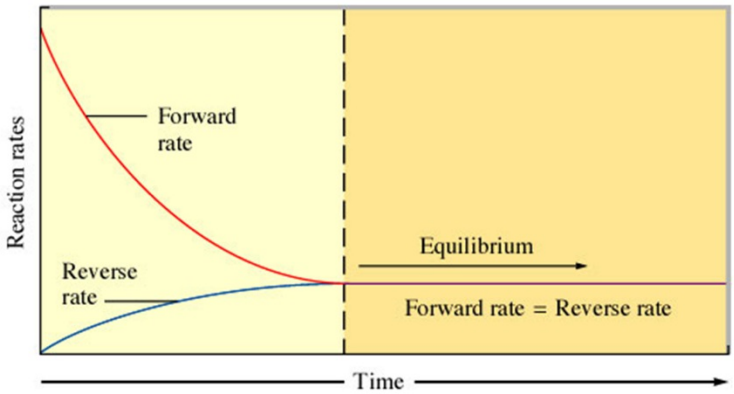
Equilibrium Notes

1. What is Equilibrium?

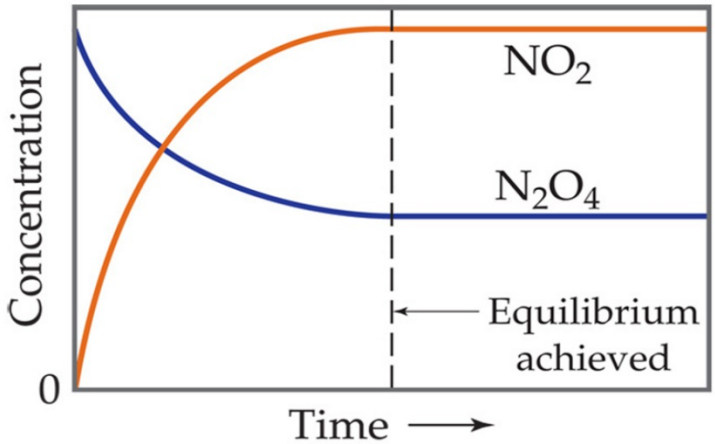


forward rxn rate
= reverse rxn rate

∴ [reactant] remains constant

& [product] remains constant

[reactants] ≠ [products]



2. What sign in a chemical equation tells you "Equilibrium"?

$\rightleftharpoons$ $\rightleftharpoons$ $\leftrightarrow$

3. What is the generic formula of the Equilibrium Constant Expression for concentration? For Pressure?

$$aA(g) + bB(g) \leftrightarrow cC(g) + dD(g)$$

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} \qquad K_p = \frac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b}$$

4. What types of species are used in K expressions?

gases & aqueous only

5. Does K change when starting concentrations/pressures are changed?

No

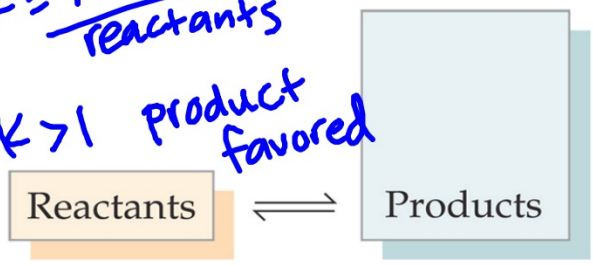
6. Does K change when temperature is changed?

yes

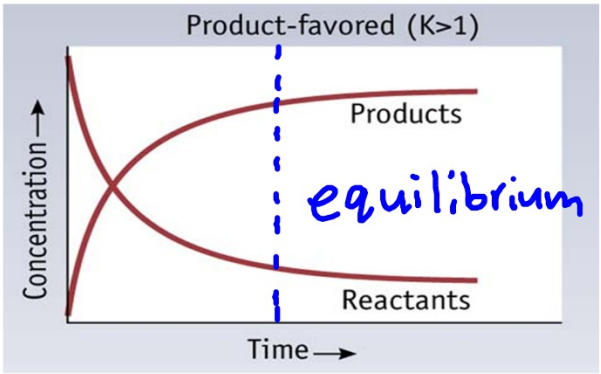
7. How can the value of K be used to tell you which side is favored?

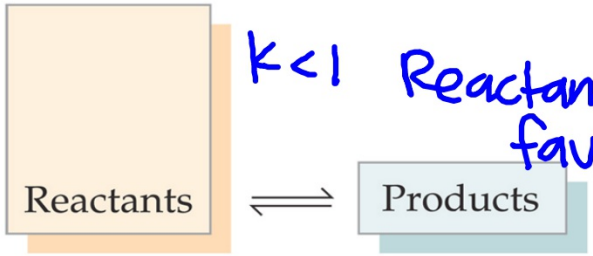
$K = \frac{\text{Products}}{\text{reactants}}$

$K > 1$ product favored



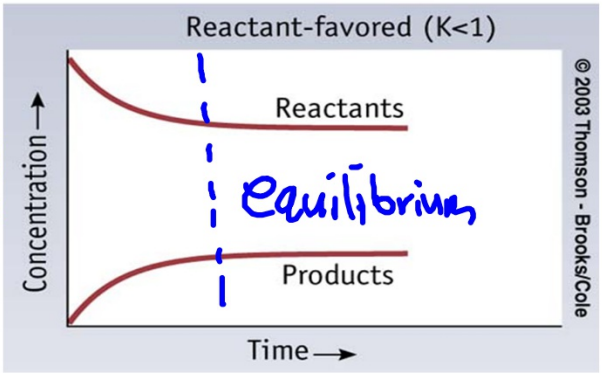
$K >> 1$





$K < 1$ Reactant favored

$K << 1$



8. What are the 3 rules for adjusting an equilibrium constant expression and explain how they work?

$K = \frac{\text{products}}{\text{reactants}}$

① Flip Reactants/Products = reciprocal of original K

$A + B \rightleftharpoons C \quad K = 2$

$C \rightleftharpoons A + B \quad K = \frac{1}{2}$

② Multiply coefficient = raise original K to the power of factor "n"

$A + B \rightleftharpoons C \quad K = 2$

$3A + 3B \rightleftharpoons 3C \quad K = (2)^3 = 8$

③ Add Eqns = Multiply K values

$A + B \rightleftharpoons C \quad K = 2 = [C]/[A][B]$

$D + E \rightleftharpoons F \quad K = 3 = [F]/[D][E]$

$A + B + D + E \rightleftharpoons C + F \quad K = (2)(3) = 6$

$$K = \frac{[C][F]}{[A][B][D][E]} = \left(\frac{[C]}{[A][B]}\right)\left(\frac{[F]}{[D][E]}\right)$$

9. What is the mathematical relationship between Kp and Kc?

$$K_p = K_c (RT)^{\Delta n}$$

10. In the mathematical relationship what is delta n? What value of R is used?

Δn = change in moles of gas (gas products − ga reactants)

★ coefficients

$R = 0.0821 \frac{L \cdot atm}{mol \cdot K}$

T = temp in kelvin

Ex) $2H_{2(g)} + O_{2(g)} \longleftrightarrow 2H_2O_{(g)}$

$\Delta n = 2-(2+1)$

$\Delta n = -1$

11. What is the Reaction Quotient (Q)? How is it used to decide which way a reaction will shift to reach equilibrium if the reaction is not yet at equilibrium?

$Q = \frac{\text{products}}{\text{reactants}}$ (calculated same way as K)

use Q when <u>not</u> at equilibrium

If $Q = 0$ (reactants only) then shifts forward →

$Q < K$ then shift forward →

$Q = K$ at equilibrium, no shift

$Q > K$ then shift reverse (backwards) ←

$Q \infty$ then shift reverse ←

(Products only)

12. What is LeChatlier's Principle?

When a stress is applied to a system at equilibrium, the system will move in a direction opposite of the stress to reestablish equilibrium

$$2H_2 + O_2 \longleftrightarrow 2H_2O$$

Stress	Shift
- incr. [reactant]	- shift forward to incr. [product]
- incr. [product]	- shift reverse to incr. [reactant]
- decr. [reactant]	- shift reverse to decr. [product] incr. [reactant]
- decr. [product]	- shift forward to decr. [reactant] incr. [product]
- decr. Volume / incr. P	- shift to side w/ less moles of gas
- Incr. Volume / decr. P	- shift to side w/ MORE moles of gas

Stress	Shift
- incr. T	- shift to side w/ NO Heat
EXO	
$A + B \rightleftharpoons C + Heat$	- shift reverse
Endo	
$Heat + A + B \rightleftharpoons C$	- shift forward
- Decr. T	- shift to side w/ Heat

Exercise 1: Write the equilibrium expressions for K_c and K_p for the following reactions.

a. $4NH_3(g) + 7O_2(g) \leftrightarrow 4NO_2(g) + 6H_2O(g)$

$$K_c = \frac{[NO_2]^4[H_2O]^6}{[NH_3]^4[O_2]^7} \qquad K_p = \frac{(P_{NO_2})^4(P_{H_2O})^6}{(P_{NH_3})^4(P_{O_2})^7}$$

b. $PCl_5(s) \leftrightarrow PCl_3(l) + Cl_2(g)$

$$K_c = [Cl_2] \qquad K_p = P_{Cl_2}$$

c. $CuSO_4 \cdot 5H_2O\ (s) \leftrightarrow 5H_2O(g) + CuSO_4(s)$

$$K_c = [H_2O]^5 \qquad K_p = (P_{H_2O})^5$$

Exercise 2: The following equilibrium concentrations were observed for the reaction at 127°C:

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$$

$[NH_3] = 3.1 \times 10^{-2}$ M $\quad [N_2] = 8.5 \times 10^{-1}$ M $\quad [H_2] = 3.1 \times 10^{-3}$ M

a. Calculate the value of K at 127°C for this reaction.

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(3.1 \times 10^{-2})^2}{(8.5 \times 10^{-1})(3.1 \times 10^{-3})^3} = \boxed{3.8 \times 10^4}$$

b. Calculate the value of K at 127°C for the reaction: $2NH_3(g) \leftrightarrow N_2(g) + 3H_2(g)$

$$K = \frac{1}{3.8 \times 10^4} = \boxed{2.6 \times 10^{-5}}$$

c. Calculate the value of K at 127°C for the reaction given by the equation: $\frac{1}{2} N_2(g) + 3/2\ H_2(g) \leftrightarrow NH_3(g)$

$$K = (3.8 \times 10^4)^{1/2} = \boxed{1.9 \times 10^2}$$