hello students welcome to the third lecture of chemical equilibrium we started with the concept of your equilibrium constant equilibrium constant the way we defined equilibrium constant is suppose we take a reaction a a plus this reaction tells you that a mole of a reacts with b mole of b to give you c mole of c plus d mole of t then equilibrium constant was defined as concentration of c raised to power this c small c into concentration of d rate power d divided by reactant a power a a reactant b power

so this is the first concept which we introduced in the your chemical equilibrium the importance of k is importance of k

so suppose i take a reaction m g plus copper two plus giving you m g two plus plus copper

so value of k of this reaction is six into ten to the power ah 90 and i take another reaction which is iron plus copper two plus gives you iron two plus plus your copper

so there are two reactions first and second for the value of this k is your k for this reaction is 3 into 10 to the power 26

so in the first case your mg reacts with copper 2 plus to give you copper whereas in the second case iron reacts with copper two plus to give you copper now what does this value suggest now you can see the value of k is different for the two reactions in this reaction your k is quite greater than suppose i take this as a k one and this is k two

so k one is quite greater than k two what does that mean is the amount of reaction are the amount of copper formed in these two case is going to be different since k1 and k2 is different this can also tell you in which reaction copper is formed in the greater amount now you can clearly see that k1 is quite greater than k2 this only means that copper will be formed in greater amount for reaction one

so value of k value of k will tell you how much a reaction can proceed or how much a product can form product will be formed in the greater amount if your k value is large then we introduce the concept of reaction quotient before that i will again explain another thing that if suppose if we are given two reactions two reactions for example if i takes cobalt oxide solid cobalt oxide solid plus s two gas giving you cobalt in solid state plus s two o in gaseous state and the another equation is cobalt oxide solid plus c o gas gives you go solid plus co2 gas

so these are the two reactions and if i know the equilibrium constant suppose this is k one this is k two we can calculate the k we can know the value of k if a reaction is given which can be expressed in terms of one and two for example we can take c o two gas plus s two gas giving you c o gas plus s two o gas

so k for this reaction can be expressed in terms of k1 and k2 since your this reaction can be expressed in terms of these two reactions now let us see whether we can do it or not see this what is reactant in this case there are two reactants co2 and s2 if you see in the first and second reaction suppose this is one this is two now c o two is product in this case where s two is reactant in this case

so if i take the reaction one and subtract the reaction two i will get this reaction and thus the axon third which is this one can be expressed in terms of reaction one and reaction two and thus k can be expressed in terms of k one and k two lets see how we can do it

so lets write the reaction one which is c o o solid plus s two gas and this gives you co solid plus h2o gas h2o gas ok

so this is reaction one and then i take the reaction two which is c o o solid plus c o gas giving you co solid plus c o two gas this is the second reaction now k for this reaction is k one will be c o s

so solid we do not take this

so we can just simply write s two o gas divided by lets take this s two o gas divided by s two gas where for this one we can simply write k two is equal to c o two gas divided by c o gas now if we take the one minus two what we are going to get is your coo

so you take minus this minus and this is your this is co

so this will be minus and you are going to get co2 just c co 2 gas this side co2 gas plus s2 gas giving you your this is minus cos

so c o will come this side co gas plus s two gas ok

so if you subtract reaction 1 and 2 this is the reaction which you will get for which we want to calculate the value of k now you can see this this k will be co gas s two gas h2o gas divided by your is to h2 gas into co2 gas co2 gas and this is nothing but your k1 divided by k2 k1 divided by q2 now you can see here k1 divided by k2

so s2o gas co gas will be at the numerator and h2 gas and co2 gas will be in denominator

so if i can express a reaction in terms of two different reaction for which k value is known then i can express the value of the third reaction the unknown reaction now let us take the second case suppose we have given a reaction which is two s o two gas plus o2 gas giving you two s o three gas two s o three gas and suppose this this has some equilibrium constant k 1 which is known known now question is can i calculate the equilibrium constant for this reaction now you see this reaction nothing but reverse of this reaction and if suppose this i take k dash

so k dash is equal to your partial pressure of so2 square partial pressure of o2 a square if i take kp suppose partial pressure of o2 divided by partial pressure of s o three square and that we can just simply write one divided by pressure of s o three s square and then divided by pso2 square into po2 now you see this this is nothing but your k of this reaction equilibrium constant of this reaction

so k p dash is simply k p dash is simply one by k now again you saw that this reaction can be written or is related to this one and

so we are able to relate equilibrium constant of the first equation and the second equation i will take same reaction

so two s o two gas plus o two gas two s o three gas and i told you that suppose equilibrium constant is k p now suppose i take this is two equivalent s o two gas plus half o two gas giving you

so three gas

so three gas now you see only thing change is now i am saying one mole of so2 is reacting with half mole of co2 to give you so3 reaction is same stoichiometry has changed now you have you will have a different value of k how this k p and k p dash is related you can simply calculate by using the formula of equilibrium constant

so k p dash is what partial pressure of s o three into partial pressure of s o two s o two gas and partial pressure of your o two power half this is nothing but a square root of partial pressure of

so three square divided by partial pressure of s o two s square into partial pressure of court and this is nothing but this whole thing in bracket is your equilibrium constant of this thing

so it is simply written like kp half

so we can express we can express equilibrium constant of a related reaction related reaction if the equilibrium constant of first reaction is known

so if i take a reaction a plus b going to c plus d c plus d and then i take a reaction c plus d going to a plus b this is a reverse reaction

so k one and k two is related by this equation k one is equal to one by k two if suppose i take a reaction a plus b giving you c plus d and if i take this as a k one if i know this and suppose i take half e plus half b giving you half c plus half d and if i take a kilogram constant is k 1 dash then your k 1 dash is equal to your k 1 power

so if reaction is multiplied by half time then your equilibrium constant will be your just k one power half if this is multiplied by two times

so two a plus two b two c two d then this will be your square this will be a square and now if he takes suppose a plus b giving you ah taking c plus d and suppose i take c plus d e plus f

so these are consecutive reaction c plus d c plus d and then product is e plus f and suppose the equilibrium constant for this one is k one this is k two i know the equilibrium constant for k one k two then what i need to do is simply add this a plus b giving you your e plus f in that case equilibrium constant for this reaction will be k 1 into k 2 k one into k two and suppose i get a reaction like this a plus b giving you c and we also know that e plus f gives you c then i can again calculate the equilibrium suppose this is equilibrium constant k1 k2 then i can know what will be the equilibrium constant for this equilibrium constant for reaction a plus b to e plus f and this i can do by just subtracting this

so if i get a reaction from the subtraction then i can simply write k is equal to k one by k2 k1 by k2 now this is regarding your equilibrium constant now let us take the case of reaction quotient

so there is a difference between reaction quotient equilibrium constant equilibrium constant the difference is

so for example if i take a plus b c plus d differences difference is difference is due to the concentration which concentration this concentration is basically your equilibrium concentration

so k is simply c equilibriums concentration of c at equilibrium into concentration of d at equilibrium divided by concentration of a at equilibrium into concentration of b at equilibrium well q is your concentration of here all the concentration is same but this is concentration at any time any time and

so q decides decides the direction of direction of reaction you decides direction and last class i told you that q is equal to k when your reaction is at equilibrium equilibrium if q is less than k reaction will proceed in reaction well

so proceed in forward direction whereas q is greater than k then reverse reaction will take place reverse reaction will take place now k and q are k and q are related to related to your delta g we know that delta g which is change in free energy tells you about a spontaneity of the reaction and k and q can also tell you about the spontaneity of reaction or whether forward reaction is taking place or backward reaction is taking place

so there is a relationship between q and k and the relationship is delta g is equal to delta g naught plus rt ln cube

so this is q reaction quotient this is a reaction quotient

so delta g is equal to delta g naught plus r t l and q and we know that delta g is equal to zero at equilibrium at equilibrium

so delta g is equal to zero

so if i put it here zero is equal to delta g naught and plus r t l n and you see q at equilibrium is equal to k and

so i can write k here q at equilibrium this is basically q at equilibrium equally brian and

so delta g naught is equal to minus rt lnk rtlnk

so what did we told is delta g is equal to delta g naught plus r t l n q and

delta g naught is equal to minus r t l and k and
 so delta g is equal to if i suppose put this value here i will get minus rt ln k plus rtln q and if i take r t common i take log i can simply write this is q by k now you can see here if q is equal to k i will got this log one ln one ln one is nothing but zero
 so at equilibrium
 so let us see delta g is equal to r t l n q by k at equilibrium brian you have q is equal to k and
 so delta g is equal to simply zero because l n one is zero when q is less than k when q is less than k what does that mean that delta g will be rt ln and this quantity q by k is going to be less than one since q is less than k and it means log q by k will be negative log q by k will be negative
 so delta g is negative and that is why your forward reaction is taking place when q is greater than k
 so delta g is equal to r t ln k by q by k in this case this is greater than one and
 so this is positive
 so forward reaction will not take place what will happen is reverse reaction will take place since delta g is positive now let us go to ah very important concept in chemical equilibria which is your ah lee lee chatelier principle this is very important from the point of view is that it tells you under what condition under what condition condition we can get we can get maximum weight under hard condition i mean if i increase or decrease the pressure increase or decrease the temperature ok
 so what does this lead chatelier's principle tells you lee chatelier's principle tells you tells what this least chateal principle does this tells you the factor if we alter the alter the condition condition condition pressure temperature of volume ok we can change the we can change the the the equilibrium and it also tells you not it does not only tell you that it will change the equilibrium it will change also the direction of equilibrium the equilibrium will shift to equilibrium equilibrium will shift to that direction that direction which tends to minimize the change this tends to minimize the change ok
 so what are the things we can change first is concentration second is pressure or volume and third is your third is your temperature temperature in some cases temperature and pressure
 so increase in pressure can increase the product but in other cases increase in pressure will decrease the pressure decrease the product similarly in some cases increase in temperature will increase the product and in some cases in other cases your increase in temperature will lead to decrease in pressure or decreasing product now let us take this reaction n 2 plus 3 s 2 giving you 2 n s 3 yes all three are in gases all three are in gases now what the leachate earlier principle tells you that if suppose i remove ammonia from the vessel the reaction will shift to ammonia side
 so that minimize the effect or minimize the effect of decrease in concentration if i suppose take into out from the solution reaction will shift towards your left hand side where more into will be formed if suppose i put nitrogen gas inside the vessel reaction will shift towards your ammonia side forward direction
 so that n2 amount of into will be minimized and that is quite clear from this k because we know that k is p n s 3 square by p n 2 into p is 2 q now you must remain ah remember this that k is a constant quantity k is a constant quantity
 so suppose i increase suppose i increase the amount of ammonia
 so this will be greater and for that to keep this constant this needs to be

greater
 so when this will be greater when reaction will shift towards this direction all right
 so that pressure of nitrogen will increase pressure of hydrogen will increase and this is whole thing will increase and the ratio of these two terms will remain constant suppose somehow i increase the pressure of nitrogen reaction will shift in that direction in which you see ammonia amount of ammonia will increase
 so pressure of ammonia will increase such that k remains constant if i remove one of them if i remove suppose one of them for example i remove ammonia this will be a smaller term this has to be a smaller term and that will only happen and reaction will go to forward direction reaction will go to forward direction
 so suppose i remove this suppose i remove ammonia then in that case your equilibrium is disturbed and q is your p n s 3 dash square by your p n 2 and p s to q now i have removed ammonia and p n s three dash is small
 so q will be less than k cube will be less than this quantity since numerator is now small and we know that when q is less than k what happens what happens reaction will go towards forward direction reaction will go towards forward direction now effect of pressure change ok effect of pressure effect of pressure chain ok or you can say volume chain suppose i have taken a gas in this cylinder ok now if i increase the volume increase the volume
 so v one v two in this case v one is less than v two
 so what we expect that pressure in a vessel initial vessel will be greater
 so p one is greater than p two
 so what happens when we do that how does reaction gets affected how does equilibrium gets affected now you can take any reaction a suppose a mole of a plus b mole of b giving you c mole of c plus d in this case what will happen suppose all are in gases for ok
 so k p will be yours partial pressure of c power c partial pressure of d power d partial pressure of a power a partial pressure of b power b ok partial pressure of b power b and now you see that what we did is we either increase the pressure suppose we increase the pressure
 so what will happen
 so we know that this is simply x c into p power c this is x d mole fraction p power d divided by x a power a into x a into p power a into x b into p power b and this quantities when i take this out they will give you k x p you have c plus d minus a minus b
 so this is simply k x into p delta n delta n and that is delta n is simply a c plus d minus a minus b
 so just look at this if this is positive what does that mean this means this term will be greater if i increase the pressure this term will be higher but k p is constant
 so what needs to change k x will change if i delta n is positive this must decrease and when this will decrease when product will go to your reactant then only your k x value will decrease on the other hand if delta n is negative then k x should increase since k p needs to be constant and k x will only increase when product is formed in greater amount
 so reaction will shift
 so suppose i take two examples one is this two s o two gas plus o two gas giving you two s o three gas now in this case k p is equal to your k x into pressure power two minus two plus one two is your this one s o three for product and for s o two two for oxygen one
 so two minus two plus one
 so is equal to k x into p power minus one now if suppose i increase the

pressure if i increase the pressure what will happen to k x if we increase the pressure we need to increase the k x am i right

so this is your k x by p this is k x by p

so i if i increase the pressure k a x should increase

so that k p remains constant when k x will increase k x will increase

so increase the p pressure k x will increase increase in k x and this means that your reaction will be forward reaction forward reaction will be failure forward reaction will be favored now take the second case p c l five your gaseous form going to pcl three gas plus cl2 gas ok now your k p in this case will be k x into p you see in product side one p c l three one one c l two plus one now reactant minus one

so this is simply k x into p

so suppose i increase p the value of p if i increase the pressure what will happen if i increase the pressure your k x should decrease to keep k k p constant k x should decrease to keep kp constant kp constant and that means that reaction will proceed in in reverse direction reaction will proceed in a reverse direction

so there are two ways in which we can increase the pressure one is by just compressing and another by your just expanding it just by sorry ah by compressing by you can increase the pressure by expanding you can decrease the pressure

so if mixture is compressed pressure increased and your reverse reaction will happen on the other hand we can think of if i decrease the pressure what will happen if i decrease the pressure then reaction will proceed in forward direction now pressure can be increased in another way pressure can be increased in another way the way is your by introduction of introduction of anode gas

so now what i am doing i am not just we have taken a gas and then

so suppose volume is v and now what we can do is we can just introduce some inert gas

so pressure increased increased ok introduce some minor gas

so that pressure increase

so at if i increase if i if i increase the pressure by just adding another gas what will happen what should happen ok

so initially what we

so showed is if i change the pressure by changing the volume i did

so it will depend on which kind of reaction we are talking about ok which kind of reaction we are talking about if delta n is positive but we did see that if i increase the pressure if i increase the pressure reaction will go to reverse direction if i decrease the pressure reaction will go to forward direction if delta n is negative then just reverse is the case but now we are increasing pressure not by changing volume by just introducing your just introducing your inert gas in that case what will happen

so let us take this case p c l five gas going to p c l three gas plus c l two gas ok and i did told you that k p is equal to pressure of p c l three multiplied by pressure of c l two divided by pressure of p c l five pressure of p c alpha ok and we can also write in terms of mole fraction

so x p c l three into p p is the total pressure x p c l three into your sorry c l two into p divided by x p c l five into p ok now you can think of this this is what n p c l three p c l three by your sigma n where sigma n is total number of moles total number of moles that will include not only mole of p c l phi p c l three c l two but also moles of inert gas ok

so this is into p into p

so let us take p outside

so i will just first write your number of moles

so number of moles of c l two divided by sigma n and then ah number of moles of p c l five e c l five by sigma n and this is one p cancels out this is p and
 so this is simply your n p c l five into n c l two divided by n sorry this is n p c l three n p c l three this is n p c l five into sigma n
 so one sigma n one sigma n cancels out
 so sigma n is left into p now you see when i am trying to increase the pressure by just adding inert gas and i keep volume constant what happens is we have this term p by sigma n okay p by sigma n and since pressure is changed by introducing n and we know p by n is constant p by n is constant at constant volume and temperature
 so this p by n sigma n is simply constant and
 so there is no effect of addition of inert gas on equilibria if pressure is increased by keeping volume constant pressure is increased by adding inert gas but keeping volume constant equilibria will be affected if i add inert gas pressure is constant but volume is not constant ok
 so lets see the effect of inert gas effect of inert gas on equilibrium effect of inert gas on equilibrium your p c l five gas two p c l three gas plus c l two gas ok and we know that k p is equal to p p c l three p c l two p p c l five and this is your n p c l three by sigma n into p n c l two by sigma n into p a square p for first p for this p c l three and the second one for p pcl and this is n p c l five by sigma n into p
 so what does that mean is your again we can write n p c l three into n c l two by your n p c l five into sigma n into p now see i told you that now what i am trying to do is i am trying to introduce in not gas keeping pressure constant
 so pressure is constant but sigma n has increased
 so we have added inert gas such that sigma n has increased
 so what is effect of inert gas when pressure is constant you can just see sigma n
 so this is your sigma n has increased
 so what need to decrease
 so that k p is constant you can see this needs to decrease
 so if i add inert gas reaction will proceed from this direction to this
 so to the left sigma n increase will increase this sorry sigma n increase will increase this
 so pcl
 so basically your forward reaction will be forward reaction is going to be favored if sigma n decrease then your reverse reaction will be favored
 so let us make a conclusion
 so effect of increase in effect of increase in pressure your delta n is delta n is equal to your positive then your forward reaction will a reverse reaction well reverse reaction will be favored in favor delta n is negative then forward reaction will be favored with increase in pressure this is with increase in pressure ok i will stop here in the next class we will discuss the effect of temperature foreign