**EQUILIBRIUM**

# Equilibrium Introduction & “Q” L2 (10.5 min)

## Three key questions about reactions

### Will it go? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### How far will it go? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (100 %) and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (<100%)

### How fast will it go? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## State of Equilibrium

### Reactions in this case are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_and do not proceed 100% to product

* The concept of “percent completion” is not as helpful (although still used!!), because it can varying with initial molarity/partial pressure values
* In marketing terms, it is useful to compare the relative (stoichiometrically speaking – impress your friends with that one!) amounts of products and reactants. We call this the **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, Q.**

**NOTE: multiplication & division, not addition/subtraction!**

**aA + bB cC + dD**

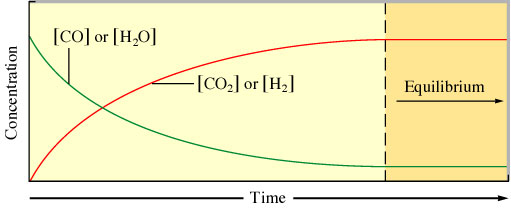
**NOTE: do not include solids and pure liquids!**

**OR**

### Q changes over the course of the reaction.

### The reaction reaches a stage at which the rate forward = rate reverse

**NOTE: the slope = zero. No change in concentration over time. BUT: the actual mlcls are changing with time**



### No \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_change in reactants and products on a macroscopic level.

### Still \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_– reactant 🡪 product & product 🡪 reactant on a microscopic level.

* “Q” becomes “K” = the equilibrium constant!
* 

# Equilibrium constant expression – L1 (9 min)

### The LAW OF MASS ACTION expresses the relative amounts as a QUOTIENT of products amounts (typically molarity or partial pressure) and reactant. Thankfully, the powers are derived directly from the coefficients of the overall balanced equation!

### We will discuss a variety of equilibrium systems over the next two units. A subscripted letter will indicate the type of equilibrium. The only real difference is the subscript! You solve them the same way.

|  |  |
| --- | --- |
| **Symbol** | **Equilibrium type** |
| **Kc** | General equilibrium expressed in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ measured as molarity |
| **Kp** | General equilibrium expressed in amounts measured as \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
| **Ksp** | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ actually dissolve a little. Ksp is called the solubility product and measures the equilibrium between the solid and the aqueous ions. |
| **Ka** | Measures an \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ equilibrium |
| **Kb** | Measures a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ equilibrium |

**EXAMPLES: Write the equilibrium constant expression for the following reactions:**

|  |  |
| --- | --- |
| **REACTION** | **EQUILIBRIUM EXPRESSSION** |
| H2(*g*) + Cl2(*g*) ⇄ 2HCl(*g*) | **KP =** |
| Cu (*s*) + 2Ag+(*aq*) ⇄ Cu2+ (*aq*) + 2Ag (*s*) | **Kc =** |
| 4KO2(*s*) + 2H2O(*g*) ⇄ 4KOH(*s*) + 3O2(*g*) | **Kc =** |

|  |  |
| --- | --- |
| **REACTION** | **EQUILIBRIUM EXPRESSSION** |
| Sr3(PO4)2 (*s*) ⇄ 3Sr2+ (*aq*) + 2PO43- (*aq*) | **Kc =** |
| C6H5O2-(*aq*) + H­2O(*l*) ⇄ HC6H5O2(*aq*) + OH-(*aq*) | **Kc =** |

# Equilibrium Constant Magnitude and Molarity – L1 (7.5 min)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Which is larger – numerator or denominator?** | **Side “favored” at equilibrium** |  | **Which is larger – numerator or denominator?** | **Side “favored” at equilibrium** |
| **K > 1** |  |  | **K < 1** |  |  |

## AS K\_\_\_\_\_\_\_AMT PROD AT EQUILIBRIUM \_\_\_\_\_\_\_

**EXAMPLES:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **INITIAL** | | | **EQUILIBRIUM** | | | **K** |
| ***[H2]*** | ***[I2]*** | ***[HI]*** | ***[H2]*** | ***[I2]*** | ***[HI]*** |  |
| ***0.50*** | ***0.50*** | ***0.0*** | ***0.11*** | ***0.11*** | ***0.78*** |  |
| ***0.0*** | ***0.0*** | ***0.50*** | ***0.055*** | ***0.055*** | ***0.39*** |  |
| ***0.50*** | ***0.50*** | ***0.50*** | ***0.165*** | ***0.165*** | ***1.17*** |  |
| ***1.0*** | ***0.5*** | ***0.0*** | ***0.53*** | ***0.033*** | ***0.934*** |  |

## As molarity or partial pressure \_\_\_\_\_\_\_\_\_\_\_ the equilibrium constant, K, \_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Equilibrium and Reaction manipulations (9.5 min)

**EXAMPLES:** Write equilibrium constant expressions for the following reactions. What is the mathematical relationship (assuming T is constant)?

|  |  |  |
| --- | --- | --- |
| **Reaction** | **Kc** | **Mathematical relationship?** |
| 1. H2(*g)* + I2 (*g*) ⇄ 2HI (*g*) | KC1 = | NA |
| 2. 2HI (*g*) ⇄ H2(*g)* + I2 (*g*) | KC2 = |  |
| 3. ½ H2(*g)* + ½ I2 (*g*) ⇄ HI (*g*) | KC3 = |  |

**EXAMPLES:** Write equilibrium constant expressions for the following reactions. How can the first two equations be manipulated to form the third? Calculate KC3.

|  |  |
| --- | --- |
| **Reaction** | **Kc** |
| 1. Co(*s*) + H­2O(*g*) ⇄ CoO(*s*) + H2(*g*) K1 = 0.0149 | KC1 = |
| 2. CoO(*s*) + CO(*g*) ⇄ Co(*s*) + CO2(*g*) K2 = 490 | KC2 = |
| 3. H2O(*g*) + CO(*g*) ⇄ H2(*g*) + CO2(*g*) K3 = ? | KC3 = |

**SUMMARY**

### If a reaction is reversed, you take the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_of the original equilibrium constant.

### If you multiply a reaction by a factor, you \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### If you \_\_\_\_\_\_\_\_\_\_\_\_\_\_reactions, you \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_equilibrium constants

**Kp = Kc(RT)∆n** where **∆n = ∑moles product gas - ∑moles reactant gas AND R=0.0821 (typically)**

## The Reaction Quotient, Q as a reaction PREDICTOR (11 min)

* Helps determine which direction a system will go to reach equilibrium
* Calculated the same as K, but uses \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_amounts instead of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |
| --- | --- | --- | --- |
|  | **NUMERATOR: TOO BIG OR TOO SMALL?** | **PRODUCT: TOO MUCH OR TOO LITTLE?** | **SHIFT: MORE REACTANT OR MORE PRODUCT?** |
| K > Q |  |  |  |
| Q = K |  |  |  |
| K < Q |  |  |  |

Q

K

K

K

Q

Q

**R 🡪 P R 🡨 P**

**EXAMPLES:** The reaction: NOBr(*g*) ⇄ NO(g) + ½ Br2(*g*) has been carefully studied at 350 ºC and the Kc is 0.079. Which direction will the reaction proceed to establish equilibrium under each of the following initial conditions? ***NOTE: the subscripted “0” indicates at t=0 or at the beginning***

**R: REACTION I: INITIAL C: CHANGE E: EQUILIBRIUM (E=I+C)**

|  |  |
| --- | --- |
| **Initial Conditions** | **“RICE” TABLE** |
| [NOBr]o = 0.100 M  [NO]o = 0  [Br2]o = 0 | |  |  |  |  | | --- | --- | --- | --- | | **R** | **NOBr(*g*) ⇄** | **NO(g) +** | **½ Br2(*g*)** | | **I** |  |  |  | | **C** |  |  |  | | **E** |  |  |  | |
| [NOBr]o = 2.00  [NO]o = 0.100 M  [Br2]o = 0.100 M | |  |  |  |  | | --- | --- | --- | --- | | **R** | **NOBr(*g*) ⇄** | **NO(g) +** | **½ Br2(*g*)** | | **I** |  |  |  | | **C** |  |  |  | | **E** |  |  |  | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [NOBr]o = 2.3 x 10─4 M  [NO]o = 2.3 x 10─3 M  [Br2]o = 2.3 x 10─3 M | |  |  |  |  | | --- | --- | --- | --- | | **R** | **NOBr(*g*) ⇄** | **NO(g) +** | **½ Br2(*g*)** | | **I** |  |  |  | | **C** |  |  |  | | **E** |  |  |  | |

## Equilibrium, DSE, and RICE (12 min)

# FRAMEWORK FOR PROBLEM SOLVING:

✔ **Identify substances present**

|  |  |
| --- | --- |
| **STOICHIOMETRY** | **EQUILIBRIUM** |
|  |  |
|  |  |
|  |  |
|  |  |

✔ **Do you need to do any dilutions?** Whenever volume is added to volume you need to VooM-VooM!

✔ **Are there any stoichiometry calculations?** soluble salts, strong acids & bases, acid + base. Results of a stoichiometry *typically* go into the initial concentration row in RICE

✔ **Let’s do the equilibrium!**

**If you can identify, then follow the acronym ‘DSE’ – Dilution, Stoichiometry, Equilibrium.**

**Memory Device: Doc Saves Everyone!**

**EXAMPLE:** A rigid vessel at a temperature of 25oC initially has a partial pressure of NO equal to 0.526 atm and a partial pressure of Br2 equal to 0.329 atm. At equilibrium the partial pressure of Br2 is 0.203 atm. (a) Calculate Kp and Kc for the reaction: 2NO(*g*) + Br2(*g*) **⇄** 2NOBr(*g*) (b) Calculate the total pressure in the container once equilibrium has been established.

✔ **Identify substances present** ✔ **Dilutions?** ✔ **stoichiometry calculations?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** | **2NO(*g*) +** | **Br2(*g*) ⇄** | **2NOBr(*g*)** | **Equilibrium Constant Expression:** |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

## Equilibrium and RICE Part 2 (11 min)

**EXAMPLE:** At some temperature, Kp = 0.050 for the reaction below. In an experiment, 0.4 mol of O2 and 0.4 mol of N2 were introduced into a flask at a total pressure of 1 atm.  Calculate the partial pressure of NO at equilibrium

✔ **Identify substances present** ✔ **Dilutions?** ✔ **stoichiometry calculations?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** | **N2 (g) +** | **O2 (g)** ⇄ | **2NO (g)** | **Equilibrium Constant Expression:** |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

**EXAMPLE:** The equilibrium constant, for the decomposition of sulfur trioxide is 1.6 x 10-10. Calculate the equilibrium concentrations of all species if a 0.100 L flask of 0.025 *M* sulfur trioxide is transferred to a 0.250 L flask under conditions that allow decomposition.

✔ **Identify substances present** ✔ **Dilutions?** ✔ **stoichiometry calculations?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** | **2SO3 (*g*) ⇄** | **2SO2 (*g*) +** | **O2 (*g*)** | **Equilibrium Constant Expression:** |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

**Equilibrium & % Reaction (11 min)**

**EXAMPLE:** The following reaction occurs at 298K. When 2.00 mol of HI are placed into a 1.00 liter container and permitted to react it is found that 20.0 % of the HI has decomposed at equilibrium. Calculate Kc.

✔ **Identify substances present** ✔ **Dilutions?** ✔ **stoichiometry calculations?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** | **2HI(*g*) ⇄** | **I2(*g*) +** | **H2(*g*)** | **Equilibrium Constant Expression:** |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

**EXAMPLE:** At 2000 K the equilibrium constant, *K*, for the synthesis of NO(*g*) is 4.0 x 10-4. You mix 10.00 mL of a 2.50 *M* solution of N2, 10.00 mL of a 2.50 *M* solution of O2, and 10.00 mL of a 8.4 x 10-2 *M* solution of NO and dilute the mixture to a final volume of 100.00 mL. (1) Determine the equilibrium concentrations of all species. HINT: calculate Q! (2) calculate the % reaction.

✔ **Identify substances present** ✔ **Dilutions?** ✔ **stoichiometry calculations?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** |  |  |  | **Equilibrium Constant Expression:** |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

**SOLUBILITY CONSTANT, Ksp (15 min)**

* Insoluble salts are actually **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**soluble.
* Equilibrium will be established between the insoluble salt (always the reactant) and the **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**ions (always products).
* Use Ksp to determine either (1) solubility **S** or (2) whether or not precipitation will occur.

|  |  |  |
| --- | --- | --- |
|  | **Prod > or < Reactant?** | **Precipitation?** |
| **Ksp > Q** |  |  |
| **Ksp < Q** |  |  |

## A. Solubility

All Ksp calculations involve a salt in equilibrium with its constituent aqueous ions.

**Ex. PbCl2(*s*) ⇄ [PbCl2(*aq*)]🡪 Pb2+(*aq*) + 2Cl─(*aq*)**

**SOLUBILITY**: **(S)** Amount of an insoluble salt that will dissolve to form a **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**at a given temperature. **WATCH UNITS**! In RICE we will deal with molarity, but the question may ask for the solubility in **g/L**!

**KEY:** The presence of **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**solid is evidence the solution is **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.** How much solid is irrelevant!

**S = [PbCl2]aq** since the mole ratio is 1:1 for the lead ion, then [Pb2+] =S. The mole ratio for Cl─ is 2:1 so [Cl─] = **2**S.

**EXAMPLES:** Write solubility equilibrium reactions for each of the following “insoluble” salts. Write expressions for each ion concentration in terms of **“S”**.

|  |  |
| --- | --- |
| **Dissociation:** | CaSO4(*s*) |
| **Ksp in terms of *M*** |  |
| **Ksp in terms of “S”** |  |
| **Dissociation:** | Ag2SO4 |
| **Ksp in terms of *M*** |  |
| **Ksp in terms of “S”** |  |
| **Dissociation:** | Ca3(PO4)2 |
| **Ksp in terms of *M*** |  |
| **Ksp in terms of “S”** |  |

**SUMMARY:**

|  |  |
| --- | --- |
| **ION RATIO** | **Ksp in terms of solubility, “S”** |
| **1:1** |  |
| **1:2** |  |
| **1:3** |  |
| **2:3** |  |
| **1:4** |  |

## SOLUBILITY EQUILIBRIUM Ksp Problems (9 min)

**EXAMPLE:** Calcium fluoride, the main component of mineral fluorite, dissolved to a slight extent in water. Calculate the Ksp value for CaF2 if the calcium ion concentration has been found to be 2.4 x 10─ 4 M.

✔ **Identify substances present – *“insoluble” salt***

**NOTE: Because the salt is a solid, it does not show up in the equilibrium expression**

✔ **Do you need to do any dilutions?** ***Nope***

✔ **Are there any stoichiometry calculations? *Nope***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** |  |  |  |  |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

**EXAMPLES:** What is the solubility of cobalt (II) phosphate in molarity and g/L at 25oC if Ksp = 2.05 x 10─35? Determine the concentrations of all ions present.

✔ **Identify substances present** ✔ **Dilutions?** ✔ **stoichiometry calculations?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** |  |  |  | **Equilibrium Constant Expression:** |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

## Ksp & Common Ions (12 min)

## The addition of a soluble salt that provides an ion that is \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ with the insoluble salt will impact the amount of salt that will dissolve. The common ion concentration typically goes in the \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ of RICE. WARNING! YOU WILL BE TEMPTED TO ADD THE TWO SUBSTANCES TOGETHER AND MAKE A VERY COMPLICATED REACTION

**EXAMPLE:** What is the solubility (in g/L) of lead (II) chloride in a solution containing 0.55 M CaCl2? Ksp = 1.7 x 10─5

✔ **Identify substances present**

✔ **Do you need to do any dilutions?**

✔ **Are there any stoichiometry calculations?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** |  |  |  |  |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

**EXAMPLE:** Calculate the solubility of silver chromate at 25oC in the presence of 0.0050 M potassium chromate solution. Determine the concentrations of all ions present in the solution. Ksp = 1.1 x 10***─*12**

✔ **Identify substances present** ✔ **Dilutions?** ✔ **stoichiometry calculations?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **R** |  |  |  | **Equilibrium Constant Expression:** |
| **I** |  |  |  |
| **C** |  |  |  |
| **E** |  |  |  |

**Ksp & Precipitation (10.5 min)**

**EXAMPLE:** Will precipitation of nickel (II) carbonate occur if solutions containing 0.0024 *M* NiCl2 and 1.2 x 10***─***4 *M* K2CO3 are mixed? Ksp = 1.4 x 10***─***7

***Watch for that helpful mmr!***

✔ **Identify substances present**

✔ **Do you need to do any dilutions?**

✔ **Are there any stoichiometry calculations?**

**EXAMPLE:** A 50.0 mL sample of 0.00152 M Na2SO4 is added to 50.0 mL of 0.00125 M Ca(NO3)2. Ksp = 9.1 x 10***─***6. Should precipitation of CaSO4 occur?

✔ **Identify substances present**

✔ **Do you need to do any dilutions?**

✔ **Are there any stoichiometry calculations?**

**Ksp Magnitude & Solubility (6 min)**

Ksp of Ti(OH)4 is 7 x 10***─***53 and Ksp of Sn(OH)4 is 1 x 10***─***57. Which salt has the greatest solubility? Justify your answer.

Magnesium phosphate, Ksp = 9.86 x 10***─***25 and Fe(OH)2, Ksp = 4.87 x 10***─***17. Which salt has the greatest solubility? Justify your answer.

**Le Chatelier Part 1 (17 min)**

In chemistry, we may purposely disturb an equilibrium in order to get more products and make more money! When an equilibrium system is disturbed by changing molarity values, partial pressures, total pressure, and temperature: rates change and Q changes. The system will “shift” (proceed in either the forward or reverse direction) to re-establish equilibrium.

**EXAMPLE: 2SO2 (g) + O2 (g) ⇄ 2SO3 (g) ΔH = —**

1. is increased:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

1. is decreased:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

1. is increased:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

1. total pressure is decreased (volume is increased):

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

1. temperature is increased:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

1. temperature is decreased:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

1. argon is added at constant volume:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

1. helium is added at constant pressure:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

1. a catalyst is added:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rate changes** | **Q change** | **Reactant change** | **Product change** | **K change** |
|  |  |  |  |  |

**If I wanted to make lots of product, would it be best to run this reaction at high or low temperatures?**

**If I wanted to make lots of product, would it be best to run this reaction at high or low pressures?**

**Le Chatelier Part 2 (11 min)**

**EXAMPLE:**

Predict and justify the response to the following stresses.

**N2 + O2 + heat ⇌ 2NO**

1. Volume is increased
2. Temperature is increased

**EXAMPLES:**

Would the solubility of the following slightly soluble ions increase or decrease under the following conditions? Justify your answers.

1. AgCl with CaCl2 added.
2. PbCl2 with more PbCl2 added
3. Ca(OH)2 with a strong acid slowly added.
4. Ca(OH)2 with a strong base slowly added.

**Summary chart:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **STRESS** | **AFFECT ON Q** | **SHIFT TO RE-ESTABLISH EQUIL.** | **EFFECT ON [REACTANTS]** | **EFFECT ON [PRODUCTS]** |
| ↑ [reactant] |  |  |  |  |
| ↓ [reactant] |  |  |  |  |
| ↑ [product] |  |  |  |  |
| ↓ [product] |  |  |  |  |
| ↑ T, endo |  |  |  |  |
| ↑ T, exo |  |  |  |  |
| ↓ T, endo |  |  |  |  |
| ↓ T, exo |  |  |  |  |
| ↑ P by ↓ V |  |  |  |  |
| ↓ P by ↑V |  |  |  |  |
| + inert gas  constant V |  |  |  |  |
| + inert gas  constant P |  |  |  |  |
| Catalyst |  |  |  |  |