welcome to the fifth lecture of the series of
lectures on kinetic theory and thermodynamics   this lecture hour will be
essentially spent
on describing the basics of thermodynamics   but as our regular practice is i
will
be doing a little bit of recapitulation   of kinetic theory of gas what we did
in the
last lecture we talked about mean free path   and non ideal gas both the things
i will touch
upon briefly before i move on to thermodynamics
 so we calculated the mean free path what is this
quantity this quantity is the distance traverse   by a molecule between two
successive collisions
since we are talking about kinetic theory i need   not remind you this is the
average distance
and this quantity is actually given in terms   of average velocity and time
between two
successive collisions which we calculated   and that gives me the mean free path
which is
one by n pi d square where d is the diameter   of the molecule and n is the
number density now
here we assume that molecules are herd spheres with a diameter d then what did
we do we constructed a cylinder this is the height and this area is pi d square
and molecular diameter is this d and this radius is t ok now we draw this
picture this is the top view of the cylinder if
you like this is the molecular radius   d by 2 and this is the radius d of the
cylinder
i have constructed
 so what is important is whenever any other molecule let me remind you
that i assumed other molecules are static in   the beginning whenever the
center
of any other static molecule comes   here tries to penetrate these cylinder
there is
a collision
 so whenever any other static molecule   has is centered either on this line or
inside that is inside the bigger cylinder   there is a collision using this we
could calculate
the total number of collisions in time delta t   total number of collisions we
found
out that it is n pi d square delta t   this is total number of collisions over
a
time delta t from that one can easily find out   what is the time between two
successive
collisions and hence the mean free path   which has this form one by n pi d
square
 so it is
important that molecule has a finite size and that   is taken into consideration
while calculating this
mean free path now there could be many questions   here this target molecule
which i mentioned
in the last lecture it suffers collisions   though it gets deflected right it
should
be deflected because its having collisions   if it has collisions then can i
talk about a

single cylindrical geometry which i am mentioning   here it is not actually the fact of course it
gets deflected but an on an average sense locally   i can assume still there is a cylindrical
geometry and whichever static molecule   does have its center lying within the bigger
cylinder will suffer a collision
 so on an average   i can assume there is a cylindrical geometry of
area pi d square and height v delta t
 so this   gives me the expression for mean free path there
is an additional approximation that approximation   is other molecules are static which is never
the case one should not take v average rather   one should be taking relative velocity
between two molecules under consideration   if you do things in a more rigorous way you will
find out a correction of factor of root two coming   into the expression of mean free path
 so i wanted
to emphasize the following point that we are   making an assumption that on an average there is a
cylindrical geometry even if my target molecule is   suffering many many collisions now then we went to
non ideal gas non ideal gas is a van der waal gash   for van der waal gas the equation of state for one
mole of van der waal gas is given like this ok so   this is very important that you note that there
are two corrections one correction is a by v   square other correction is b okay first correction
as i told you is a correction to pressure and this   fellow a by v square must be having dimension
of pressure where does this correction come from   i told you that i am assuming molecules
are completely non interacting but remember   there is a weak attractive interaction
between the molecules this a by v square   captures that it is actually the average
of these attractive interaction i gave   more specific example by saying if a molecule
hits the wall is at the wall this molecule will   be pulled by an attractive force by all the
other molecules which are inside the container   and number of molecules which are on the
wall at any instant will be proportional to   n by v similarly number of molecules which are
inside the container will also be proportional   to n over v
 so average correction to
pressure will be of the form constant   by v square
 so this correction arises due to
attractive nature of interaction which is very   weak and when a molecule is inside the container
i can conclude that on an average this is zero but   when it is at the wall there will be an attractive
force which effectively corrects pressure   now second correction was b why does

become

b comes because of the fact that molecules   as i also had explained in the case of mean free

path that molecules are of finite size we assumed   they are actually heard spheres of diameter

d in that case i explicitly calculated   with some phenomenological arguments that b should

be proportional to 4 times number of molecules in   the container and then volume of a particular

molecule which i calculated i showed assuming   the spherical molecules this expression is

four third pi d by two q this is the volume   of a molecule ok

 so b is proportional to volume

of the molecule what does b represented for us   b tells us if i take a molecule the entire volume

is not accessible to it each molecule has a volume   which is excluded i say it if this is a molecule

and took two molecules i can assume a spherical   concentric spherical volume which has radius d

which is excluded for the other molecules ok so   excluded volume correction is incorporated in this

parameter b and i have my van der waal equation   of state which is p plus a by v square correction

to pressure due to average attractive interaction   b correction to volume because the entire

volume is not accessible to the molecule   each molecule has a finite size hence a

finite amount of volume will be excluded for   any molecule i have in consideration and then

this b will be naturally proportional to number   of molecules i have in the container and volume

of each molecule ok that explains the origin of a   and b now if someone wants to generalize to n

moles ideal gas we know p v is equal to n r t

 so what should be the form in the case of van der

waals gas or the real gas let us assume n moles   ok for n moles you know correction to volume will

be more because i have more molecules now in the   same volume

 so my excluded volume will be n times

more excluded volume will be n times more ok that   is what is reflected v minus n b and then here

also density goes down by a factor of n

 so its n and v into n by n v

 so you will be having

a n square term coming here

 so your van der   waal equation i write it down again will

now turn out to be v minus n b is equal to   n rt then the limit a going to 0 that means when

you ignore you are allowed to completely ignore   the interaction this attractive force a is equal

to zero when you can assume the point particle   nature of the gas molecules then you can

ignore b and when you set a is equal to zero   is equal to b you retrieve your ideal gas

equation ok but these two corrections are   very nontrivial corrections ok and these allows
us to explain the phase transition for example   the liquid gas phase transition that we often
talk about and that we encounter in our real life   okay
 so having said that i wanted
to bridge a connection between   the van der waal equation of state and the phase transition liquid gas phase transition   ok
 so i drew the isotherms water
isotherms i fix the temperature   ok i fix temperature plot pressure as a function
of volume and i claimed these are the curves well i wanted to note something here which i
not intentionally mention in the last lecture   if you really plot van der waal equations
mathematically you can use it in your computer   you will see the curves are not really like
that typically a isotherm will look like this   ok without much explanation which is far
beyond your syllabus i will say there is   something called maxwell's construction which
gives this form which i have drawn and this form   is experimentally verified what i said here
there are different temperatures t one t two   t c let us say and this is term t 3 which is
greater than t c temperature is increasing so   t 2 is greater than t 1 t c is greater than
t 2 and
 so on
 so there is a liquid phase   which is high pressure low volume
there is a gaseous phase which is   high volume low pressure
 so i can go from one
phase to the other by changing temperature   or by changing pressure but there is a difference
there is this temperature t c and i draw   drew a dotted line here i said this region is
actually the coexistence region coexistence region in which liquid and gas coexist
i have to correct myself   liquid and vapor coexist why it is important
because i gave you the definition of vapor   vapor is the gas below this critical temperature
t c as i repeatedly mentioned above the critical   temperature t c which is this t three remember
i am plotting isotherms p as a function of v for   different temperature
 so if i look at the isotherm
at the temperature t 3 which is higher than t c   no amount of pressure can liquefy the
gas its always in the gaseous state
 so liquefication of a gas by application of
pressure is not possible if i am at a temperature   which exceeds the critical temperature so
van der waal equation two simple corrections   we gave two simple corrections one to pressure
coming due to the fact of attractive interactions   finite size gives one more

correction that is
correction to volume very phenomenologically i   explained the origin of these two corrections
these correction terms have drastic effect on   the physics i am studying it explains liquid gas
transition you see through a coexistence region   ok below tc there is a coexistence region i change
pressure i go from liquid phase to the gaseous   phase or the vapor phase through a coexistence
region in which liquid and vapor coexist and   above the critical temperature no amount of
pressure can liquefy a gas ok if you like   one can draw a p versus t diagram keeping volume
fixed you can see it coexists on this coexistence   line that ends at this critical temperature
okay this also i explained
 so phase transition   can only come through interactions and
van der waal equation simplest possible   correction to ideal gas equation gives us
phase transition which is very very important   having recapitulated whatever i said in the
last lecture i will be now moving on to describe   thermodynamics and basics of thermodynamics
there is a fundamental difference between kinetic   theory and thermodynamics which i explained
in the very first lecture thermodynamics is a   macroscopic approach to understand the properties
of matter macroscopic approach what do we mean by   that i do not care about what is happening
at the molecular level i do not care about   the velocity distribution or speed distribution
or average velocity all i will look at   is experimental measurable quantity ok i will
be looking at only pressure volume temperature   which i measure experimentally
 so its a coarse
grain description in that sense which i mentioned   that means i am looking at the macroscopically
measurable objects like pressure volume   temperature remember in kinetic theory also we
are talking about average speed average velocity   but eventually everything was connected to
pressure volume and temperature
 so kinetic theory   had its own definition of temperature that is
given in terms of average kinetic energy of the   molecules similarly thermodynamics will have its
own definition of temperature but it will be again   connected to experimentally observed temperature
in absolute or kelvin scale which i introduced   in the very beginning of this set of lectures so
its a coarse grained description does not probe   the system at the molecular level we do not
care what is happening at the molecular level   and thats why i call it a macroscopic approach
so v t these i will call thermodynamic variables well you know degrees of

freedom in mechanics you
learn degrees of freedom position and momenta when   i discussed equi partition theorem i talked about
x and p both contributing half k t to the energy   here in thermodynamics there is no x no p all
degrees of freedom i will be talking about are p v   p and there are other quantities for other systems
but we will restrict ourselves to p v and t   ok now basic idea is this thermodynamic
approach talks about a system a system   plus the rest of the universe
 so i will
have a system which my experimental system   and then the rest of the universe
which is interacting with the system ok   this is very important statement so
i will have a system this is my s   and then i will have the rest of the
universe which i will call the resolver   ok
 so i have a system and a resolver
and they are separated by a wall ok
 so you see the difference i do not know what is
there what molecules are doing but i know there   is a system which is described by pressure volume
and temperature may be chemical potential let us   not go into that and this is separated from the
rest of the universe whatever else is there in   the universe with some wall and these walls play
very important role in defining thermodynamic   variables which i will come soon the walls
determine what type of interaction the system   will be having with the rest of the universe
which i will simply call universe subsequently   and the equilibrium that system reaches now since
i mentioned thermodynamic variables i must say   that they are of two kinds one is
extensive other is intensive let me define   what do i mean by extensive and intensive
thermodynamic variables let us take a big system described by n v t
p and things are in equilibrium which means that nothing depends on time so
they have a fixed value constant in time value   now if i divide it into two
highers is the volume v by two v by
two ok now volume is halved   what happens to number of particles i am assuming
the system is divided into two equal halves in   equilibrium
 so whatever equilibrium was there
before i am making this division that equilibrium   is maintained
 so if pressure was p here that let
me see this is the container one of the wall of   the container this pressure was p for equilibrium
ok
 so pressure will remain the same when i divide   into two halves temperature again if i have to
keep things in equilibrium that is nothing depends   on time temperature should not change but you see
v goes to v by two similarly n goes to n by two
 so you see that there are some quantities
which become half of their initial value   there are some quantities which are not

at all influenced or affected by this   division of the system into two halves ok

quantities which are indicative of system size   that means if i have the system they get

halved they become half of their initial value   these are called extensive quantities for example

volume number of particles and also a quantity   which i am going to define very soon is called

the internal energy these are extensive quantities   ok for example if i define external

energy it is a function of volume   sorry this is the internal energy the

internal energy which is a function of volume   if i increase the volume by a factor x three

times more

 so volume let us say volume goes to   x volume x can be any number it could be two

three half in the present example internal energy   actually will show that goes to x

u these are extensive quantities   maintaining equilibrium you make the

volumes x times the initial value   the internal energy number of particles they all

go x times internal energy u goes to x u let me be   more precise i am saying increase the volume of

the system maintaining equilibrium the simplest   way to think that i am considering a bigger volume

of this same system okay as i have shown in this   example henceforth whenever in the context

of extensivity i say increasing the volume   maintaining equilibrium i mean i am considering a

bigger volume of the same system question is what   are other types of variables these are intensive

for example pressure temperature they do not have   any change because of this multiplying by a

factor of x

 so these are intensive quantities so   intensive quantities are completely insensitive

to the size of the system whereas extensive   quantities are indicative of the size of the

system maintaining equilibrium if i double the   system all these extensive quantities will become

double but there is an interesting thing density   what is density density is n

by v ok if volume goes to x v   number of particle which is also an

extensive quantity will go to x n so   x cancels with x you see density remains the

same

 so density is an intensive quantity true for   any ratio of two extensive quantities whenever

i take the ratio of two extensive variables   that becomes an intensive quantity ok

 so this was

important to tell you that thermodynamic variables   they describe entire thermodynamics and they are

of two type one intensive and other is extensive   having said this lets go to the walls i

told you i will be having a thermodynamic   system and this thermodynamic system will be
separated from the rest of the universe or simply   the universe as i will say and this is my system
separated by a wall ok this walls will determine   what type of interaction exists between this
system and the universe first is adiabatic world   what do you mean by an adiabatic wall let us
come to this adiabatic wall means this wall is   completely non-conducting so system is insulated
from the rest of the universe system is insulated   from the rest of the universe this implies
there is no heat exchange here no heat exchange this is called an adiabatic wall ok this
is very important there is no heat exchange   then how can this system interact with the
universe it can interact with the universe   only through mechanical interaction i can
have this wall movable if i move this wall   then there is some energy supplied to the
system i am doing some work on the system   ok thats how it can interact with the rest of
the universe ok then there is a diathermic wall   diathermic wall is just opposite of what i
defined as an adiabatic wall diathermic wall   on the other hand allows for heat exchange this is
very very important one wall is not allowing any   heat exchange system is completely insulated that
is adiabatic wall system is completely insulated   from the rest of the universe ok diathermic all
on the other hand it allows for heat exchange ok   so there is mechanical interaction in the case of
adiabatic world which is possible and then in the   diathermic wall there is a thermal interaction
possible that means there is heat exchange also   mechanical interaction is not stopped so
we can in general have a wall in which you   will have both thermal interaction and mechanical
interaction but these are two idealized situation   in one there is no heat exchange possible in the
other heat exchange is possible also it is not   part of our syllabus will not go into that there
could be porous walls which allow for particle   exchange ok you can allow particle exchange and
then reach some situation when chemical potential   of the system and the universe become equal and
then there is a equally an equilibrium reached ok   but i will not discuss anything about this
chemical interaction we will restrict ourselves   to adiabatic walls and diathermic walls ok and
talk about thermal interaction means heat exchange   and mechanical interaction that is i am moving
this wall of the container ok
 so let us proceed   what is equilibrium ok i have told you that

there are walls and walls give my interaction   now question is what is equilibrium equilibrium
i defined in the beginning of the kinetic theory   lecture also that nothing depends on life i
measure measure pressure at time t is equal to t 0   if it is p and then i measure at t is equal to
two t zero even then pressure will be p it does   not depend on time ok equilibrium is an idealized
concept but we will always assume that system is   in equilibrium and nothing depends on time
 so i
define equilibrium constant value of thermodynamic   variables constant in time they do not change
with time i told you thermal interaction then that gives me notion of one equilibrium
that is called thermal equilibrium what is   thermal equilibrium we already know that there is
a quantity called temperature
 so i have a system   and the rest of the universe they can
exchange heat if it is a diathermic wall   ok and when they reach the equilibrium we
know basic notion of temperature tells us   in equilibrium this temperature of the system   should be equal to the temperature of the
rest of the universe
 so t s is equal to t u   ok there is no heat exchange there is no energy
exchange equilibrium has reached and since   reserve wire is very big i can say
i give the term reserve wire for you its a very big thing rest of the universe ok
and i can say it has infinite heat capacity   its also an idealized concept but
very useful infinite heat capacity   if it has infinite heat capacity its temperature
does not change
 so there is exchange of heat   between the universe and the system when
equilibrium is reached temperature of the system   will be equal to the temperature of the reservoir
that is the temperature at equilibrium
 so that is   thermal equilibrium
 so thermal equilibrium means
that temperature is equal between the system   and there is a wire there is no further heat
exchange what is then let us say mechanical   or adiabatic situation if you like
 so in
the mechanical equilibrium what will happen   i will show in more details later that pressure
ok pressure i can move this wall of the container there is a pressure of the system
there is a pressure of the universe   i can move this container in such a way
ok that in equilibrium ps is equal to p   of the universe
 so pressure should be equal
remember i am always equating some intensive   variables in one case thermal interaction it was
the temperature other case mechanical interaction   it is the pressure which becomes equal and i
say there is a mechanical equilibrium if you   like achieved ok but most of the

cases i will be
talking about both mechanical and thermal that   means i will be allowing heat exchange as well as
mechanical interactions ok and then system reaches   an equilibrium and i will do the thermodynamics of
that system which is now in equilibrium
 so let me   summarize what i said there are walls walls
are separating the system from the universe   the walls can be diathermic or adiabatic in the
adiabatic situation there is no heat exchange   diathermic situation there is heat exchange
once determined also what type of equilibrium   i will have for example if i allow heat exchange
then equilibrium will reach when the temperature   of the universe will be equal to the temperature
of the system that is equilibrium situation no   further heat exchange and i work can work on the
with the system which has reached the equilibrium   similarly one can talk about a mechanical
equilibrium in which the wall of the   container is movable i move it in such a way
that pressure is balanced pressure is same   between the system and the universe that
is the mechanical equilibrium ok and   i will be talking about situation which
has reached mechanical thermal equilibrium   nothing depends on time and then i will do
the thermodynamics of that particular system   ok now having said all this walls mechanical
interaction heat exchange i will establish for you   rather i will propose the first law of
thermodynamics and i as i said first law   of thermodynamics is nothing but the conservation
of energy if you remember these i mentioned maybe   in my second lecture
 so first let consider let me
consider a container inside that you can assume   this gas molecules i have been talking about
in kinetic theory they are moving around   but in thermodynamics i do not want
to know their velocity distribution ok   now lets say i supply an amount of heat
delta q or let me use this notation delta q   ok an amount of heat delta q i supply to
this system what would happen to this system   this energy goes up but if i do not allow any
mechanical interaction ok i do not allow any   change in volume what will happen to this energy
supply to the gas system something should increase   that is my conservation of energy
tells me energy cannot be dissipated   ok
 so you have to keep in mind something
additional is there other than mechanical energy   and thermal energy i have been talking
about
 so first i can change energy by supplying heat by supplying heat then forget
about heat which i already explained you move this

wall you move this wall with some velocity u
 so what will happen this is moved ok you can
roughly think that molecules coming with some   velocity here hitting the wall
but unlike kinetic
theory where i was assuming this wall is a static   object this molecules will
not go back
with the same velocity or same speed   because there is now a relative velocity
wall
is also moving ok
 so since wall is also moving   the molecule which hit this wall will go back
with
a different speed
 so its kinetic energy changes   ok this is a very heuristic very
phenomenological
idea but all i wanted to say by doing   this mechanical work by moving the
wall of the container i am changing   the energy of the system
 so energy of the system
can be changed in two ways one by supplying   or extracting heat i can take heat
away from the
system or i can supply some heat to the system   energy increases and then this
mechanical part
of the energy which tells me if i move the wall   ok if i move the wall what
will happen that energy
will change that i very roughly very approximately   said that if molecules
coming with average speed
v they will not go back after hitting the wall   with the same average speed
there will be a
change because this fellow the wall itself   is moving with a velocity u
 so there is
a change in energy
 so change in energy can be achieved also due to mechanical work this
is what i learnt in mechanics ok i do some work ok
 so i get some change in energy now question
is i am changing how what is the process   am i changing the wall of
container very fast very rapidly ok that is not true you i am not really doing
that all the processes i have talked about   heat exchange i have talked about
mechanical
interaction in which i change the wall of the   container move the wall of the
container
but i am not doing it very very rapidly   this brings in the concept of quasi
static
process ok what is a quasi static process   quasi static process means its a
very very slow
process how slow is flow you can ask me it is   very slow in the sense you draw
a pv diagram right
you have a pv diagram ok given a p you always give   me a value of v i choose a
value of p i
immediately get a volume value of volume   v ok and i expect them to satisfy the
equation
for an ideal gas pv is equal to rt and i said this   equation is valid only in
the equilibrium
 so quasi
static process is a process you should understand   its quasi is static that
means almost static i

am changing the parameters be it movement of wall   or supply of heat very very slowly there is
an infinitesimal change slower than any other   characteristics time scales of the problem ok any
other characteristic time scale of the problem   which is very slow more importantly i am making a
change but every instant i can assume that system   is in equilibrium
 so this is a quasi static
process a quasi static process means its a   very slow process and every instant of time i can
assume system is in equilibrium for an ideal gas   i can write pv is equal to rt okay this is very
important notion which will keep coming back to ok
 so whatever changes i mentioned
here are all quasi static changes   whatever i am saying will completely
break down if i do very rapid process ok what happens if i do a rapid process ok there
will be final state reached i have to wait for   the system to equilibrate when system equilibrates
once again all thermodynamic variables reach a   time independent value i can do thermodynamics
but in between what happen i do not know   but what is the difference in the pv diagram at
every instant of time i am assuming that system   is in equilibrium and i can write pv is equal
to rt
 so this is a very important notion walls   equilibrium and to be always in equilibrium i need
quasi static processes whatever process mechanical   thermal i am talking about are all quasi static
processes ok now i have said that the two types   of energy which i will talk about one is thermal
exchange exchange of heat i wrote it as delta q   let me say the mechanical work this is delta w ok
now should i then say delta q is equal to delta w   and that is my energy conservation no i will be in
trouble because here i am just allowing exchange   of heat there is no work done on this system
so heat must go to some other form of energy   ok this point should be clear here i am not
talking about any work no work if no work   there is no mechanical energy
 so there must exist
some other form of energy in which the heat is   getting converted to similarly here
if i do not allow any heat exchange what would happen there must be some other form of
energy to which this mechanical energy is going ok   remember here if no work is done
in this process i am supplying heat   some energy of the gas must go up and that
energy is called the internal energy ok   this is a very important concept
that if you do not do any work here   system is not allowed to do any work
 so where
does the heat energy go heat energy goes in   increasing the

so called internal energy of the
system similarly here if you do not allow any   heat exchange the mechanical work that you
do on the system goes on to increasing the   internal energy of the system
 so this is
first fundamental notation or fundamental   concept which i brought in which is called
the concept of internal energy
 so when   you talk about conservation of energy when
you talk about this conservation of energy   please remember the conservation of energy
includes heat energy thermal energy here   mechanical energy here or the work done and the
change in internal energy with all this preamble   system resource wire walls interactions okay
notion of internal energy quasi static processes   i now put before you what is the first law
of thermodynamics this is the first law of   thermodynamics which is written out on this slide
you can see delta q heat supplied to the system   i am supplying an amount of heat which is delta
q and then delta w is the work done by the system   see previous example i took two extreme cases
here i said heat supplied no work here i said i   am doing some mechanical work on the system not
allowing any heat exchange here i am doing both   that is why in one of the previous slide set i
said that i will be talking about both mechanical   and thermal interactions and then system reaches
the equilibrium i will deal with that particular   system and do heat exchange or mechanical
interaction in a very quasi static way
 so that i   can always assume that system is in equilibrium
so delta q is the heat supplied to the system   delta w work done by the system and then first law
of thermodynamics age delta q is equal to delta w   plus this new quantity which is called delta
u that i will be calling the internal energy ok
 so you see if delta w is 0 first example
of the previous slide delta q is delta u so   whatever heat i supplied went into
increasing this internal energy ok   and then if i do some work but do not allow ok
do not allow any heat exchange
 so that delta q   is zero
 so you see delta u is equal to minus
delta w ok minus delta w and this is where   i need to fix a convention ok i will fix
the convention in the following way delta   q positive when heat is supplied to the system
internal energy increases delta w is positive   work done by the system ok in the previous
example if i was doing some work ok on this system   then it would be negative
and internal energy goes

up
 so i repeat the first law of thermodynamics   delta q heat supplied to the system delta w work
done by the system ok and then again i write it in   the form which is written here that is delta q is
equal to delta u plus delta w okay convention is   delta q is positive heat supplied to the system
heat is extracted from the system delta q   will be negative ok if you set delta w is equal
to 0 delta q is equal to delta u
 so whatever   heat you supply to the system it goes into
increasing the internal energy of the system   if you extract heat from the system then delta q
is negative internal energy goes down ok and now   other way around if you talk about this one
you can see from this expression in one case   internal energy will increase when i work on
the system ok then this delta w itself will   be negative from the equation for the first
law of thermodynamics i get this one if delta   w is negative means i am working on the system
internal energy increases if delta w is positive   that means system is working at the cost of its
internal energy
 so you see for energy conservation   internal energy must be there we should
understand what is this internal energy   ok before i proceed to that let me write
it in the following form the first law of   thermodynamics what i have written here which
is actually conservation of three quantities   thermal energy work done or mechanical energy
and the internal energy can be written in a   differential form ok it says delta q delta w
and d u this is where one has to be careful   why these two are delta and this one is d these
i will explain briefly today and elaborately   in the next lecture but let me proceed
a little bit what is the internal energy   i said if supply heat to the system and do
not let it work its internal energy goes up   what is this internal energy ok you know if you
supply heat kinetic theory has already told me   that average kinetic energy increases
which implies that temperature increases ok   without further proof at the moment
i will just say let us say ideal gas   ideal gas molecules let us say monoatomic   if it is mono atomic ok i know the translational
kinetic energy if i take lets say one mole   of monoatomic ideal gas p three by two n k
b t here it is the avogadro number which we   kept referring to
 so this translational kinetic
energy is actually the internal energy how do you   know this analogy clearly you know this analogy
clearly because you know when you supply heat   temperature increases kinetic

theory teaches
us that average kinetic energy increases   translational kinetic energy ideal gas mono atomic
only translational
 so for mono atomic ideal gas   it is the translational kinetic energy that is the
internal energy
 so you increase the temperature   what goes up is the translational kinetic energy
of the monoatomic cache molecules ok
 so what is   internal energy internal energy is equal to this
form which i will not prove probably but i will   expect because of this analogy it
is c v t plus constant for ideal gas   and you know cv has the information whether
ideal gas is mono atomic diatomic or poly atomic   i count the degrees of freedom taking either
translational or translational plus rotational   or translational plus rotational plus
vibrational all those informations go into   this cv
 so its the kinetic energy if you talk
about ideal gas molecules ok this is a good point   i think where we should stop but i have to tell
you this is a very important thing this delta q   delta w and t u actually delta q and delta
w they depend on the thermodynamic processes   i have already shown you two examples in which
i have in one i have delta q is equal to 0 only   delta w was there in the other there was a
delta q but no delta w
 so this delta q and   delta w if i go from a initial state to final
state ok let us say this is p i this is p f   i go from an initial to final state let me p i
to p f ok or v i to v f this delta q and delta   w depend on how i have reached from the initial to
the final state but d u does not depend on how i   went from the initial to the final state rather it
depends upon only the initial state and the final   state ok that is a very important concept which i
will explain from the point of view of mechanics   where you already know there is a concept
of potential for a conservative force field   that i will generalize here to explain to you
what is this internal energy and what do i mean by   the terminology that it is a state
function
 so i end this by saying that   this quantity actually is a state function this
quantity u is actually a state function depends on initial and final state that means initial and final values of the thermodynamic
variables if it is ideal gas   i already have tried to explain to you that it is cvt
 so it will actually be   given by the difference in temperature of
these two states ok thank you for today you