw
actually the
dumbbells the lobes of these dumbbells were actually within the two axis or i
can
so these three are within the axis the lobes are within the axis and
the remaining are actually on the axis in this case you see the dumbbell the
lobes
are on x axis and y axis and this is slightly difficult to explain because it
is a linear
combination of two different orientations but we see that there are five
different possible
orientations for d orbitals
so for d orbitals number of orientations that are possible are
five
so what we see here the s orbitals can be oriented only in one way because it
has spherical
symmetry the p orbitals can be oriented either along x axis y l axis or z axis
we call them p x
p y p z or the d orbitals can be arranged right in five different ways called
d x y d x z d
y z this is called d x square minus y square

so ah this is d x y d x z d y z d x square minus y
square d z square
so there are five different ways that the d orbitals can orient
so this magnetic
quantum number tells what is the orientation of the orbital that i am
interested in when l
is 3 it is very difficult to even drive point by showing a beautiful
illustration i will will
skip that part and i just tell you that there are seven different ways to
reorient this
l equals three which is the f orbital right
so what did we see
so far we saw
that s orbitals can be oriented in one way p orbital can be oriented in three
different
ways we call them p x p y p z d orbitals can be oriented in five different
ways d x y
d y z d z x d x square minus y square d z square these five two ways and f
orbitals
can be arranged in seven different orientations
so you see for a given value ah we can we
can actually generalize this ah for a given value of l because this s p d f
they signify
a particular value of l for a given value of l there are two l plus one
orientations possible and what are these values of the two
l plus one orientation they go from minus l to plus l in the step of one
so minus
l then minus l plus one it and then l minus one and l
so there are two different
so in between the zero will come
so there are this way there are two two l plus
one different orientation starting from minus l to plus l
so let us say ah our l is ah here
i give the value of l let us say l is zero
so how many ah number of orientations given by two
l plus one
so two l plus one is one because l is zero and what are the values
so it goes from minus
l to plus l by a zero what is my l zero
so minus l is zero plus l is zero
so we got only one value so
this is the value of the magnetic quantum number m when l is one how many
possible values are there
twelve plus one is three and what are there it starts from minus l that is
minus one in a step of
one minus one plus one is zero and one more step minus zero plus one is plus
one
so it can be minus
one zero plus one these are the three different magnetic quantum numbers when
l is two how many
different orientations are possible that is five two l plus one is five what
are they they are
minus 2 minus 1 0 plus 1 plus 2
so when it is 3 there are 7 different ways and they go from

minus 3 to plus 3 7 different ways when it is l is zero we just call it s when l is one we call them p x or p y or p z but please note that there is no direct correspondence of you cannot say that minus one belongs to p x ah or zero corresponds to p y or plus one ah corresponds to p z ah they have a relation but their relation is slightly complicated

so we we will be ah happy if we know this much that for l equals one there are three different orientations their magnetic quantum numbers are minus one zero plus one and we call them p x p y p z will not try to direct ah provide a one to one correlation between them and similarly when l equals two we have d x y d y z d z x d x square minus y square d z square and f will have ah seven different ah let us look at this example let us say my n value is three the task is find out the number of orbitals right

so when n is three what are the possible values of l l can be zero

so there are since n is three there are three three possible values of l and they are zero one two

so it goes from zero to n minus one all right when l is 0 what do we call it we call it 3 s and when l l is 1 and n is 3 what do we call it it is 3 p when l is n is 3 and l is 2 we call it 3d

so this orbital ah denote notation identifies the principal quantum number and azimuthal quantum number but we know thats not the end of the story 3s has only one possible orientation because it is an s orbital three p has got ah three different orientations that are they are three p x three p y three p z and three d has got five different orientations three d x y three d y z three d z x three d x square minus y square and three d z square

so one two three four five these are five different ways right

so if i count the number of orbitals corresponding to n equals three i would see from three s i got one from three p i got three from three d i got five orbitals in total one plus three plus five is 9.

so i saw that when n equals 3 there exist total 9 orbitals

so we can have a general rule as to say that for when prints for principle quantum number ah n there are n square number of orbitals

so when n is one there is only one orbital what is that one s when n is two there are four orbitals what are the two s two p x two p y two p z when n equal to three there are nine orbitals and who are they these are the orbitals that we ah wrote down here so we saw three different ah quantum numbers principal quantum number or vital quantum number and magnetic quantum number we saw that principal quantum number n is the leading quantum number which decides what are the possible values of l and in turn l decides what are the possible values of m with using n l and m the three quantum numbers we can go up to identifying the orbital or the house of the electron but then ah there was something else that is called a spin it turned out that electron has an intrinsic property which is known as spin by intrinsic i mean that it is inherent to the nature of electron you cannot separate spin from electron if there is an electron there has has to be a spin the spin is inbuilt in electron and therefore you have to take into account of the fourth quantum number and that is the spin quantum number

so together with n l and m the three quantum numbers when spin quantum number ah comes into play we uniquely i can identify a particular electron this is what we are going to do next the spin quantum number so our fourth quantum number is a spin quantum number as i said it turned out that each electron has ah has has as a spin associated with it and this pin quantum number is denoted by m s and if principal quantum number n said about the size of the orbital azimuthal quantum numbers ah talked about the shape of the orbital magnetic quantum number talked about the orientation of the ah orbital the spin quantum number talks about the spin orientation of the electron remember when we discuss magnetic quantum number we said that magnetic quantum number signifies the s orientation in space of the orbitals the orientation of the orbital in space in x axis y x is z axis or within x y ah or on the x y plane or on y z plane

so for

so so and

so forth but spin quantum number talks about the spin orientation its not special orientation it is spin orientation of an electron there are only two possible values of possible spin orientations there are only two ah spin orientation for electron they are ah given as m s value of plus half or minus half the amount they signify up spin or down spin they are also called as alpha or alberta

so these are the two spin orientation of an electron

so so to summarize we discussed about n l m m s the principle quantum number which talked about the size this talked about shape this orientation this is spin orientation n can be one two three

so and so

forth l can go from zero one two to n minus one m can have value minus l ah minus l plus one 0 l minus 1 l and m s can have plus plus half or minus half these are the this quantum numbers that are used to uniquely identify an orbital
or to uniquely identify an electron since orbitals are the place where electrons are found we will now discuss little more about the shapes of the orbitals
if you remember we obtained these orbitals by solving the schrodinger equation x i
equals e psi where the wave function psi are are essentially the orbitals and we saw that
to identify an orbital we require a few quantum numbers
so the wave function therefore is a
function of n l m these three quantum numbers are there in this wave function
so this this simply
means wave function depends on l m and m
so if you have different n l or m you will have a different
value of the wave different form of the wave function we got to know this we also know from
bonds hypothesis that the wave function itself we call it orbital but it does not have a physical
significance what has a physical significance is the square of the wave function the psi n l
m ah square
so this tells us the probability density of the electron at any at a given point at a given
point this is important because at a particular point you have a particular value
of this wave function and the square of it is actually the the probability of finding
that ah electron at that point right the wave function of course as i said the wave
function contains this information about the position of the electron that you are interested
so the position of the electron how can i signify the position of the electron of course
i have to tell about that where it is located its x value y its its value in the x axis y x
is z axis then only i can specially in the space i can pinpoint the position of the electron
so i
can have i to define the position i can have ah r which is the position of the electron
as a function of x y z in this is given in cartesian coordinate equivalently what
happens is that it is it was found that it is easier since the electron actually ah goes around
the nucleus in a circular path
so it turned out that if we use another coordinate system instead
of cartesian if we use spherical polar coordinate then ah the solution ah of hydrogen atom problem
becomes easier and this is what ah i show you here
so here this spherical polar coordinates are given
ah the relationship with the cartesian coordinates are given

so we have this x axis y axis z
axis the three axis this is the origin
so you can since electron is going around ah this this
sphere in three dimension
so you can define one one coordinate in the spherical coordinate
that is r which is the radius of the circle ah radius of the sphere or we can you can
define an azimuth angle which is given as ah phi and you can also have another
angle which is switched which which ah shows you this movement pretty clear and
that is given as ah theta
so instead of x y z ah my position the position of the
electron is given as r theta phi ah this r is ah is overall position and
this r is actually the radius of this sphere
so i have now these three coordinates
very uh r theta and phi which using which i uh define the position of the electron
so since
the wave function contains information about the electrons position
so therefore this wave function
which requires n l m to be a uniquely identified is a function of r theta and phi this is radial
coordinate these two are angle two angles this wave function this form of wave function
can also be written down as product of two wave function which is which contains one
radial part which is given as rnl multiplied by an angular part which depends on theta and phi
so this is the total wave function which depends on r theta and phi and is signified by three
quantum numbers n l and m and i am now what we are showing you is that we have broken the down
this wave function into two different components one is one first term depends only on the
radial part
so this is the radial component the second part depends on theta and phi
that that is called angular component right
so its radial component angular component
the radial component is def
so it is sufficient to use n and l to define them the leading quantum
number is n for angular moment angular component we have two quantum numbers l and m and the
leading quantum number is l the azimuthal quantum number
so this is the definition of the wave
function in in the spherical ah coordinates
so we must appreciate that the wave function depends on
the radial part and the angular parts now the wave function square gives you the probability density
there is a special term that we would uh need here is while the orbital the square of the wave
function tells you the probability density when the probe when the wave function is 0 or
the probability when the wave function is 0 the region sometimes what happens

there
are some region in the in the space   the region where your wave function is
0 and therefore the probability vanishes   if probability vanishes what does
that mean
that means that i in that region you cannot   you do not expect the electron to
be present
the probability of finding the electron at that   place or that point or or that
region is 0 and
when that is the case we have we call that region   as node this region i am
intentionally using
region it can be a point or a along a line or   along a plane or along a surface
whichever
so when whenever the probability vanishes   exactly
so the wave function is 0 and therefore
the probability is 0 we call that node now you   look at this wave function
so the will get a node
if this wave function becomes 0 this wave function   psi has two parts one is
radial part another is
angular part
so how can it this wave function be   0 it can either be 0 when the radial
component is
0 or it can be 0 when the angular component is 0.

so either this can be 0 or this can be 0 when
the angular component is 0 that is again the   node because the wave function
vanishes when
angular component is 0 we call that angular node when the radial component is 0
we call that
radial node
so this zero when the radial component   is zero this is radial node when this
angular
component is zero then we call it angular node   now we will discuss about what
we can
know about this radial and angular nodes let us first discuss about the angular
nodes ah where y l m which is a
function of theta and phi is zero   all right the leading quantum number is l is
is l
here
so let us say when l is 0 we know when l is 0   what kind of shape do we get we
get a spherical
shape of the orbital when it is spherical shape   you see that ah no matter what
value of theta
or phi you take since it is a sphere you always   have that probability ah
probability density
so when l is 0 you do not have any angular node no angular node or here will
count number
of nodes that are angular when l is zero there are zero number of angular
nodes when l is one we know the shape is   ah like this if you look at ah the p
x p y p z
orbitals that we have already shown what you see   here is that the three p
orbitals p x p y and p
z orbitals the lobes you can identify and what is   shown here is this plane the
probability density
becomes 0

so that means on this plane that is highlighted here along on this plane you have no
chance of finding the electron
so the electron can either be in this side or this side but not along this this plane
so this is called a nodal plane
so this plane is coming because the orbital has
a particular shape you can see where p x p y p z they all have one nodal plane h and that is
coming because of ah the angular component is zero
so at this val at this in this plane the y
l m this part of the wave function becomes zero therefore you see this node
so number of nodes
for p orbitals is you can see one in each case p x there is one plane p y there is another p z
there is another
so the number of angular nodes are ah is is one for p orbitals when
l is two we know the shape is ah double dumbbell and we can i can show you
ah another figure here you can see d x y d y z d ah z x d z square d x square minus y square
and you can see since it is a double dumbbell you can define two different planes along which
the wave function or the angular component of the wave function vanishes as you can see in each
of these d orbitals there are two angular nodes
so in d orbitals you got two angular nodes so
we can in general write number of angular nodes is equivalent to the value of l
so the value of l determines how many angular
nodes are there how many regions where the wave function vanishes because this component of
the wave function is 0 and the answer is l if l is 0 for s orbital there is no angular
node for ah p orbital there is one angular node therefore d orbital there are two angular
nodes and next we discuss about the radial nodes the radial part of the wave function
depend only on the radial coordinate r and this is zero we see we will
say that when does this component rnl or the radial component of the wave function
becomes zero we will first look for s orbitals for s orbitals what i am showing
you here is the wave function so this the radial component of the wave
function in the x axis it is r ah plotted the three figures that you see here are one is for
one s the other is for two is 13 is for three yes in each of the cases the angular part is the same
this is given as s they are all spherical orbital what i am showing you here is the radial component
as a function of r this r is the distance between electron and nucleus
so this is my nucleus
this is electron and this is the distance when you look at the wave function the
radial component of the wave function for one s orbital you see this is the shape of
the plot you see that it exponentially decreases when you look at 2s you see

the curve looks
like goes like this i am retracing the curve you see at one point of time at one point of
at one distance of r at a certain distance of r this wave function the radial component of the
wave function it it becomes zero this is the x axis at at zero
so at one value at this value
are at this value of r the wave function is zero
so that means at this value of r the probability
of finding the electron in the two s orbital is zero but as you go at higher values of r you
see the wave function has some negative value but when you square it when you calculate the
probability the probability of course becomes positive
so at only one point at one value of r
you saw that the probabilities does not exist so below that value of r you have the chances of
finding the electron after the value of r after that value of r you again have the chance of
finding electron
so between while going along r axis we get a point get a value of r where there
is no probability distribution below that value of r and after that value of r we get probability
distribution that means at that point of time at that point of ah value of r there exists a node
and this node is a radial node
so we saw in one s orbital there was no such radial node in two
s orbital we saw one radial node when we look at three s orbital this gives an interesting feature
what does it show let me ah retrace this curve when i am drawing this asymptotic region
at very large value of r i am not making it 0 they do not exactly become 0 they just
tend to go to go to 0 very slowly the decay
so i see again there is a sharp decrease in the
wave function and therefore the probability as r goes on but at again one value of r there appears
a radial node and then again the prob the wave function is non zero
so therefore the probability
is finite and again at one more value of r the probability is again zero
so therefore i get two nodes two radial nodes in three s orbital
one radial node in ah two s orbital and zero nodes in one s orbital
so even if i have
these three orbitals which who have azimuthal quantum numbers same they have same shape s shape
spherical shape ic zero node or one node or two nodes i can ah reach i can show that in another
way what i am plotting here in this picture is ah in the y axis you have r n l square of it multiplied by r square and this
is the in the x axis you have the distance here this is called radial
distribution function this is the definition of this but we can actually
go through the results when i look at this picture i see that for 1 s orbital the radial distr so

this is the square of this wave function
so that means if this is this was the radial component of
the wave function i have already taken the square
so the plot that i am showing you signifies the
probability of finding the electron at that value of r
so for 1s the radial distribution function
has this kind of shape what do you see you see a maximum probability at a certain value of r below
that value of r and beyond that value of r the probability decreases if i show that ah as a in a
different way this is how i am showing this is the distribution electron distribution when the
electron is in one s orbital you can see it is a sp it is spherically ah distributed
so it is a sphere with a certain value of r now when i go to two s since the the radial wave
function look like this when i take a square
so i see first it goes like this and then i have this
point where it switches at node
so the probability this density becomes 0 and beyond that again i
see n what does that mean when i plot in this way i see that in the under the center there is
a density probability density this central sphere signifi ah identifies this region and the sphere
beyond that the second sphere that you can say is is due to this probability distribution and
in between there are two spheres there is a ah region where the electron is not formed
and that is called a node
so the white region that you see in this picture is a radial node
so this is in two s
so you have got one node when you look at the three s the
radial distribution function has now three peaks ah you can you can find this out because there
are two places where the wave function becomes zero and therefore there are two places where
this probability density becomes zero that means there are nodes and this is signifi shown in
this diagram this way
so the lower the inside component the inter ah internal component sphere
is due to this this next sphere is due to this and the final the last sphere is due to this so
there are three concentric spheres each separated by a region of space where the electron is not
found
so in this case you can see there are two regions of space where there are radial nodes
and
so therefore there are two radial nodes now we will discuss about the radial
nodes for p orbitals again radial node is obtained when the radial
component of the wave function vanishes i have two pictures here this the picture
in the right hand side shows the radial component of the wave function for a

two p orbital
and the left hand side picture says the shows the   radial component of the wave function for a three
p orbital and the x axis is again the distance   between uh electron and the nucleus
 so when the
electron is in a two p orbital the wave function   has this behavior you see the radial component
component does not show any node what you see here   at r equals 0 that what does that mean that in
case of 1 s orbital sorry in case of any s orbital   there was always a finite probability of finding
the electron on the nucleus however when it is   a p orbital this probability is always zero so
right
 so this is not a node this is actually a ah result from a from one limit when r goes
to zero and again similarly you have   at very high large value of r this asymptotically
goes to zero
 so in this case you see the radial   function radial part of the wave function has
no nodes
 so this has got 0 nodes and in case of   3 p orbital
 so the wave function ah looks like
this and how many nodes are there you have to   find out how many places this function crossed
the zero axis and you can see there is only one   one point where it formed
 so there is only one
radial load in the in case of three p orbitals
 so we saw that two p orbital has known radial
node and three p orbital has one radial node   will now ah will now ah try to generalize ah
about the number of radial nodes let us first outline what we saw we saw that for ah one
s orbital radial number of radial nodes here   i will write number of radial nodes for
one s orbital i got zero for two s i got   one for three s i got two for two
p i saw zero for three p i got one   right this is what we ah we saw now
we can have a general definition as to   number of radial nodes that an orbital will
exhibit is given by n minus l minus one right now using this relation we will try to
find out number of radial nodes in a few more   orbitals let us say about four p orbitals in
case of four p n is four
 so n is four l is one   minus one and again minus one
 so four p orbital
will have two radial nodes what about three d   in case of three d you see n is three
d is d orbital signifies l l value two
 so three minus two minus one this is zero so
three d orbital has zero radial nodes four d   will have four minus two minus one which is

one and four f orbital will have four because of n minus l since f is the
azimuthal quantum
number which corresponds to the quantum number three
so four minus three minus one which
is this is zero
so this way we can calculate the number of radian rules if you remember
we found out that number of angular nodes was equivalent to l right
so number
of radial nodes is n minus l minus 1 and number of angular nodes
is l
so total number of nodes is n minus l minus 1 plus l which is n minus 1 this is
the total number of nodes only depends
on the value of principal quantum number our net next point of discussion
is boundary surface diagrams now when i solve the schrodinger equation
of hydrogen atom i get one s orbital i get two s orbital i get three s
orbital
the probe square of those wave functions are essentially the probability
distribution so
probability distribution means is that how many times i will find the electron
at at a particular
value of r what i am showing you here is a dot diagram each dot signifies that
there exist
a the electron was found at that point of time
so you can see that in this first picture which
is before 1s this is for 2s this is for 3s in 1s you see a single sphere but
then you can also
see that you cannot actually identify the sphere within which all possible
locations of electrons
are all possible locations of electrons are denoted because you see here i
have a dot
here i have another dot but most of the dots are concentrated in this place if
i look
here two s i see this in this orange color i mean these colors are actually
for illustrative
purposes they do not have any other significance i see when i look at two s
orbitals i see some
dots each dot corresponds to that i found the electron at that point of time
this is the meaning
of the dot
so i see
so many orange dots are concentrated at one place and then there is a gap
which you can see the white space here and beyond that again i again start
finding the electrons
and this time they are given in green color dots
so i see that electrons are present here and
then again the electrons are present here again i cannot really define a
sphere a circular shape
within which the electron location will be formed again similar story if i go
to 3s orbital
i see the central region and then another peripheral region and then there is
a gap
and again some more dots
so this is a tip this is the typical situation where i ah face
problem as to what what can i do about it now when you look at this kind of ah

situation then
you would ask how did i get this a particular value of r for one s how did i get this two
spheres how did i get three spheres for three the answer to that is that we try to estimate you try
to make sure that at least ninety percent of the of the probability density should be accounted for
so it says that the the red
the radius of this 1s orbital can be up to that point up to which the up
to which the region explains or accounts for about up to 90 percent of the probability density
so you can see i can start from the center i can keep on going and finding out the net probability
and when i see that ok i have already accounted for the ninety percent of the my experiments ah
the results from my experiments then i say ok this is this is all right i am happy with this so
this is the boundary surface diagram
so then i can bound the surface at the region where i found
90 percent of the electron density similarly when i look at the 2s orbital i start from the
nucleus and i go on on and on and then i see at this point i saw i have accounted for 90 percent
of the electrons location
so i say ok this is my bound region
so this becomes the boundary surface
diagram for 2s and similarly for 3s i do this the boundary surface diagrams help us obtain
the pictures that we showed for example the p p x p y p z orbitals that i showed you
earlier you see these lobes
so the lobe actually indicates i am the size the size
of the lobe will be determined by the fact that within this region 90 percent of the
probability density should be accounted for this boundary surface diagram is a very
useful tool to discuss the orbital shape
so far we have discussed the orbitals of the
ah hydrogen atom if you remember we got this orbitals by solving schrodinger equation which
is h i equals e psi where h was the hamiltonian psi is the wave function which we call orbitals
or atomic orbitals and e is the energy when you started solving schrodinger equation we said that
the only known quantity we have is the hamiltonian the operator what is unknown is the wave function
and also the energy by solving schrodinger equation we get the wave function which we have
discussed
so far as orbitals and now we will spend some time in discussing about the energy that
we get corresponding to those wave functions let us look at the energy
so we started from h i
equals e psi we discussed about the orbitals and now we are going to discuss

about this this energy
so they by energy i mean energy of the orbitals all right we will break our discussion into
two parts first because there is a there is an interesting story here first we will discuss
about the energy of the orbitals for hydrogen atom for hydrogen atom and this discussion is also
discussion is also valid for all hydrogen like atoms what are hydrogen like if you remember
bohr's atomic model was also uh applicable to all single electronic species
so they are all single
electronic spaces and we call them hydrogen like h e two helium i am sorry helium plus ah lithium ah
two plus and and
so so forth helium plus has one electron because helium has two electrons and
i removed one electron
so helium plus has one electron lithium two plus has again one electron
so they are all called hydrogen like systems
so when i solve the wave ah schringer
equation i got psi n l m this is the wave function that i got and we discussed
about it and then i got the energy and for hydrogen atom the energy only depends on
n depends only on the principal counter number it does not matter what value of l or m is
as long as n is given there is a fixed value of energy this is what the result from for
hydrogen like systems are
so let us find ah write down the wave functions that we have already discussed
so psi n l m
so i will call it psi one s then i will have psi two s then i will
have psi two p x psi two p y psi two p is z
so n l m you can find out two p x means n is 2
l is 1 m is not exactly identifiable but either minus 1 or 0 or r plus 1 then then i can have
psi 3 s i 3 p x i 3 p y psi 3 p z and
so on
so forth each wave function corresponds to an
energy right this is what this solution of the schrodinger equation said
so this energy can be
1s this is e2s e2px e2py the energy corresponding to 2pz orbital energy corresponds to 3ds and so
on
so the solution for hydrogen atom showed that this is how the solution looks like e 1 s is has
the lowest energy then comes e 2 s and the energy of e 2 x is exactly equivalent to the energy
of e to p x which is e to p y which is e to p z because as a as we discussed the energy
only depends on the principal quantum number n all these four orbitals have same principal
quantum number that is n and similarly e three s which is again equivalent to

e three p ah x
y z and it will also be similar to e three d x y y z z x ah x square minus y square or z square
so this here you can see one orbital from three s three orbitals from three p five orbitals from
three d
so total nine orbitals have same energy
so let us call this energy as e3
so there are nine
different orbitals which have same energy and here i see one two three four four different orbitals
have the same energy and let me call it e two and here for one s there is only one orbital
which has got that energy and it is e one when we see that there are more than one wave
functions psi 2 s i 2 p y x psi 2 p y psi 2 p z that four different wave functions but they carry
all they all of them they carry the same energy we call these energy levels as a degenerate that
means they are they are the same they have the same energy and since there are four energy levels
which are same energy
so we call them they call this situation as four fold degeneracy and this situation has nine fold degeneracy
so third energy level of hydrogen atom is nine fold degenerate
the second ah energy level of hydrogen atom is four fold degenerate and the first energy level
of hydrogen atom is non degenerate or simply ah single fold ah degeneracy now we will talk about
the second case for multi electronic systems for single electronic systems like hydrogen we had ah the wave functions i n l m and here also
we have the same wave function but here the energy value depends on n as well as l
so energy value depends on on n and l but it does not depend on m ok
so what
do we have let us write down the orbitals that we know
so 1 s 2 s 2 p
so i am not writing down
now to p x 2 p y 2 p z because i already know that it the energy does not depend on m
so then
three s three p ah three d i have four s four p four d four f these are the different orbitals
that i got i know their n value and l value and i know that energy actually depends on n and
l in fact the energy depends on their n plus l value
so what we will do is now write down the
n plus l value for all these orbitals that i wrote down here for one s n is one l is zero so
this is one for two s it is two for two p it is three because n is two and p is l is one so
this is again three for three p it is four for three d it is five four five 4 d is 6 4 f is 7
you can you can do that easily now what we know is of what we found out is

that energy increases with n plus l value right now if we want to
write down the energy levels in increasing order this is how it will be the lowest value
of n plus l is because of one s
so this is the lowest energy e one s its energy is less than
what is the next value of n plus l that is two
so that is because of two s orbital and what
is ah next one that is two 2p and then you see both 2p and 3s they have the same value of n
plus l when they have the same value of n plus l the lower the value of n gets the precedence
or has lower energy
so then comes e two p e three s then energy is e three
p we have to be careful here because three p has four four s has ah four
so the next orbital will be e four s and then five will have to
look again be careful three d and e four p
so the energy ordering is following
the value of n plus l and when there is same value of n plus l we will say that ah will will we
know that the lower value of n has lower energy ah just to remind you that at this point that
2p has three fold degeneracy because it has 2px 2py 2pz there are 3 orbitals for the same
energy
so i will write down degree of degeneracy hash d
so this is single fold designer one this
has three fold degeneracy this is one because three s three p has three four s has one because
it's s orbital three d has five four degeneracy four p has three fold degeneracy this degeneracy
is only coming because of the magnetic quantum number because we are not defining p x p y p z e
two p x two p y two p z they have the same value of energy will continue our discussion on the
orbital energy of hydrogen atoms in our next class we will see what other features are there
in the in the orbital energies and what physical intuitions we can we can physical insights
you can obtain ah from the solutions of schrodinger equation and that is what we are
going to discuss in our next class thank you you