

7. Quantitative Equilibrium (II.6)

a) Equilibrium Expression

i) we can quantify (attach a numerical value) the equilibrium for most reactions by creating a **ratio of products to reactants**.

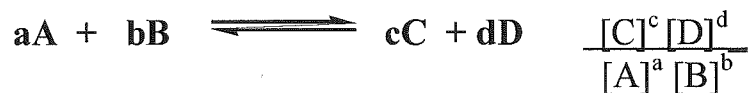


$$\frac{[C][D]}{[A][B]} \quad \text{or} \quad \frac{[\text{Products}]}{[\text{Reactants}]}$$



$$\frac{[\text{H}_2][\text{I}_2]}{[\text{HI}][\text{HI}]} \quad \text{or} \quad \frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]^2}$$

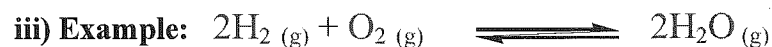
iv) The general expression for the equilibrium reaction is:



b) Equilibrium Constant

i) the **ratio** obtained from the above equilibrium expression is a number unique to a particular reaction.

ii) This ratio is called the **Equilibrium Constant** or **Keq**



$$\text{Keq} = \frac{[\text{H}_2\text{O}]^2}{[\text{H}_2]^2 [\text{O}_2]}$$



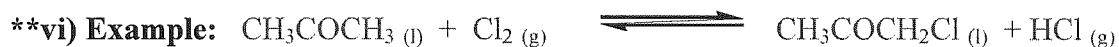
$$K_{eq} = [\text{Ba}^{+2}][\text{SO}_4^{-2}]$$

(Solids are omitted in the K_{eq} expression, because they do not affect the equilibrium.
[solids] is not possible to change!! You ever hear of weak sugar? Strong sugar?!)



$$K_{eq} = [\text{N}_2][\text{H}_2]^3$$

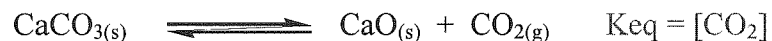
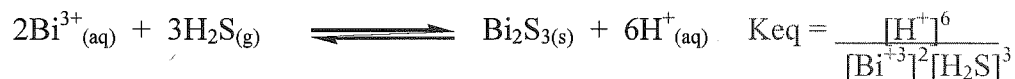
(Liquids are omitted in the K_{eq} expression, because they do not affect the equilibrium.
Can water ever be strong or weak? No. Water is water. Its [] doesn't change.)



$$K_{eq} = \frac{[\text{CH}_3\text{COCH}_2\text{Cl}][\text{HCl}]}{[\text{CH}_3\text{COCH}_3][\text{Cl}_2]}$$

(*Exception: if TWO liquids are in a reaction, they will dilute each other. This affects the concentration and thus the equilibrium. So they are included in the K_{eq} expression)

vii) Write the K_{eq} for the following reactions:



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c) **What does the K_{eq} Value Mean?** $K_{eq} = \frac{[products]}{[reactants]}$

- a Large K_{eq} = Large amount of products present at equilibrium $K_{eq} = \frac{[10]}{[1]} = \text{large } K_{eq}$
- a Small K_{eq} = Small amount of products present at equilibrium $K_{eq} = \frac{[1]}{[10]} = \text{small } K_{eq}$
(large amounts of reactants present at equilibrium)

d) **Factors that Affect K_{eq}**

i) **Pressure, concentration, surface area, catalyst**

- The K_{eq} for every reaction is unique.
- If we change one of the above factors, the K_{eq} is momentarily altered.
- But according to Le Chatelier's principle, the equilibrium will re-establish at the original K_{eq} !
- Changes in pressure, concentration, surface area and catalyst have no effect on K_{eq} .

ii) **Temperature.**

- If we add a bunch of heat to the reaction and then stop, the equilibrium will re-establish at the original K_{eq} (just like above for pressure etc.)
- BUT if we heat to a certain temperature and hold that temperature indefinitely, the equilibrium will permanently shift (according to exo or endothermic)
- This permanent shift will change the K_{eq}

iii) **Summary**

- all factors, if changed, will momentarily shift an equilibrium, but the equilibrium will re-establish thus not affecting the K_{eq} value.
- temperature is the only factor that we can continually keep adding or removing, and if this is done we can affect the K_{eq} value.

iv) **Example:** $2\text{NO}(g) + \text{Cl}_2(g) \rightleftharpoons 2\text{NOCl}(g) + 76\text{kJ}$

What happens to the K_{eq} in the above reaction if:

- temperature is increased and held K_{eq} decreases...rxn initially shifts left
- heat is added for 5 seconds nothing to K_{eq} ...rxn initially shifts left
- temperature is decreased and held K_{eq} increasesrxn initially shifts right
- $\text{NO}_{(g)}$ is added nothing to K_{eq} ...rxn initially shifts right