

hello students welcome to second lecture of chemical equilibrium i will start with recap and then we will discuss more other concepts which is important in chemical equilibrium we started with definition of equilibrium brilliant and then i told you what is equilibrium it is basically a state of balance between two opposing forces forces that what an equilibrium in a broader sense means in case of chemical equilibrium in case of chemical equilibrium brian we are talking about equilibrium in a chemical reaction suppose a to b where a is a reactant and b is the product there is also tendency to go from b to a and that is your reverse reaction here two forces are two forces are first rate of forward reaction and the second is rate of reverse reaction as in case of other equilibrium when rate of forward reaction forward reaction is equal to rate of reverse reaction we have condition what is called equilibrium equilibrium chemical equilibrium or physical equilibrium

so two balancing forces are rate of forward reaction and rate of reverse reaction when they becomes equal you have condition of equilibrium then we talked about your type of equilibrium constant constants and i introduced terms like K_c K_p and K_x for a reaction a to b we define what is what we mean by K_c K_p and K_x

so K_c is your concentration of b by concentration of a concentration of b by concentration of a K_p is pressure of b by pressure of a and K_x is mole fraction of b by mole fraction of a here i am talking about equilibrium concentration of b and equilibrium concentration of a

so K_c is your ratio of equilibrium concentration of b divided by equilibrium concentration of a similarly K_p is your equilibrium pressure of b divided by equilibrium pressure of a and similarly K_x is your equilibrium mole fraction of b divided by equilibrium mole fraction of a for a reaction like

so if you look at this reaction what does that mean is a mole of reactant a reacts with b mole of reactant b

so this is your number stoichiometry and this these are reactants reactants these are c and d are product

so this reaction tells you that a mole of a reactant a when combines with b mole of reactant b it gives you c mole of c and d mole of product d ok in that case K_c is written as concentration of c power this number c concentration of d power stoichiometry d divided by a comes power a and concentration of b raised to power your b whereas K_p is your pressure of c power c p d equilibrium pressure of the power d equilibrium pressure of a power a equilibrium pressure of b power again i will like to emphasize that these are equilibrium concentration

so we can simply write e_q e_q e_q e_q and here e_q e_q e_q and e

so these are the two terms which we came across in our first lecture once we have we know the concept of equilibrium constant we can go and solve some equilibrium problems equilibrium problems there are two types of equilibrium problem which we can come across your first is suppose you if i take this reaction and if i know what is the equilibrium concentration of a b c and d if i know this then i will be told to you know calculate K_c K_p K_x this is type one problem type one problem there is another type in which in which K_c K_p or K_x is given and then we have to calculate equilibrium concentration of equilibrium concentration or pressure of a b c d

so we will go one by one and try to see how to calculate your equilibrium how to solve the problem let us look at this case in this problem what you need to calculate is equilibrium constant

so question is calculate the equilibrium constant for the reaction below if they are present they means this reactants or products a² b² or a b two are present at equilibrium ok

so what is given is five moles of a two is present at equilibrium three moles of b two is present at equilibrium and two moles of a b two is present at equilibrium and also you have been given what is the pressure and temperature of the ah vessel

so now question is to calculate k c equilibrium constant k c and we know this reaction we have to calculate k c for this reaction ok

so we know that k c is equal to a b two this is the concentration you must remember this is the concentration and you see number is two

so we will put two

so a b two concentration of a b two s square divided by product ah sorry product of these two ah concentration of reactants

so the reactants are a two and you can see that stoichiometry is one

so we will just put one and now concentration of b two and here stoichiometry is two

so we will put two

so this is how we can calculate the value of kc now you see this what is given to you the things which is given is number of moles of a two

so you have been given n a two is equal to five mole other thing which is given is n b two that is your three mole and n a b two is your two mole now you see what we need is concentration of a b two not number of mole of a b two and we know the relationship between concentration and number of mole

so concentration is equal to n by v where v is the volume ok

so we need to find out the volume and for volume we can use your equation pv is equal to nrt assuming that all reactants behave as reactant and product behave as behave as an ideal gas behave as an ideal gas

so in this case we can simply apply p v is equal to n r t and v is equal to n r t by p ok

so n r t by p we know n n is total number of moles of gases which is in this case five plus three plus five plus three plus two is equal to eight plus two ten now if we know if we can calculate volume ah we can calculate it because we know r is gas constant n is ten temperature is given three hundred k and pressure is given this is three hundred k and pressure is given as eight point two one atmosphere

so it is quite simple to calculate the volume once you know the volume we can simply calculate concentration of a two concentration of a two is number of mole of a two by volume a number of moles of a two is your five and divided by v and similarly you can calculate your concentration of b two which is n b two by v and that is your three by v and then you can calculate concentration of your a b two we know that number of mole of a b two is your two

so just divide by b we which we calculated from n r t by p n r t by p now we have the concentration of we are able to calculate concentration of a two b two and a b two now it is easier to calculate k c k c is simply a b two s square by a two into b two s square and then you just put these numbers you will be able to get the value of k c you will be able to get the value of k c

so now you can see that if equilibrium equilibrium concentration is known equilibrium concentration of reactant and products you know it is easy to calculate your value of kc now in this problem i will start with a heterogeneous reaction in the previous question it was a homogeneous equation homogeneous equation why i am i was saying homogeneous because your a 2 b 2 and a b 2 was in gaseous phase in this question we will take a an example of heterogeneous reaction now you see this is your reaction you can see this strontium chloride two s two o is it in solid phase while water is in gaseous phase and this thing or s r c l two six s two is in solid phase

so now you can see that there are three phases present two solids and one gas

two solid and one gas

so this is a heterogeneous reaction and for that K_p is given one into ten to the power minus twelve atmosphere minus four and then what you are needed to do is what you need to do is to calculate equilibrium vapor pressure

so you see this is the second type of question in which K_p is given your equilibrium constant is given and now you have to calculate equilibrium pressure ok

so in that case you can simply start with K_p and you see this two are solid phases these two are solid phases and

so you can simply ignore that and we can write K_p is equal to $p_{H_2O}^2$ what is the power here you can see at this point is four ok four is the stoichiometry of water in gases phase

so you just simply put four here and we know from the problem that K_p is equal to $1 \times 10^{\text{power minus } 12}$ and

so you can simply write $p_{H_2O}^4$ is equal to $1 \times 10^{\text{to the power } 12}$ ok i just did this way ok

so you can simply write this and then you will be able to calculate p_{H_2} which is nothing but $1 \times 10^{\text{to the power } 3}$ atmosphere

so you will be able to calculate equilibrium vapor pressure in this case if K_p is given now let us take third question and this came into came ah in 2016 for iit advance the question is thermal decomposition of gaseous X_2 to gaseous X

so it is basically dissociation reaction at two ninety eight k takes place according to equation this X_2 is going to two X basically dissociation is happening at the start of the reaction there is one mole of X_2 and no X

so X_2 is 1 initial mole of X_2 is 1 whereas 0 is the your number of mole for X ok

so you started with pure X_2 at the reaction process the number of moles of X formed is given by your beta sorry this is beta

so thus beta equilibrium is the number of moles of X formed at equilibrium

so at equilibrium the concentration of this X is your beta the reaction is carried out at a constant total pressure of 2 bar and then it is asking what is the equilibrium constant K_p for the reaction at 298 k in terms of beta equilibrium now you see here here equilibrium concentration of product is given equilibrium concentration of product is given equilibrium concentration of reactant is not given ok but you know initial concentration of you know the initial concentration of your initial mole of reactant

so what are known lets see here

so we have X_2 gas this is the reaction to two X gas

so what is known is initial concentration we know that this is one one mole of X_2 and no X means zero this and what we know at is your equilibrium concentration of equilibrium concentration of this thing and this is beta equilibrium ok and now question asked that what is the value of K_p in terms of beta equilibrium

so we know that K_p is equal to pressure of X square you see two here

so this is a square divided by pressure of X_2 pressure of X_2 ok pressure of X_2

so what we need to calculate is and this this is you must remember this is equilibrium pressure what we are talking about is equilibrium pressing

so first thing is we need to calculate your number of moles of X_2 what is this thing and once we know number of moles of X_2 and number of moles of X then we need to calculate mole fraction of X_2

so this is your mole fraction of X_2 and mole fraction of X and then finally we can calculate your K_p

so lets go and see

so first step here is your calculation of calculation of equilibrium concentration of your x_2

so lets write this initial you have one more zero and at equilibrium you have beta ok now what is the number of mole of x_2 this is the first question okay so the way you can do is just looking at the reaction and number of moles form number of moles of x_2 formed at equilibrium

so what this reaction tells you that if one mole of x_2 is used two mole of x_2 will form two mole of x_2 is formed ok or you can just think in opposite way if two mole of x_2 is formed one mole of x_2 is used ok

so if i think in a this way now think of this if beta mole of x_2 is form beta mole of x_2 is formed how many moles of x_2 will be used

so i told you two mole of x_2 one mole of x_2 used an i right two x_2 form two mole of x_2 form means one mole of two mole of x_2 form one mole of x_2 is used

so one mole of x_2 is formed in that case half mole of x_2 will be used and beta mole of x_2 is formed means beta by two mole of x_2 will be used

so what is the equilibrium mole of x_2 we started with one mole of x_2 and now you know that beta by two mole of x_2 is being used what does that mean what is left out you started with one and used up is beta by two

so left one is one minus beta by two

so this is one minus beta by two

so i hope this is clear you must first calculate how much mole of x_2 is at equilibrium and that you can do by using the fact that beta mole of x_2 is formed and two x_2 mole of two mole of x_2 is formed from one mole of x_2

so what we have calculated is the equilibrium concentration for the reaction

so x_2 gas going to two x_2 gas this is the reaction and we already calculated what is the equilibrium concentration or number of moles at equilibrium

so this is $1 - \frac{\beta}{2}$ and this is your beta one minus beta by two number of moles of x_2 and beta mole of x_2 is present at the equilibrium

so now we need to calculate K_p and for that we need to know partial pressure of x_2 and partial pressure of x_2

so partial pressure of x_2 is equal to mole fraction of x_2

so this is mole fraction of x_2 into total pressure total pressure and what is mole fraction mole fraction is your n_{x_2} divided by total number of gaseous molecule multiplied by what is n_t total number of molecule is number of molecule of x_2 and plus number of molecule of x_2 number of mole of x_2

so n_t is equal to one minus beta by two plus beta and this is equal to one plus beta by two

so your p_{x_2} is equal to n_{x_2} / n_t n_{x_2} is one minus beta by two divided by total number of molecule is one plus beta by two and into p whereas p_{x_2} is equal to n_{x_2} / n_t into p n_{x_2} is your beta

so beta divided by n_t is your one plus beta by two into total pressure

so now we know what is p_{x_2} and we know what is p_{x_2} we can calculate what is K_p value ok

so now we can calculate K_p and K_p for this reaction is pressure of x_2 square divided by pressure of x_2 and just we calculated pressure of x_2 pressure of x_2 is your beta by $1 + \frac{\beta}{2}$ into p and this is whole square divided by one minus beta by two by one plus beta by two into p

so this is equal to K_p is equal to your beta square by $2 + \frac{\beta}{2}$ square into p a square divided by your two minus beta and two minus beta divided by two two plus beta divided by two into p p cancels out this term cancels out this two two cancels out

so what you are left with is your beta sorry this is your beta

so this is beta square by two plus beta square into this two goes up

so four into p divided by two minus beta this two plus beta goes up two plus

beta that's all two plus beta and this square terms cancels out

so what you are left with is four p beta square by four minus beta square and since p is equal to two atmosphere you can simply write eight beta square by four minus beta square ok

so this type of question can also come in which initial concentration is known one of equilibrium concentration of one of the product is known and then you need to calculate k p you can easily do that first you need to calculate equilibrium concentration of the reactants for which equilibrium concentration is not known and then you can simply calculate the value of kp

so in this question you have to you have been given equilibrium concentration of a b c the reaction is a going to b plus c and equilibrium concentration is known four point six two point three two point three moles per liter at twenty five degree celsius if two moles per liter of a are removed calculate the equilibrium concentration of a b and c at same temperature ok

so it is going to utilize it is basically a mixture of type 1 and type 2 questions mixture of type one and type two question in this first you have to calculate k p or k c and then you disturb the equilibrium by removing your a and then you need to calculate equilibrium concentration of a b c and here you can utilize the fact that you have already calculated k c

so lets think of this question

so reaction is a going to b plus c ok and equilibrium concentration is known equilibrium concentration is given equilibrium concentration is given this is a is 4.

6 b is 2.

3 and c is 2.

3

so value of k c will be what simply concentration of b into c divided by a is quite simple to calculate and you can do b is two point three into two point three divided by four point six ok

so this is quite simple to calculate k c but now question is that that two moles per liter of a is removed

so basically this is equilibrium what you are doing going to do is you remove two moles of this four point six minus two what happens in that case is now it is no longer at equilibrium no longer at equilibrium now reaction is no longer at equilibrium now question is which side it will shift ok

so 4 0.

6 minus 2 and then you have 2.

3 2.

3 this side 2.

3 what equilibrium is not disturbed

so at equilibrium what can happen this is your two point six ok

so suppose reaction basically goes from this to this side ok in that case what will happen you can simply write two point three minus x suppose x mole of c reacts with x mole of d and x mole of a is formed this is at new equilibrium ok

so in this case k c is equal to your 2.

3 minus x square divided by a square because you are multiplying concentration of b with concentration of c

so two point three minus x square and divided by two point six plus x two point six plus six and this you have already calculated that was two point three square divided by four point six now you see you have a equation there is only one unknown and you have one equation

so you will be able to calculate x you will be able to calculate x and

so you will be able to x calculate x then you can just put it here and now you know what will be the equilibrium concentration of abc here i told that reaction

will go to your left hand side a reverse reaction will take place how you can tell that it is quite simple here we know that K_c is equal to $\frac{b}{a}$ by your a what we are removing at this one ok if you take out a this K_c is constant you must remember K_c is constant okay K_c is constant ok

so if i remove a then what will happen concentration of b and c will decrease so that $\frac{b}{a}$ remains constant and that's why b and c when b and c can decrease when reverse reaction will take place and

so we can simply write that c is decreasing by x amount

so b will also decrease by x amount both are reacting they must react in the same stoichiometry and

so if concentration decreases by x for b and c concentration of a will increase by x and

so you can simply write $2.6 + x$ $2.3 - x$ $2.3 - x$ and

so K_c can be calculated ok

so this is about the problem which can be solved using concepts from your equilibrium constant ok now lets talk about another important term in chemical reaction this is called reaction quotient i have already introduced this to you but now i will again define and then finally i go and tell you what is the importance of this term

so i told you that if i start with some ok some reactant a i am talking about a reaction a going to b and suppose we start with reaction a as sorry ah only reactant a in the box and what will happen is this will convert to b first suppose one of a went to b this is your b then i wait for some more time and then we get your one more molecule goes to b again wait for some time one more molecule goes to b suppose ok after sometime what after something what will happen is that this now does not change if i suppose wait for for few more hours and what you are able to see that there is no change in that case what we say that this we have just the condition of equilibrium ok condition of equilibrium and your $\frac{b}{a}$ which is $\frac{b}{a}$ equilibrium by a equilibrium which is basically three by three this is one and this is your K_p of this reaction K_p a K_c of this reaction here you must keep in mind that this is the equilibrium concentration of b by a

so this is concentration at this point not at this point ok because in this state equilibrium has not reached

so this is not the equilibrium concentration of a and b what is this is your q reaction quotient and that is again equal to $\frac{b}{a}$ but now this is not a concentration at equilibrium this is concentration at any time ok

so q changes with time q changes with time and at this point q is equal to one by five one by five q is different from equilibrium constant is that equilibrium constant is fixed at one temperature while q changes with time

so suppose i start with pure a pure a and

so you have pure a quantity pure a then what will happen suppose reaction is going from a to this is your extent of reaction it is going from here to here and this is somewhere is the equilibrium constant ok

so in this side in this side the reaction quotient product by reactant

so before reaching equilibrium your reactant is more in number while product is less product is less in this case q will be if i compare with p equilibrium if i compare with p equilibrium by r equilibrium r equilibrium what we expect is your produ since product is less reactant is high

so this quantity is smaller than this

so q is less than your k before equilibrium is reached now what happens is if i start with pure b pure b in that case again there will be some time at which only one of product has gone to reactor

so in this you see this we are starting with b and this is your a
so in this case q is i am again calculating only q for a forward reaction
so i am not going to change this b by a
so b by a will be your 5 by your 1 and now q is greater than k in this case
your reverse reaction reverse reaction will take place

so we have three different conditions one is q is your less than k then
reaction will proceed to proceed in forward direction q is equal to k then your
equilibrium is established and q is greater than k implies reverse reaction will
take place reverse reaction will take place

so if i plot reaction quotient q with time we get this kind of curve this is q
is greater than k and this is for q is less than ok q is your product by
reactant

so q is decreasing what does that mean product is converting into reactant
so reverse reaction is taking place reverse reaction reverse reaction is taking
place taking place reverse reaction is taking place while if q is less than k
then q increases with time q increases with time and q when q will increase when
p increases and r decreases and this means forward reaction

so this is for forward and this is for reverse reaction and this is being used
to know whether a reaction will go in a forward direction or reverse direction

so simple thing is if reaction quotient is greater than k then reverse reaction
is spontaneous if reaction coefficient is equal to k then your reaction is at
equilibrium when reaction quotient is less than k then your forward reaction
will proceed forward reaction will proceed the another graph which we can think
of is g versus extent of reaction extent of reaction

so suppose you have g of a is here g of b is here reaction will like to take
place what we expect that this should go down like this but this does not happen
and that is basically why equilibrium exist and i told you that there will be a
deep there will be a deep and this deep minima will be obtained at equilibrium
and this minima is due to delta g of mixing when a and b is getting mixed a and
b is getting mixed a when a and b gets mixed entropy increases and

so delta a g ah makes a contribution to your total delta g what do mean by
delta g is basically if i go from here to here delta g is less than

so till this point your delta g is you can see b gb minus ga delta g is less
than zero and in this resin delta g is greater than zero and

so reaction will your go from b to a in this region reaction it will go to a to
b and this is the when q is less than k and this is when q is greater than k

so reaction quotient is less than k then forward reaction is taking place and
reaction quotient is greater than k then it is no reverse reaction is
spontaneous and at this point where q is equal to k we have equilibrium

so there are three very important points is first is when q is less than kc ok
your reaction will proceed in forward direction reaction will proceed in forward
direction second when q is equal to k then reaction is in equilibrium and third
is q is greater than k reaction will proceed then proceed in reverse direction
reverse direction

so reaction quotient and q reaction quotient and quotient this is q and
equilibrium constant constant k can be used to know the direction of the
reaction direction of the reaction for example take this case a going to b and
suppose i know that k equilibrium constant k c is your value is four and suppose
in a reaction mixture we have two moles at certain time t or you are putting
suppose ah four more per liter of this and two mole per liter of this per liter
of b now can we predict can we predict whether reaction is going in forward
direction or reaction is going in reverse direction we can do that since we have
k c and we know the value of q in this case q is what two by four and

so q is your half you see here what is k c k c is four

so q is your less than k_c q is less than k_c and
 so reaction will go action will proceed in proceed in forward direction forward
 direction reaction will proceed in forward direction now you can take another
 case a going to b and suppose k_c is half k_c is half and if i take a box which
 has box and add suppose two mole of a and four mole of b and then i want to know
 whether it will convert to b or b will convert to a what we need to do is simply
 calculate the value of q and q is your simply b^2 by a^2 and this is your two
 so four by two
 so four by two is two now you see q is greater than k_c and
 so the reaction
 so basically your reverse reaction is will proceed
 so more b will be converted to a and what you will get is $4 - 2x + x^2$
 and you can calculate what is the amount of x converting by simply adding using
 k_c k_c is equal to $4 - 2x + x^2$ and that should be equal to half that
 should be equal to half
 so first thing we can simply know in which direction if i mix if we mix a and b
 a and b in which direction which direction reaction will proceed whether in from
 b to a or a to b and if i know the value of this we can know by comparing the
 value of q k_c and q k_c and q and if i know the value of k_c and q value of k_c and q
 value of k_c and concentration of concentration of a and b we can also tell that
 how much how much a goes to b r or how much b goes to a if reaction goes to a if
 reaction if reverse reaction if reverse reaction is happening if reverse
 reaction is taking place taking place it is very you know you just see just
 simple two concept of k_c and q we are able to tell not only we are able to tell
 direction of reaction direction of reaction but we are also able to tell will be
 also able to tell how much how much your reaction reaction how much your
 reaction will go in forward direction forward direction or reverse direction or
 reverse direction
 so there is we will be able to calculate that how much a goes to b or b goes to
 a how much a goes to b or b goes to s
 so here we will stop in this lecture in next lecture we will discuss about lee
 shatilia principle thank you very much you