CHE 1302

Basic Principles of Modern Chemistry II

Week 7

Hello and welcome to the weekly resources for Chemistry 1302! This resource covers topics typically taught by professors during the 7th week of classes.

On our website, https://baylor.edu/tutoring, you'll find the following links:

"Online Study Guide Resources" – If you don't see the topics you're learning right now, click here to find the weekly resources for the rest of the semester!

"How to Participate in Group Tutoring" - See if there is a Chemistry 1302 group tutoring session being hosted this semester – these are weekly question/answer sessions taught by our master tutors!

You can also view tutoring times for your course or schedule a private 30-minute appointment! Check out the website to learn more. You can also give us a call at (254)710-4135, or drop in. Our hours are Monday-Thursday 9 am – 8 pm on class days.

KEY WORDS: Worked Equilbrium Examples, Problem-Solving Strategies

TOPIC OF THE WEEK: Equilibrium: Worked Examples

When solving a chemistry problem (can also be applied to other word problems!), it's best to think of them backwards. This thinking is because it gives direction to your problem-solving – by knowing what you're trying to find, you figure out the steps to get there. Here is a good strategy for math problems that can be applied throughout Chem 2:

1. Identify values. What is given, and what do you want to find?
2. Identify equations that relate these values.
3. Solve for unknowns.

Kc is the ratio of products to reactants at equilibrium. In other words, it is a particular reaction's **"preference"** for how much **product is in solution** in comparison to **the amount of reactant**.

$$K_c = \frac{[C]^m * [D]^n}{[A]^j * [B]^k}$$

So, when given a K value, this equation is what it represents. Here are the values – start by identifying what is given, and what you want to find.

Kc (equilibrium constant)

Initial concentrations

Change in concentration

Equilibrium concentrations

Next, write out the mathematical relationships between them. Those between I/C/E are nicely organized using (R)ICE tables. K's expression is above, and it refers to the equilibrium row of the ICE table!

Now, you can solve for unknowns.

Highlight 1: An I/C/E table that uses the quadratic

Here's an example of an I/C/E table where x is not small. For most Gen Chem problems, x will be small, but it's nice to see what it looks like when it's not:

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_g \; K_c = 4.1 * 10^{-4} at\ 2000\ K$$

See Week 6 for more I/C/E table calculation tips! Start with writing the equation for Kc.

$$K_c = \frac{[NO]^2}{[N_2][O_2]}$$

Now, write out the initial concentrations, changes in concentration, and equilibrium concentrations. Q=0, which is less than $4.1 * 10^{-4}$, so the reaction will move to the right. Reactant "changes" in the ice table will be negative, and product "changes" will be positive.

I	0.250 M	0.430 M	0 M
C	-x	-x	+2x
E	(0.250-x)	(0.430 -x)	2x

$$K_c = \frac{(2x)^2}{(0.250 - x)(0.430 - x)}$$

Here, we assume at first that x is small. But then, we get that x=0.03 M, and that's more than 20% (or 1/5) of 0.250 M. So, use the quadratic formula.

When using the quadratic formula: Combine like terms, then move all terms to one side of the equation so that it is in the form $Ax^2 + Bx + C = 0$. Here's a video on what to do once you have a "quadratic equation:" [The quadratic formula | Algebra (video) | Khan Academy]

$$x = 3.28 * 10^{-3} M$$

See this problem solved: https://www.youtube.com/watch?v=Acm11-OHwYA

Highlight 2: Manipulating Equilibrium Constants

Week 5's resources listed some of the rules for manipulating equilibrium constants when you are given an equation and K (as seen below) and need to find the K for a new equation. Let's see what this looks like in practice:

At a given temperature, K = 1.3 x 10^{-2} for the reaction

$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$

Calculate the values of K for the following reactions at this temperature.

a. $2NH_3\,(g) \rightleftharpoons N_2\,(g) + 3H_2\,(g)$

b. $\frac{1}{2}N_2\,(g) + \frac{3}{2}H_2\,(g) \rightleftharpoons NH_3\,(g)$

c. $NH_3\,(g) \rightleftharpoons \frac{1}{2}N_2\,(g) + \frac{3}{2}H_2\,(g)$

a. *Ask: How is this equation different from the original?* It's the reverse! If the K that we're given is equal to $\frac{[NH_3]^2}{[N_2][H_2]^3}$, how can we modify it to get $\frac{[N_2][H_2]^3}{[NH_3]^2}$? We should take the inverse. This aligns with the rule that we learned: $K' = K^{-1}$. So, since the original K = 1.3 x 10^-2, the new K is equal to $\frac{1}{1.3*10^{-2}} = 77$
b. *How is this equation different from the original?* The coefficients are different. How are they different. N2's coefficient used to be 1; now it's ½. It seems like everything has been multiplied by ½. Check and make sure that this is true of the other coefficients: 3*1/2=3/2, and 2*1/2=1. Yes and yes! The K that we're given is $\frac{[NH_3]^2}{[N_2][H_2]^3}$, and the K that we want is $\frac{[NH_3]^{2/2}}{[N_2]^{1/2}[H_2]^{3/2}} = \frac{([NH_3]^2)^{1/2}}{[N_2]^{\frac{1}{2}}([H_2]^3)\text{^}(1/2)} = \left(\frac{[NH_3]^2}{[N_2][H_2]^3}\right)^{\frac{1}{2}} = (original\ K)^{\frac{1}{2}}$. This aligns with the rule that we learned: $K' = K^r$ where r=constant by which all of the coefficients are multiplied. In this case, K'=0.11
c. Give c a try! The answer is at the end of this doc.

Highlight 3: Le Chatelier's Principle Applied

Given the following *exothermic* reaction,

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

What would be the impact of adding oxygen to the reaction at equilibrium?

You've increased the concentration of one of the reactants. $K = \frac{[SO_3]^2}{[SO_2]^2*[O_2]}$, and the reaction was at this "perfect ratio" before. But now, **Q** (remember, this basically means "K, but at any time, not just equilibrium") is less than what it was, because its denominator has increased. The reaction can counter this in several ways, summarized by stating that it will "**shift to the left**." More specifically…

What would happen to the SO2 concentration?

In an attempt to increase Q, to counter the addition of oxygen, the concentration of SO2 will decrease.

What would happen to the SO3 concentration?

In attempt to increase K, the SO3 concentration would increase.

What would be the impact of increasing the pressure?

Now, the reaction "feels" crowded. To reduce crowding, it will shift toward the side of the equation with less moles of gas. That is the right side, so concentration of SO3 will increase, and the other two will decrease.

According to Le Chatelier's, what would be the impact of heating the reaction?

The reaction is exothermic. That means that we can think of heat as one of the products. Having added a product is analogous to increasing Q, which means that the reaction will try to shift to the left. So, theoretically, the SO2 and O2 concentrations will increase, and the SO3 concentration will decrease.

This reality is why K is different at different temperatures! The ratio of products/reactants acceptable for a reaction depends on how fast the particles are moving. **It is how close they are to each other that matters; at any given temperature and pressure, this is regulated through concentration. But temperature and pressure change how close they are to each other, which is why they have an effect on K.**

Check Your Learning

Given the following reaction: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

1. If the initial concentrations are: $[H_2]_0 = 1.00 * 10^{-3}M, [I_2]_0 = 2.00 * 10^{-3}$, and HI at equilibrium is $[HI]_{eq} = 1.87 * 10^{-3}$, find Kc.
2. The reaction has a positive ΔG. What will be the effect on the ratio of products/reactants if it is cooled?
3. Don't forget to try Highlight 2 (c).

Things You May Struggle With

1. Don't forget to calculate Q before starting an I/C/E table problem, so that you know which "C" values are positive and which are negative.
2. The rules for manipulating equilibrium constants can be counterintuitive. For example, if the equation is multiplied by a constant, one cannot multiply the K value by that constant to get the K'. Instead, K is raised to the power of the constant. When in doubt, try writing out the original K equation, in terms of concentrations, and the K' equation that you are looking for, and compare the two.
3. Get lots of practice with Le Chatelier's. Make sure you practice temperature and pressure as well as effects of changing concentrations.

4. Understanding why the reaction shifts is very important and helps to avoid memorization! Spend some time reading the two bolded sentences right before the Check Your Understanding section.

That's all this week! Please reach out if you have any questions and don't forget to visit the Tutoring Center website for further information at www.baylor.edu/tutoring. Answers to Check Your Learning are below.

1. Kc=51, solved here: Lec6 - Equilibrium ICE Table Problems - YouTube
2. Reaction shifts to the left. Note: a positive ΔG means that the reaction is endothermic. It has more heat at the end than it did at the beginning. So, heat is like a reactant. Decreasing the amount of reactant is analogous to increasing Q, which means that the reaction will shift to the left. The product concentrations will increase, and the reactant concentrations will decrease.
3. Highlight 2 (c): Kc=8.8 (inverse of part b)