today we shall start again recapitulating what we do it in the last lecture the new things those we learnt and then we will do something more with kinetic theory and plan is that towards the end of today's lecture hour i will tell you briefly about non-ideal situations why non ideal situations are important it is important because of the fact that you know ideal gas what we are dealing so far there is no interaction and if there is no interaction there is no phase transition possible most of the situations only one exception to be correct i tell you that without interaction phase transition happens that is called bose einstein condensation i quoted this name because it involves the name of a great indian scientist satyanranath bhosh but that is essentially a quantum phenomena happening at very low temperature where there is no interaction in that sense it is the nature of both particles or rather to be precise the statistics of both particles that give us the phase transition so called formation of bose condensate which at least you know about them in popular level at least but what i want to tell you at the moment that we are dealing with ideal gases and these ideal gases cannot lead to any phase transition because there is no interaction so first and foremost criteria of a phase transition should be interactions between the particles i am dealing with so that is why i will bring in some non ideal nature and tell you what is vapor and how does the pv diagram for a liquid gas transition looks like but before that lets start with what i wrote here recapitulating what we learned new thing i talked about pressure ok pressure is related to m n l cube v r m s square i remind you what is v r m s square v r m s square actually it is a vector dot product if you like i can decompose it in three components z square and divided by one over n so that its the average ok its the average and i am summing over all the particles i have ok so this is the average information that is carried here and this is mass of each gas molecule n is the number of particles in the container and l cube is the volume of the container where i chose a cube but it is not essential to choose a cube you can have a sphere if you like and this you can write further as p is equal to one third rho v rmss square or i can go further p v is equal to one third m v r m s s square which i can write also as if my mass of each molecule is m m n v r m s square so this is i will drop this expression rms in the subscript from the time being and i will be assuming that i am dealing with average velocities which are root mean square velocities now question was how do you relate it to temperature so have pressure volume but they are related to microscopic objects which we can never measure in experiments what we measure with a thermometer is temperature so it is important that re this relation should be connected to temperature so what i did first ideal gas equation of state what is an equation of state equation of state is something that connects the different thermodynamic variables or i am talking about chemical system involving p v and t so my equation of state will be something that connects pressure volume and temperature this is true for an ideal gas and this is a combination of charles law which says either p is proportional to t if i keep volume constant or v is proportional to t if i keep pressure constant or its boyle's law which tells me that pv itself is a constant if i keep temperature a constant ok these can be verified for a gas which is at very high temperature and very low density which is the limiting situation for any real gas where i can approximately treat it as an ideal gas ok so now to i put this things together this equation i got here this is my ideal gas equation of state pv is equal to nrt i can simply write pv is equal to n k b t and then what we have found out very important expression that half v rms square is equal to 3 by 2 k b t and then this gives me very important relation that temperature is defined in terms of average kinetic energy of the gas molecules this i can physically interpret in the following way if i increase the temperature i expect the gas molecules to have more kinetic energy so if you can think of this way kbt has dimension of energy these i will call the thermal energy if you have higher and higher temperature they will have more kinetic energy the gases will move with more kinetic energy this is something i physically expect and this is what kinetic theory tells me about so once i have this i have a new definition of temperature so far we were dealing with definition of temperature which we measure in thermometer that is in our calorimetry but kinetic theory gives me a more fundamental definition of temperature that mean translational kinetic energy is related to three by two k b t ok now these two taken together pv is equal to this and kinetic energy for n molecules if i have n molecules total kinetic energy will be v r m s s square three by two n k b t if i have both of them together

then i
arrive at a expression p v is equal to two third e translational and its all
kinetic i told
you why it is kinetic its kinetic because i am assuming ideal gas and ideal
gas does not have any
potential energy because there is no interaction between the molecules this is
the first point and
second point i said that it is all translational because i am dealing with a
monoatomic gas and
there is only translational degrees of freedom ok
so if i increase the temperature translational
degrees of freedom translational energy increases and that defines my
temperature this is an
equation in which i have completely gotten rid of i have completely gotten rid
of temperature
i am connecting pressure volume to the average kinetic energy of the system ok
and secondly i
mentioned briefly that this is a very sacrosanct equation because p v is equal
to n k t is valid
for ideal gases which are classical which are very high temperature low
density situation i
cannot write a similar equation if i go to very low temperature but as long as
i am dealing
with a monoatomic gas and as long as i am treating ideal systems that means
there is
no interaction i arrive at this equation even the bose gas i was mentioning
before
you can have an equation like this and i told you that this two and three
these two
comes from the fact if ep energy of a particle simply i am doing newtonian
mechanics so
any particle with momentum p with energy p square by two m
so there is a two factor
coming here and three coming in because of the factor that i have considered
three components of
velocity usually our world is in our conventional physics classical physics
world is three
dimensional as three components of velocities and there is no difference
between these three
components of velocities there is something called isotropy which i may refer
to it many times
now i told you very something very very important since these three are
completely equivalent
then i can have a equi partition of energy ok i can have an equi partition of
energy ok
what do i mean by equi partition of energy equi partition what do we mean by
equi partition of energy
that my v square i can think of its consisting of three pieces v y square and
v z square
this is my v square ok
so kinetic energy has contribution from x component of velocity y
component of velocity and z component of velocity
so since v x v y v z are equivalent in the
probabilistic sense these are all rms i am talking about i can write it as

three v x square in the
average sense ok since i can write it as three v x   square i get three v x
square if i multiply
by one half m is equal to three by two   k t k b t
so k always stands for the bold
band constant even if sometimes i may forget   to put this b subscript here
though immediately
give me half m v x square is equal to half k b   t
so you see the kinetic energy if you
like contribution to the kinetic energy   for the x component of velocity half m
v x
square is equal to half k t similarly there   is nothing great about x i can
write half m
v y square as half k t this is equi partition   which i said that three
components of
velocity three components of velocities ok and energy is apparently half
kt for each molecule on an average   in each direction ok well what i
mean by each direction is clear   that half m v x s square is equal to half k v
t half m v y square is equal to half k v t and   these three adds and gives me
three by two k b t
if i have for n molecules then half v x square ok will be first half n v x
square
translational kinetic energy   associated with v x this will be this
quantity which will be n by two k t   ok
so this is called the equi partition energy
whenever you have this type of from ideal gas   then you can ask me that what is
the energy
associated with each degrees of freedom   i should be very very careful when i
mean
mean what do i mean by degrees of freedom   ok let us recall a bit of classical
mechanics
ok in classical mechanics if a particle is   moving along a line let us say x
axis then
i can immediately characterize the particle   by x and also velocity v x ok if
it is under a
force then i can say x and v x
so x if you like is   the degrees of freedom ok you can also think of v
x is one of the degrees of freedom if you have an   x if you you have a v x
so there is one degree
of freedom ok now if particle is allowed to move   on the floor of this room you
have a v x
similarly you have a v y right
so i will say x y that gives me the coordinates it has two
degrees of freedom similarly if i have a particle   moving anywhere in this room
i will need three
coordinates x y and z and correspondingly three   components of velocities v x v
y and v z so
essentially i have three degrees of freedom   and i am saying for each particle
on an
average ok on an average if temperature is t   i am talking about equilibrium
situation if
temperature is t for each particle on an average   for each degree of freedom
that means associated
with each v x here x has no role to play   because its free particles ideal gas

for each
v x i will have an energy average energy which   is half kt this is called equi partition
of energy and this is very very important   now if you think of n such particles where
this is your capital and you know you will   need many many three for three for each three
for each particles these i explained for one particle now you may have n particles so
n particles each moving in three dimensions
 so i will have v i x v i y v i z ok v a y v i x v i y and v i z and now for each of
this average kinetic energy i will have half kt ok n number of particles because they are not
interacting and i will have same term for v y   n k t and i will have a similar term half n k
b t for this and the total will be three by two   n k v t ok this is how i get to this expression   using the equi partition or rather kinetic
theory tells me about the equi partition theorem   now i can go further i told you there
could be other special cases for example i can get harmonic oscillators which
have energy p square over two m and this is the potential energy ok this is the form of potential energy for a
harmonic oscillator and if i have this potential   energy then energy of this average energy of this
harmonic oscillator when this oscillator is at a   temperature t is k t k b t this is equi partition
applicable to harmonic oscillators ok whenever   you have this quadratic form ok here ideal gas i
was only having translational degrees of freedom   but here you see i have x and p both both i can
treat as independent degrees of freedom both   are contributing to my energy and both is
quadratic in form this is very very important
 so so for ideal gas i was calling my
degrees of freedom only as v x v y v z ok   but when it comes to harmonic oscillator
where force is of the form minus k   x and potential is the of the form half k x square
as we have learnt in my mechanics course then   total energy is this form and i have
effectively two degrees of freedom   which are piece and x and both giving me half kt
giving me average energy of an harmonic oscillator   is k b t ideal gas molecules it is half kbt and
harmonic oscillator it is kbt i just argued it   out using the equi partition which i try to
invoke upon you using the kinetic theory of   gas now this is the average for harmonic
oscillator if you are in non interacting   this word is very important non interacting
harmonic oscillators then simply you can write this now you see these harmonic oscillators
are not oscillating in one dimension rather   in three dimensions then you will

have a term
three sitting here ok that tells us a lot about equi partition of thing i explain to you
what each degrees of freedom means and then i will proceed further to calculate something
measurable in the experiment which i briefly touched upon in my last lecture that ok i talked about specific heat
and specific heat can be of two types firstly you calculate ah specific heat keeping volume of the container fixed that i call c v ok this is c v ok and then i can
have it keeping the pressure constant measure the specific heat which i can write
in general c is equal to d e sorry d e d t ok you know heat energy specificate you define
in calorimetry in terms of amount of heat that is being absorbed or released in raising the
temperature here we know heat is an energy and we are dealing with energy here specific heat is
equivalently related to change in this derivative simply tells me this is the change in energy
average energy if i change temperature or if i use more familiar notation for you it is del e del
t ok you change temperature by an amount delta t and that this is the change in energy you take
the limit delta t tending to zero you can write in your calculus form if you keep volume fixed
then it is called cv if you keep pressure fixed it is called cp and for an ideal gas i just quote
it without any proof or further for ideal gas cp minus cv is r this i will try to
elaborate more and there is a ratio gamma which we will calculate c p by c v which i will
use when i go into thermodynamics i talk about adiabatic processes then these things will be
useful now if you do this you can immediately see c v let us focus on only c v for an ideal gas it should be three by two n k b which is
called the dulong petite law if you do it for an harmonic oscillator using the equi
partition you do it for an harmonic oscillator this expression three n k t which i have
wrote here gives me c v is equal to three k b t three n k ok
so you see these are called
dulong petits law ideal gas it is three by two i told you in the last class this three comes from
dimensionality of the thing and here it is three because where do you get the other half factor
form in the harmonic oscillator because in this harmonic oscillator if there is a half k x square
which is very very important because now you have two degrees of freedom in that sense one given by
x and one given by p both contributing half kt to my average energy
so harmonic oscillator this is
cp this is cv and you can calculate cv cp using this relationship you have here you remember r

is equal to nkb but coming back to the ideal gas
so when i talk about cpcv its ideal gas
harmonic oscillator it is just three nkb   now coming back to ideal gas
so far
we have been talking about mono atomic   and hence i was talking about only
translational degrees of freedom and now   if i have a diatomic cache ok
so go beyond
mono atomic you do diatomic cache okay all you have to do remember how many
how many degrees of freedom do you have   and how does this degrees of
freedom contribute to your energy   degrees of freedom contribute all degrees
of
freedom contribute half kt to energy ok
so diatomic case diatomic
so first thing is translational
again this molecule is moving in a three   dimensional container
so i know again
there is no interaction
so its ideal gas freedom container and i do not consider any interaction so
one is translational degrees of freedom   how many three
so what do they contribute three
by two k b t ok but thats not the end of the story   ok let us take an oxygen o2
ok
so you have
two atoms ok there are translational degrees   of freedom but of course if i
take a dumbbell
like shape i know molecules can rotate if i   take an axis it can rotate about
this axis
i know what is rotational kinetic energy   i have done it in my rotation chapter
in
mechanics
so i have a rotational kinetic energy   and what is this these are two axis of
rotation if
i rotate about one two possible rotations and this   gives me half i omega one
square and half i omega
two square
so i have fixed this axis and i am   allowing rotations i can have 2 rotations
so those
both of them giving me half i omega square
so i   have 2 degrees of freedom here and remember this
is also what i say quadratic in nature if that   be the case i immediately know
that i am going
to get a three by two kt here i am going to get   half kt for each rotational
degrees of freedom so
total i will be having total average energy for a   diatomic molecule is f by
two k b t and then
specific head if i take n such molecules average   energy will be five by two n
k b t giving me
a specific head that is 5 by 2 n k
so you see   that number of degrees of freedom i increase i get
a different expression for my total average energy   this is the total average
energy
for n such diatomic molecules   and once i put that in the expression of
specific heat which i experimentally can measure   ok that goes into five by two
instead of three chi

two next question you will ask what will happen as a polyatomic molecules so for a polyatomic molecule you have to be bit more careful and one has to go further than this diameter now let us go to polyatomic now i have many many atoms forming a molecule polyatomic situations and i will use this equi partition theorem which i talked about roughly if you have a polyatomic molecules you can think of its as a rigid body for example firstly crudest possible approximation let us consider its at a rigid body ok now if it is a rigid body you know rigid body mechanics teaches us a rigid body has six degrees of freedom ok six degrees of freedom y six you may be knowing only a rigid body rotating about a fixed axis and you know l is equal to i omega but truly speaking a rigid body can rotate about a fixed point what do i mean by that its rotating about a fixed point means instantaneous axis of rotation passes through this points ok or since that can happen at the same time i can always give a translation to any particular point you know the concept of center of mass so let us focus on centre of mass i can say rigid body is rotating about its center of mass and then the center of ma mass may have a translational degrees of freedom and it can move in any direction so there will be three translation and three rotations okay since you may not be very familiar with this 6 degrees out of freedom business let us invoke upon you that how does this 6 come ok what is the definition of a rigid body definition of rigid body tells you that distance between the any two points in the rigid body is fixed ok any two points is fixed so if i put particular one particular point a mass here then it has three degrees of freedom because it has no constraint with it this is the my first particle this is my second particle this is my third particle ok now first particle has three degrees of freedom three what about the second particle second particle can do whatever it likes but it has to be at a fixed distance from the first particle so second particle has degrees of freedom too ok because it has to maintain a distance as i said in the diatomic molecule case ok two two and now third particle has to keep a fixed distance from two and one both so it can move only in three dimensions actually but always keeping this constraint that it has to be at a fixed

distance from two and from one
so it has one ok this gives me six total degrees of freedom of this
system of particles but if i what about if i bring a fourth particle here the
fourth particle ok
well fourth particle has to keep a fixed distance with all the other particles
in the business
it has to keep a fixed distance from one two and three
so it does not have any free degrees
of freedom in that sense
so total degrees of freedom is six i told you that 10 to the power
23 particles if you have to deal with you cannot write 10 to the power 23
second order differential
equations with given the force form and you cannot solve it for that matter ok
so but what helps us
in mechanics is this rigid body approximation so this is a rigid body
approximation which you
may not be very familiar with that is why i am spending some time in in this
rigid body thing
rigid body approximation why it is approximation there is no ideal rigid body
in world you already
know i am pretty sure of that einstein's theory of relativity tells us that no
information can
propagate at a speed which is greater than speed of light
so i cannot have anything instantaneous
in our real world ok there is always a time required but rigid body assumes
that if i give
a disturbance to any point of rigid body ok any point of the rigid body then
rigid body should
information should propagate to other part of the rigid body instantaneously
which is not possible
and that is why rigid body is an approximation but that is a very good
approximation and
secondly i have 10 to the power 23 particles let us say in a rigid body but i
deal with just 6
degrees of freedom three translational and three rotational and you know that
simplifies life to
a great extent ok if that be the case what is the polyatomic molecule energy
there are six
degrees of freedom each giving me half kt and n of such molecules i will
simply have three
n k t
so number of degrees of freedom is actually doubled ok
so specific it will be 3 n k but that
is not the end of the story i am assuming i say its a rigid body approximation
there could be some
vibrational mode and if you count this vibrational modes there could be f such
vibrational modes
so you will be having for each vibrational mode you will have three kt that is
coming from my
rigid body thing and then i will have f by two k t for possible vibrational
mode of the rigid bodies
and this will be my total energy and accordingly this specific heat gets
modified
so this is

all i wanted to discuss about specificate if we partition and if you follow your book you will
see there are many discussion on this and also you can refer to professor a c vermont's book where
also things are done at some length
so what i have done
so far that p is equal to again i write m n
v square this is v r m s square and kinetic energy gives me the proportionality to temperature
v square is proportional to k v t if you like ok this is a very fundamental thing of ah kinetic
theory of gas what i am dealing with now if i have a different approach which actually i pick up
from professor harish verma's book you can see if you have one gash for which p v is equal to
m n v square now you can motivate yourself that actually temperature will be a function of half m
v square ok this functional form i derived using the ideal gas equation ok i use the ideal
gan equation to arrive at this functional form physically i argued that temperature is
increasing mean kinetic energy of the molecules i am considering they must also increase and
this is the what this functional form tells us
so it should be a proportional from my physical
arguments but this can be elaborated in the following way also if i take the same gas in
the same container at a different temperature and pressure which i know for example this
temperature which i measure could be if you like some temperature which is of the order of two
seventy three point one six absolutes and you can write m n v naught square ok then you immediately know p by p 0 will be equal to v square
i remind you these are all rms's rms velocities
so v square by v naught square once
you have this form now you recall your charles law p is proportional to t for a given volume
you can write v square is equal to p by p naught into v naught square and if you
remember your charles law and if you know that p naught and v naught are constant for a gash
ok you immediately arrive at something which is v square is equal to v naught square by t naught into t
so that gives you precisely the
proportionality i am talking about and then kinetic energy if you v square if you
extract the kinetic energy from this this is a constant for a gas given gas this is a constant
so you get v square is proportional to t and now hydro is said this
proportionality just by argument hand working argument if i make it energy and dimensionally
this quantity should be bohemian constant and i can have some number this number i are good
to be three by two ok because dimensional analysis argument cannot give me

whatever this number
a is ok having done all these things
so far i will proceed and tell you little bit about
ah how to use kinetic theory for different situation and that will probably end today's
whatever i wanted to do
so if i mix two gases two gases but everything is in
equilibrium i call it thermal equilibrium which already tells me there are other equilibriums and it will be discussed in the thermodynamics
part of this lecture series thermal equilibrium means temperature everywhere in the gas is the same
so i do not need to bother about the temperature which is same everywhere
and if it is this i have two gas molecules one is having mass m one other is mass m two i must have
m one v one again in average sense thats r m s m two v two square ok
so this is an important
thing if those two gas molecules are in equilibrium i must have this condition satisfied
on an average ok from this you can calculate the rms velocity if i give you the temperature an
rms velocity of one of the gas molecules you know what you can mathematically calculate
what is the rms velocity of the other one ok
so now second will proceed further ok
now let us proceed do i have boyle's law p v is equal to constant negative
temperature what did i find out for pv ok p b is related to as i wrote one third capital m one third capital m small n v
square average ok now this is my p v now i have already told you this fellow is nothing but proportional to temperature ok we have already used boyle's law in getting
into this equation p is equal to one third m and v square but i will make thing slightly
more complicated ah rather i am doing a self consistency check here just i am saying that if this quantity is temperature proportional to temperature
so this
right hand side must be equal to a constant if temperature is constant
so pv is constant if t is constant because right hand side of this
equation is entirely proportional to temperature and this gives me my boys law similarly you can
argue about charles law if you keep fee fixed ok and this quantity is proportional to temperature
so if you keep v fixed ok
so pre is proportional to temperature that is your charles law ok now
let me see what else we can talk about okay in ok now have i got this law what does avogadro say that given t that means i fixing the temperature i am p equal
volumes of all gases have equal number of particles that's what we say the avogadro number
if we call one mole of the sample
so equal volume given temperature given pressure
i am fixing temperature i am fixing pressure ok now what is pv equation for the first
one third n one m one v one square ok well sometimes i will put this bar to remind you
that these velocities we are talking about are the average velocities now for

the second gas i do have p v is equal to one third n two ok m two v two square this is my p v equation ok volume is same but there is one more to this which i wrote earlier this only tells us nothing because i have quantities involving n one m two v one v two to arrive at this claim which avogadro made ok avogadro's hypothesis that if i want to do that i need one more since temperature is fixed t is fixed i must have this quantity which i wrote few minutes back that when you have two gashes at same temperature this must be satisfied once you have both these together put both these equations together which gives me n one is equal to n two so completely see charles and boyle's law were somehow expected to come out of it because in arriving at this equation at some point p v equation some point i used ideal gas ok to at least get the energy p is equal to one third m n c square p v is equal to one third m n c square or m n v square whatever i derived from the kinetic consideration but to connect it to energy p v is equal to two third e what i needed is ideal gas equation or some way i inspired that using the definition of absolute scale and the thing i did from professor a c verma's book but what is not expected here ok that it also gives me the avogadro hypothesis whatever other laws of thermodynamics laws of thermal physics i know can be arrived at similar fashion ok so you see that microscopic physics what i am doing here ok are all will follow or lead to the macroscopic equations i know from my school early school days for example second examples will be for example ah dalton's law of partial pressure dalton's law of partial pressure which says that you have many types of gases let us assume all of them mono atomic and then i put them in a container ok so i put them in a container and ask what is the pressure pressure in the container ok its called partial pressure law which tells you that if i have for example some types of gas molecules then this total pressure which is b which is being exerted on the wall of the container have many pieces p one p two p one corresponds to fast cache fuzzy physically what it means that if i only had ok the gash number 1 in the same container the pressure exerted by the gas number 1 to the container ok would have been ok p one similarly if there are no one two one three etcetera only second type of gas then the pressure exerted will be p two but when all of them are put together then its p 1 plus p 2 plus p 3 and so on well this is partial pressure you should bear clearly

in mind what i mean when i say p 1 or when i say p 2 if i remember how do we
define pressure pressure
we defined in terms of momentum transferred right momentum transferred per unit
time so
momentum transferred per unit time divided by l square this area of the
container
so it
was important that momentum transferred ok now first molecules they are all
independent
non interacting goes and hits this wall ok that will lead to a momentum
transfer delta
f1 and if i take all of this first molecules then the momentum transfer will
be simply
f one ok now second one will again give me a momentum transfer of f two
so net
momentum transfer will be summation over i f i this is the net momentum
transfer because
of the all molecules present in the container per unit time and net momentum
transfer will
be this quantity i have written with summation here where some extends over
all
the molecules i have and then if i calculate pressure which is just dividing
the net momentum transfer per unit time which i was interested in
so pressure that this system of gas molecules with excerpt
on the wall of the container will be given by net momentum transfer by l
square and which
you can see see p one p two etcetera
so p one is just due to momentum transferred by the gas
molecules one p two is just the momentum transfer by the gas molecule two and
so on third thing
or the last thing in this regard
so that tells us the physical origin of the dalton's law
of partial pressure finally if two gashes two gases maintaining same pressure
and
temperature we allow it to diffuse allow to diffuse you can very
easily argue that diffusion rate what should be the diffusion rate how
fast they diffuse it diffuses because they have a rms velocity and they want
to spread
out
so one molecule spreads into the other now rate if i say can simply be
proportional rate simply be proportional to r one by r two
simply be proportional to v one again rms remember whatever i am talking about
rms and we
already have seen rms m vrms is simply given by three p by rho
so if you substitute this the
rate of diffusion will be inversely proportional to density
so how do you get it i repeat the
argument the argument is the following that two gases same pressure and
temperature are
allowed to diffuse one is diffusing into the other gas is coming out of a
cooking gas cylinder
and diffusing into air
so i expect the rate of diffusion how fast it diffuses ok now r
1 by r 2 should be proportional to how fast the gas molecules are moving

so that will be given in terms of these rms speeds and if this is given in terms of rms we know the expression of rms okay if i substitute it back here i will find out this rate is proportional to ok inversely proportional to the square root of density ok this is called the grams law of diffusion all these things we have say are experimentally measured ok and kinetic theory though in kinetic theory we are talking about a microscopic description microscopic description given in terms of velocity distribution which i told you that there is a speed distribution there is a velocity distribution there is an rms speed but all the experimental observations which we make can be reflected here since i talked about last two minutes of today's thing since i have talked about so much about the diffusion in last two three minutes i will try to tell you something now we have assumed all through which i will complete in the next lecture that i have been telling you that see i am dealing with gases which are not colliding except for the wall when i calculated if you remember the momentum transferred and hence the pressure i was specific this particle is not having any collisions it is successively bouncing back and forth between the two walls of the container and this is obviously a very very drastic assumption ok now there is a concept if i keep a gas here there is a concept its called mean free path ok mean free path cache molecules collide and there is a concept of mean free path if you see gas cylinders gas leaking out of gas cylinders they do not go uniformly ok if you could see ok by a microscope how the molecules are moving they will have some zigzag motion because there are collisions between the molecules between the molecules there are collision between the gas molecules this is an important thing what is mean free path mean free path is average again the word average is very important average distance that a gas molecule traverses between two successive collisions two successive position this is a very important concept because you know what we have been doing is very idealized we have to come closer to real world and you can find out that which i will do in details in the next lecture that its roughly proportional to n pi ok d square with some constant here which i cannot find out ok you can check whether i am writing this expression correct density of particles density of particles and this is the diameter of the molecules so i am assuming molecules have a finite size ok assuming molecules having a

finite size
this is the diameter of the molecule this is   the density of molecules now if you assume the
limit this i will prove in the next class i am   just telling you a bit about it if we assume
the limit n goes to zero or d is zero ok   they are very very small impo in compared to the
other length scales of the problem this quantity   is very very large and the approximation i was
making that there is no collision ok between   it hits two walls ok and i neglected all the
collisions that is not true if n is very large   and d is appreciably large if they are very
small this fellow goes very half very high   and i can make this approximation so here i stop
telling you that there is a role of finite size   ok and you see i always talked about low density
so that mean free path is very very large ok   there is a size of the there is a size of the gas
molecules that has to be taken in consideration   that brings in the concept of mean free path that
is useful in many many cases even if you consider   free electrons in a metal and you consider the
conductivity you use some free electron theory and   that free electron theory also needs a concept of
mean free path i will stop it here today thank you you