welcome students to today's lecture my
name is ah pramit chaudhary and i am a faculty in the department of chemistry
at indian institute of technology iit delhi
so the topic we are going to discuss in today's
lecture and in the fourth coming lectures is chemical kinetics as is written
on
this piece of paper now before we go on to the details of chemical kinetics
lets try to
understand the importance of chemical kinetics
so when we say chemical kinetics both of
these words have very significant implications
so for example when we are talking about chemical
kinetics that means we are talking about processes processes related to
chemistry
or chemical processes for example one kind of change might be a
reaction of a plus b say going to c where a and b are the products and uh
rather
sorry are the reactants and c is the product also now this is a this is the
case where there
are two reactants which are combining to give a product right now there can be
another case
where i have just a transformation for example a state a right see in one
phase phase one to the same a but in phase two
so in the
second case what has happened is i had a phase transformation for example say
i am going from
you know ice to liquid water or i am going from liquid water to water vapor
thats what the second
one is talking about now
so you know like this there are many many examples in chemistry
right
so if you consider these two what they are representing is they are
representing
representing change or changes happening in whatever you are dealing with or
whatever is
in front of you or whatever you are working on then what about kinetics
kinetics is going to tell you how fast or how quickly this change happens
right
so if you write this then what kinetics refers to is how fast or how quickly
the particular process is going on then essentially what we are saying
is we are saying what is the rate of that process now if you think about this
why do we need
chemical kinetics see all almost all of you have been taught or you yourself
have studied about
thermodynamics the importance of thermodynamics and chemistry now if you talk
about thermodynamics
in chemistry what does thermodynamics tell you is there any need for us to go
for
chemical kinetics can we not get it from thermodynamics itself
so let us talk about
thermodynamics a little bit
so that we understand the necessity of this topic or the
significance of this topic to chemistry
so in thermodynamics when we are

talking about thermodynamics remember if we write and think about thermodynamics
then this is what we are focusing on it is about the initial state at the initial state right of your reaction
or whatever and we refer to it as i then you have the final state which you refer to as f
so thermodynamics
mainly deals about these two states only the initial state when you start a reaction and the final state what is the final state the final state is when you have when you have reached a chemical equilibrium when you have reached a chemical equilibrium and
that is why it is also referred to as chemical thermodynamics but see what is happening is
yes you are talking about the initial state you are talking about the final state
good but what is happening in between you are not being able to focus too much on for
example you know think about a certain process say ice going to water liquid right now what will
thermodynamics tell you thermodynamics tell you that if i have to make this transformation from
ice to water right i would need to supply heat
so that this transformation can be brought
about which tells me that the process thereby this process is endothermic
similarly if i go from liquid water to water vapor right which is the gaseous state again what you are doing is you are transforming the
molecules the same water molecules from the liquid state to a gaseous state again
you are supplying energy
so this process is also endothermic and thermodynamics tells you that
that you have to supply heat
so that this process or this transformation
is being brought about along with this
so this is only a part of it
along with this there are some other very common thermodynamic parameters that you obtain or get
from these sort of reactions
so common things you ask for is or you know parameters
you ask for like the free energy change of the reaction or process right
so this free energy change is often referred
to as delta g and we know
so i am not going to write that you know that which delta g is negative
that means the process is spontaneous if the delta g is positive the process is a non-spontaneous
process also you can talk about entropy changes which is given by delta s
so so far so
good right you have the initial state you have the final state and because you are talking about delta g delta s or delta h right whether its delta h is endothermic
so that means you are supplying heat or exothermic that means heat is getting released
so delta h is negative right
so for an example if you take
if it you know if you talk about dilution of concentrated sulphuric acid ok let

us talk about this very briefly so
you have very concentrated sulfuric acid what you do is you take some sulphuric
acid from the chemical reagent bottle and you dilute
so i will give you ah you
know ah some ah you know measures of the heat that is released this is a highly exothermic
process
so for example suppose you are ah having say this is h two s o four in milliliters
considered sulfuric acid remember you have taken directly from the reagent bottle
considerably agent bottle then you have h2o in milliliters ok you are mixing these
so how you are
mixing
so suppose the volume of h2o is 100 ml and the volume of h2so4 you are adding to this
100 ml of water is 10 ml
so then the delta h that means enthalpy change of this reaction the
enthalpy change of this reaction in kilojoules in kilojoules is minus 11 kilo joules right and
then the corresponding change in temperature is 25 degree celsius what does this mean what it
means is when you are taking 100 ml of water say in a beaker or in a suitable container you
are adding 10 ml of concentrated sulfuric acid then this amount of heat is released and
the temperature increases 25
so that is why the container feels
so warm
so this
is an exothermic process exothermic being referred to or being signified by the presence
of this negative sign ok now lets increase the volume of sulphuric acid
so added say if you go
to 30 ml of sulfuric acid again added to the same amount of water then the heat released is about
minus 30 kilo joules and the temperature change is about 70 degree celsius
so you can immediately
understand while in one case well in one case say for example the phase transformation of ice to
water liquid water and liquid water to water vapor you had to supply heat
so that they can make
the next transformation or go to the next phase in this case when you are diluting sulfuric
acid concentrated sulfuric acid water you are having a huge amount of heat coming out or getting
released and that is why the container also feels very hot or warm depending upon the amount
of temperature change you are having hence this process hence this process of dilution is referred to as an exothermic process ok
so then this again comes under the rearm of
thermodynamics because someone is telling you that ok this is the energy that

is coming out
because of the dilution or this is the energy of the supply
so as to bring about the phase
change for the previous endothermic processes but you have to realize one
thing now if you ask
the question how long does it take for the phase change to happen how long
does it take for the
reaction to happen for any reaction to happen thermodynamics does not give you
an answer for
that
so then we can write from thermodynamics from thermodynamics we do not have any
information any information about time ok
so if i can write it again
i can say that thermo dynamics gives me no time information gives me no
information about time
so the only way i can get information about the
time that is the rate at which this transformation or any transformation is
taking place is to
resort to or take help of chemical kinetics that's why this topic in itself is
having such
a significant place in the heart of chemistry or as a topic it is
so very
important to chemistry ok now when you talk about kinetics
as we just said we are mainly interested in the time taken right how slow how
fast it's one
also the question is remember when we are talking about thermodynamics we said
that calculations
involved when they include this delta h or delta g or delta s we say that this
is the difference
between the final state and the initial state
so these are the only two states we are
concerned about in thermodynamics all the time however in case of kinetics you
start asking this
question if i have a process
so that means if i have a going to b and if this is a process
then i start asking how does this process happen
so when you ask this question which everybody
should right
so the biggest question is how what takes place for this change to happen
then its not only the time you are referring to well time is definite aspect
but what
you also referring to is the mechanism the mechanism at the molecular level
that is mechanism at the molecular level you need to know if i have to go from a
to b then
what is taking place at the level of the molecules in that reaction system or
in that container
so that this transformation or following which this transformation is
happening that is
a is going to b
so this also is addressed by chemical kinetics this you can immediately
understand
right the significance hopefully it is becoming a little more relevant in
terms of discussion of chemical kinetics in chemistry which is not only the
rate yes how fast how slow but also when this transformation is taking place

on when this process is taking place what steps might come in or what is the mechanism through which that particular process is happening all these can be addressed through kinetics now once you think about this you start asking other questions right

so suppose you are thinking about the rate of the reaction of any particular reaction

so i say rate of reaction then immediately the question that comes to your mind can i control the rate of the reaction if i can what are the factors

so that means the first question that comes to your mind is can i have a control on the rate of the reaction you say i say yes then your next question is great if

so please tell me how i can control that means what are the factors what are the factors these are this is this what is factors that will control the reaction rate now as we will go through our lectures we are going to spend time on this and discuss the different factors but i am sure most of you already know can already realize that some of the factors are very commonly used factors that can control the rate

so one would be concentration one would be concentration then another one would be temperature

so generally with increase in temperature the reaction rate increases and then there is something which is a very uni which is having a very unique place in chemistry

so catalyst a catalyst is something which increases the rate of the reaction

so that means if you have to control the rate of a reaction

so suppose you see that the reaction went too fast you are doing a you are doing an experiment in a certain laboratory

so you are doing a practical experiment say in one of your practical classes and then you are following this transformation say from a to b and you certainly found out oh this reaction just went too fast for me to capture what was happening or to capture the rate because it was just too fast

so how can i decrease the rate a i can play with the concentration two i can play with the temperature and catalyst also has its own unique place which we will discover later as we go through this course more and more ok now kinetics is mainly referred to kinetics is mainly referred to as a branch of physical chemistry ok but this is generally what you know kinetics is ah thought as being a branch of physical chemistry but you know what if you really think about kinetics it is actually a unifying topic so kinetics i can see it is a unifying topic covering many branches

so it has relevance in biochemistry it is applicable in biology right now talk about mechanisms in organic and in organic chemistry the moment you talk about mechanisms that is the very moment you also start talking about kinetics again how fast how slow do these things happen can i speed the reaction up by adding a catalyst can i speed the reaction up by changing the

concentration of this
so what it means is that kinetics the importance of kinetics is not only in the branch of physical chemistry as its supposed to be but it really is spread over
all branches and that is why the relevance of kinetics are the importance of kinetics and
hence i think this is a very good starting point based on which we can build on this topic or
this concept of chemical kinetics but you know before i discuss about the rate equations and
other aspects or features of chemical kinetics i would like to discuss some examples with you in a daily life where chemical reactions and that to kinetics become quite important so as an example first i will discuss about chemistry in cars now you must have seen cars flying on
the roads right nowadays there are many many cars on the roads and many different
cars there are many different car companies like honda hyundai you know many many different car companies maruti now what happens is the way the cars run
so at different places in cities or on the highways you would see that there are petrol pumps where the car
so tank needs
to be filled with petrol now this petrol which the car runs on this petrol or gasoline named as is a mixture of hydrocarbons ok it is a mixture of hydrocarbons
you can say this c x h y right
so the hydrocarbon i am referring
to is the generic symbolism where i have x atoms of carbon and y atoms of hydrogen right so
if it is methane
so suppose if it is methane c h four then x is equal to one y is equal to four if
it is ethan c two h six then i have x equal to two y equal to six and
so on now what happens
is when you turn a car on this petrol which had filled the tank with from the petrol pump is burnt
so this petrol during the running of the car the petrol is burnt right now when the petrol is burnt so
that means the hydrocarbons are getting burnt if it is an ideal if it is an ideal condition if it is an ideal condition
then this is typically what you would get
so that means c x h y
would combine with say the oxygen of air to give you c o two and h two o
so this is
what you expect under ideal conditions if the fuel i am taking which is composed
of these mixtures of hydrocarbons are being burnt or the fuel is being burnt then
they are burning full burning and ideal burning i am why i am talking about ideal it will
soon realize
so the ideal burning should lead to the formation of carbon dioxide and water which are not very harmful however what happens is now this is an ideal case

right now suppose there is in complete fuel burning
so that means the all fuel is not
getting burnt if all fuel is not getting burnt then what can happen is i can have some unburned
hydrocarbon still out there not only that when you burn this what happens is you give rise to a
high temperature that means the temperature rises when the temperature rises and also because of
incomplete burning you can have other reactions happening for example this incomplete burning of
c x h by can give rise to not carbon dioxide but carbon monoxide as one of the gases is coming out
then you also have
so you know this is your where are you getting the oxygen from you are getting
the oxygen from air the air is also having lots of nitrogen
so what can also happen is that nitrogen
can combine during burning to give rise to nitric oxides n o x
so this n
o x is typically composed of n o and n o two
so this one you know is nitrogen dioxide and this one is nitric oxide
so see what has happened the ideal
condition was this diagonal condition was that you have fuel it combines with the oxygen of the
air and it gives rise to carbon dioxide and water this is the ideal condition good but then under
non ideal cases this is typically what happens you know like when you read about ideal gas non
ideal gas see ideal gas is an ideal condition mostly all gases are non ideal in nature
similarly here incomplete fuel burning gives rise to some gases which we do not want which are poisonous for us i will come to that very soon but what are
those gases one is unburned hydrocarbon then you also have this unbound hydrocarbon reacting
with oxygen going to co which is again incomplete combustion that means it does not go to co2
you have nitrogen from the air now which can combine at this high temperature to give rise
to oxides of nitrogen represented as n o x and under this no x umbrella we have n o
which is the nitric oxide and n o two which is nitrogen dioxide
so then in one shot
i can write that if i have air plus petrol that is what you are burning will give rise to c o two plus h two you know these are the ideal ones plus c o plus n o x
these are the ones which we do not want plus unburnt hydrocarbons the main problem rises from these three and that is
why these three are often clubbed as pollutants or environment sorry this should
be this should read as in viron mental pollutants that means they pollute the environment
so see you are talking about fuel burning right you talking about an ideal combustion where i

should be getting ideally carbon dioxide and water i do not have much to worry about but then
because the combustion is not ideal because of the conditions there will be some hydrocarbons
which should not be burnt there would be carbon which would be incompletely oxidized
that means it would not go to carbon dioxide it would rather go to carbon monoxide this
carbon coming from the hydrocarbon and then you have
so much of nitrogen in air
so this
nitrogen can combine at this high temperature with oxygen to give rise to different oxides
you know nox under which we have no and no2
so why are these referred to
as pollutants now before i write something else down
let me show you something as a picture now if you look at this
picture if you look at this picture and if you look at my or the white pointer
what you see is at the top of this picture its written photo chemical smog i will come
to that ward later or those two words later but remember this smog which means that you
have heavy pollutants in the air now look at the picture below what you see is not only do
you see
so many cards running but if you look at the atmosphere its very very hazy no way can you
say that it is clean air that you are breathing its very hazy it is hazy why one of
the main reasons why we have pollutants why we have pollutants is the emission coming
out from cars
so then i can write emission from cars are a huge source of environmental pollution it is a huge source ok
now what do cars do to stop this
so let us look at a picture of a car
so if you look at this car
and again if you follow my arrow
so you can see its written as
so this is the skeleton of a car
and you are seeing some components inside i will tell you which the which are the main components
right now we will be discussing about are relevant for our discussion if you look at this one this is
called the exhaust manifold exhaust manifold means nothing that when the engine is driving your
hydrocarbon is burning that means your fuel is burning then whatever gases you produce they come
out through these exhaust pipes ok
so this is what is exhaust pipe a all these gases come out to the exhaust pipes now if you would not do anything to these gases then what would happen is these
exhaust gases would go straight out into the air and pollute your environment

but that is a big no
no right because pollution is very harmful for us and in big cities it is directly related that is
big cities the more the number of cars you have the more number of automobiles you have the
greater is the pollution
so then each and every car has to do something about it and this
is compulsory this is compulsory
so what do cards do
so each and every car each and every car
is equipped with something referred to as a catalytic converter referred to as a catalytic
converter if you see my pointer or arrow i am moving this pointer over this word catalytic
then converter do not worry about the three a but what the catalytic converter is supposed
to do is it is supposed to take these gases the harmful ones and convert them to non harmful
ones
so that when finally the gases come out through this pipe you can see out here exhaust
pipe tip then these pollutants like nox co and the unburned hydrocarbons are not there so
this is one of the most important features one of the most important features
environmentally that a car has to have such that pollution of the
environment is kept to the minimum ok now what you see in this picture its assumed into
figure of this catalytic converter
so typically if you would be having access to a car or if you
see would your neighbors have cars your friends have cars and if you look at the bottom of
the car you will see an object like this very much
so like this you know not too much
difference is design but the catalytic converters of most of the cars would be having this structure
now let us decide or let us look at what the catalytic converter does see is by the name
what does it mean by the name if i say the name catalytic converter then by the name it
suggests that i am converting something what am i converting here i am converting the gases under nox then i am converting carbon
monoxide and i am converting unbound fuel how am i doing it because it is called a catalytic
converter
so i say it is doing with the help of catalyst now if you go back to one of our
discussions before you know when we are slowly moving into this concept of chemical kinetics
and we said that as opposed to thermodynamics chemical kinetics tells you about the
rate of the reaction and also about some idea of what goes on during the reaction then a question that comes to your mind
automatically is can i control the rate and we discussed that it can be concentration

say one it can be temperature second and it can also be a catalyst which ends up changing the rates of reactions
so that means this catalytic converter would be having some catalysts either one catalyst or a combination of catalysts which we will just see which will help converting these harmful pollutants to something which would not harm us or pollute the environment and with the idea and with the fact that the number of cars on roads the number of auto mobiles not only cars trucks motorcycles everything on bikes on road are increasing day by day it just makes sense that this level of pollution coming out or being contributed by these automobiles would increase if measures are not taken to control that level of pollutants being emitted through the exhaust pipe of the cars ok
so here as we were talking remember we looked at this catalytic converter right now what i am going to show you is the inside of a catalytic converter now there is a reason we are going to this because do understand that this is we are talking about the chemistry in something as modern technology as cars with the technology improving day by day
so now if you look at the inside of this catalytic converter what do we see
so the construction is very simple on the two sides you have two ports what are these ports if you see this red arrow you follow you follow my white arrow if you see this big red arrow then this is the inlet port
so the inlet pipe what does it do it comes from the exhaust manifold where the gases are produced after burning on fuel so then you can see you have those unbound c x h y then carbon monoxide then oxides of nitrogen which would enter the catalytic converter to this port ok now the inside of the catalytic converter you can see there are two slabs now without going into the very details also realize one thing that these slabs are built with certain high temperature materials which can resist the temperature at which these fuel is being burnt
so that those do not get bad or not affected but not only that in these slabs you have catalysts embedded
so for example the first slab you can see out here this slab has rhodium as a catalyst what does rhodium do as it is said out here rhodium as a catalyst it reduces the oxides of nitrogen what is it reduced to
so n o x gets transformed to nitrogen and oxygen
so what does rhodium do that means rhodium is reducing n o x as oxidization origin to nitrogen and oxygen gases

so that's why rhodium is the
catalyst now also if you look at this small circle which is a part of this
catalyst
so what happens is the way this catalyst is made or the way this you know this
this structure
is made where the rhodium catalyst is there it is full of it is porous that
means it is full
of pores why do you need pores you need pores
so that the gas which is coming out of the
gases which coming out from the exhaust pipe or through the exhaust pipe from
the exhaust
manifold can pass through this one during passing what is happening is these
are getting reduced
at least x in this case the oxidizer is normally getting reduced to nitrogen
and oxygen now comes
the next one remember you have been able to take care of the oxides of
nitrogen but what are you
left with you are still left with remember still left with the carbon monoxide
gas and then the
incompletely burnt hydrocarbons what do you do here
so in the second slab or structure
what you have is you have two catalysts what are these catalysts the second
one the two
catalysts are as shown
so platinum and palladium what do they do they should be oxidizes
so they
oxidize carbon monoxide and the hydrocarbons
so the next lab which is the second
one out here have as catalysts platinum and palladium right they oxidize c o and
c
x h y ok
so that means c o plus o two gas gives me c o two gas right and also
remember
from before c s ah x h y plus o two gas
so this is also gas would be giving me c o
two gas plus h two gas ok
so if i balance this this is how it would come
so what has this
catalytic catalytic converter done for you what this catalytic candidate
converter has
done is it has taken these harmful gases the first being oxidized of nitrogen
which were reduced to nitrogen and oxygen no pollutants then the ones which
are coming
out carbon monoxide and the hydrocarbons they are now being oxidized using
platinum
and palladium to carbon dioxide and water by this way and by efficient design
of the
catalytic converter you can try to minimize you can try to minimize the
extent
of harmful pollutants that are being given out by the car or are coming out
from you
can see this blue solid arrow this is the other side of your catalytic
converter to which the
gases which just got converted or some percentage we did not get converted go

through
so this is
really fascinating right
so within that short time and i will tell you what typically the time
is within the short time the car engine is running the fuels are being burnt
you know
these pollutants are being produced these pollutants are sent to the exhaust
pipe into the catalytic converter they are passing through the catalytic
converter during that time simultaneously what is happening is the nitric
oxides the
oxygen nitrogen are getting reduced and cx hy and carbon monoxide these are
getting
oxidized to less harmful or non polluting species ok now if you go by the time
ah that it takes so
because we are talking about kinetics it is always ah you know good to give
you some sense of time
so the time for which you know it ah kind of stays in contact you know if you
think about how
fast does this whole process happen or how fast or how how long does this one
remain you know
these gases remain in contact with the catalyst then it takes about fifty to
seventy milliseconds
so if i can write out here see takes about fifty to seventy milliseconds
for the gas to go through the converter right remember the
car is running
so m s stands for milliseconds and during this time this
whole conversion has to take place
so you realize that it is not only
about the reaction that is happening understand conditions reaction or
reactions when the temperature is raised because your burning fuel and
so on but it is also
that in the catalytic converter when the gases are passing through the two
slabs where you
had these catalysts for a short time for a very short time the gas gases get
the
opportunity to pass over the catalysts or in other words the catalysts have
only that much amount of
time to make sure that the conversion can happen as efficiently as possible ok
now
based on this if you read newspapers then you would come across some
guidelines what
are those guidelines in terms of environmental pollution one very common
guideline for
automobiles is going by that bharath stage say 4 what does this mean what it
means
is that under this every car say has to comply by the restrictions imposed
under this concept or this heading bharat stage 4 what is it related to it is
directly related to
the pollutants or the amount of these pollutants which are coming out through
your exhaust
so in
the coming days you would see that cars would have to comply by say var stage
6 that means the amount
of carbon monoxide that can come out through the exhaust which was not

oxidized to carbon dioxide
has to be even lower than what is permissible now or the amount of oxides of nitrogen that
can come out permissible amount would be much lower than what is being used now which is
part stage four right
so this was one example where chemistry in cars along with the rates of
the reaction high temperature high rates right then because of burning of fuel then
also the application of catalyst everything is happening together right that is
why chemical kinetics is such an important concept
so what we will do in the next lecture
is again before you know we delve into the real equations about the rate of chemical reactions and
so on we will look at another example and
if you can work on that yourself or think about that yourself i will tell you what the example is that example is about airbags a safety feature in cars and i will tell you how or what
fascinating chemistry goes on in there as a direct relevance to our discussion on chemical kinetics thank you you