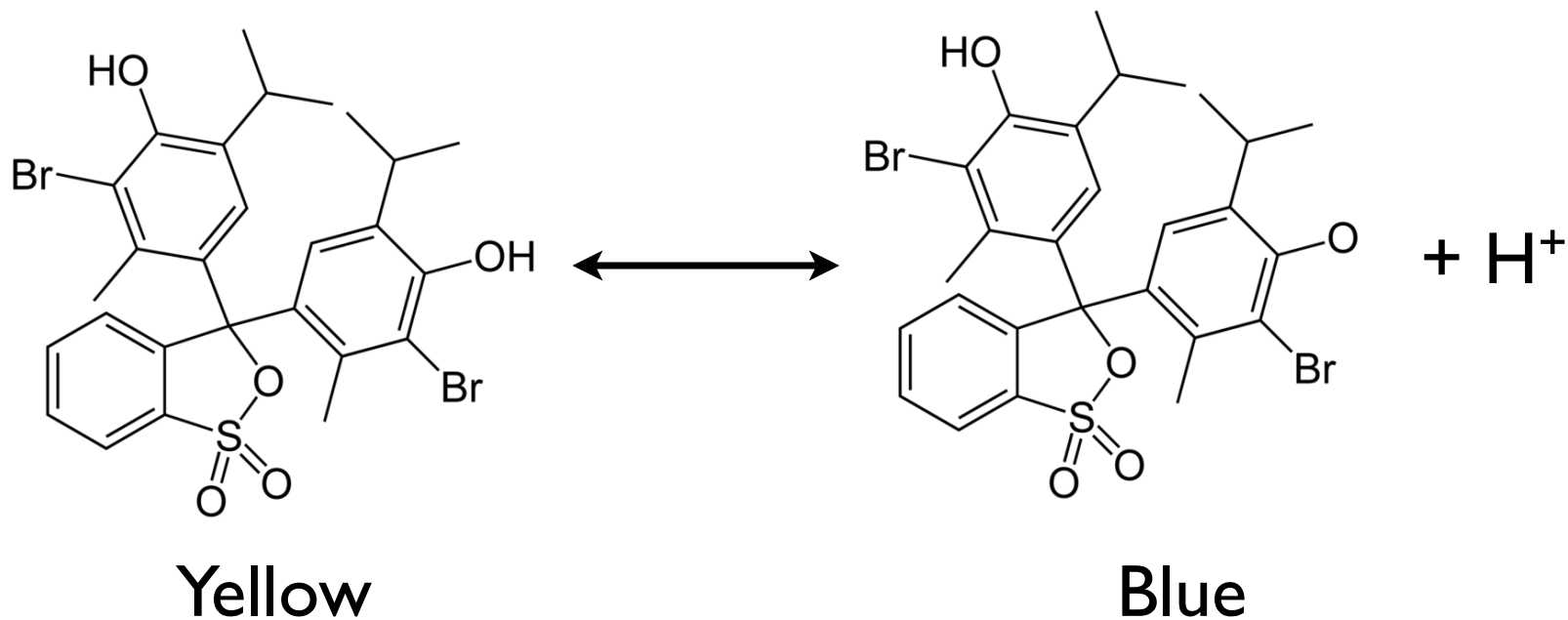


Why did the color stop changing?

- A. the reactants were all converted into products
- B. the reaction came to equilibrium
- C. the forward and backward reaction had the same rate
- D. B & C
- E. all of the above



What is changing is the ratio of the yellow form to the blue form

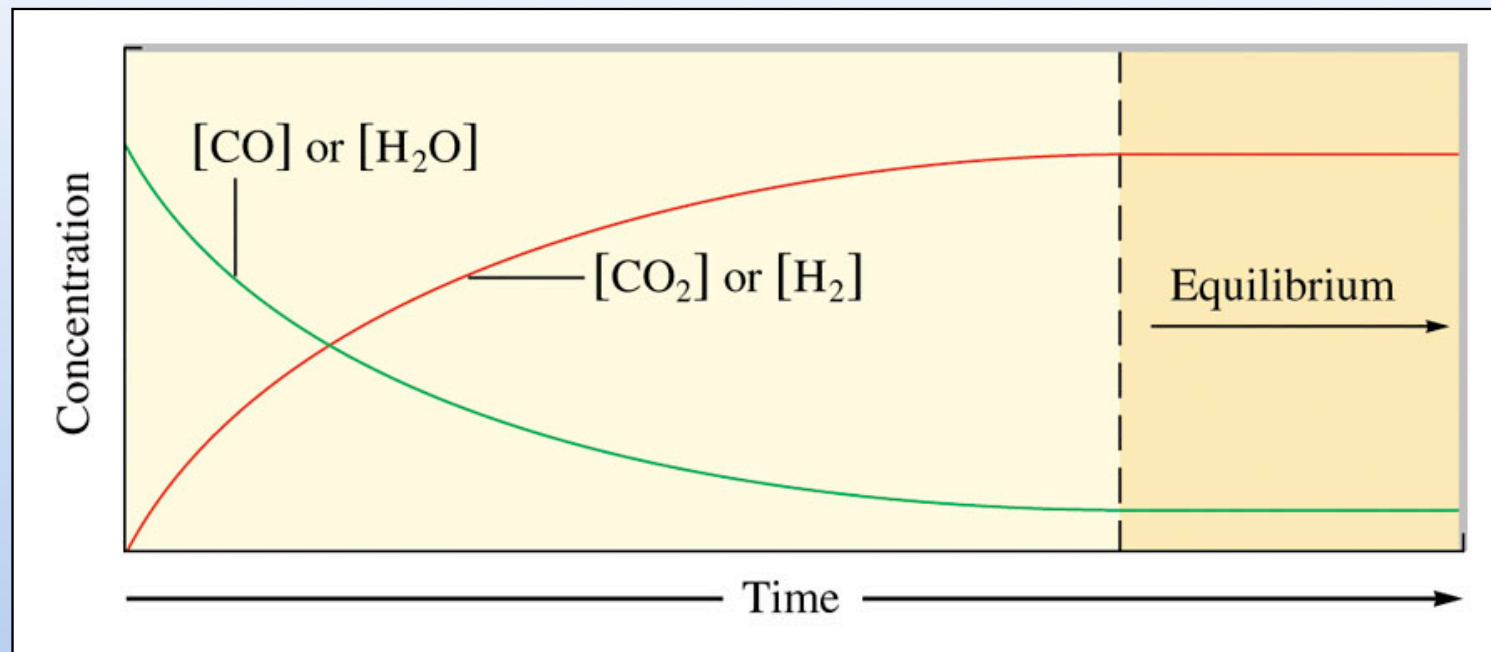


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At equilibrium the ratio of the molecules stops changing

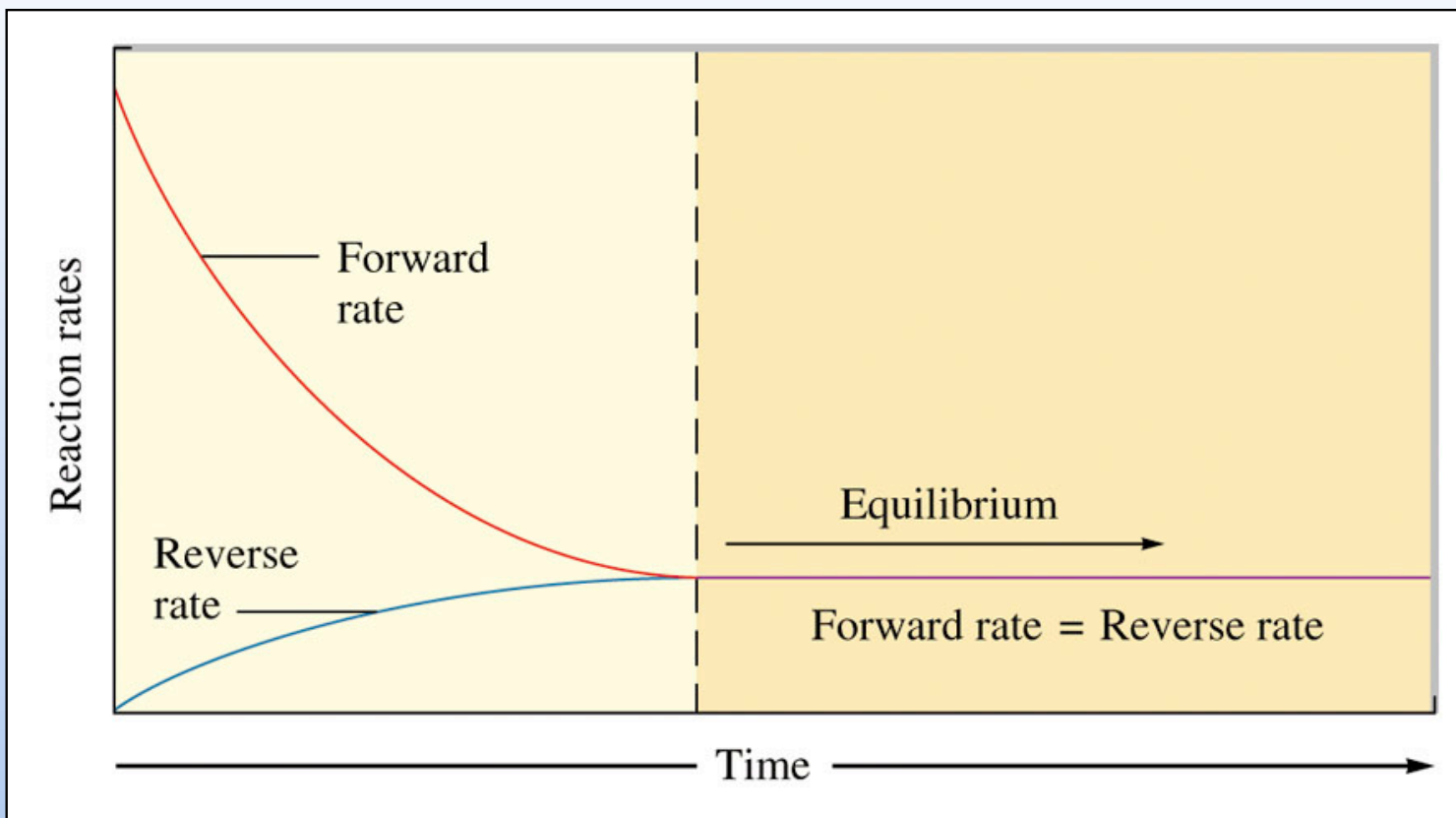


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Key Idea

At equilibrium the ratio of the products to the reactants is fixed

We'll give the ratio a name

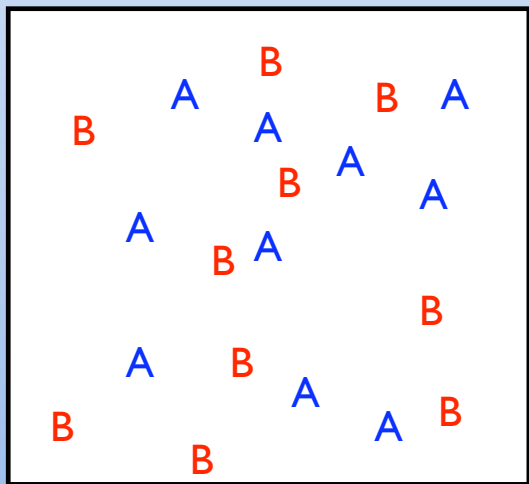
K

we'll call it the Equilibrium Constant
since it is related to equilibria and a constant

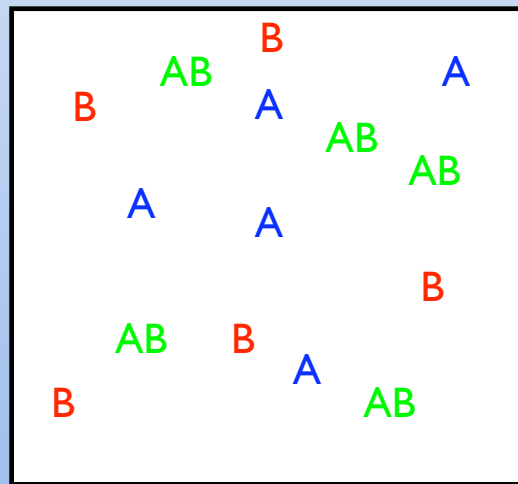
Let's look at a simple reaction between two molecules

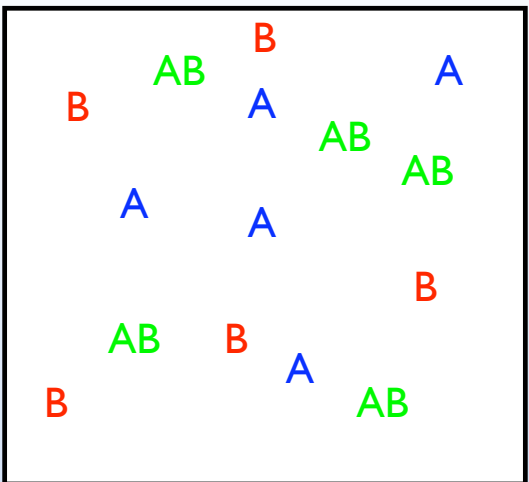


Let's start with
10 molecules of A
10 molecules of B



At equilibrium we find
5 A, 5 B, and 5 AB



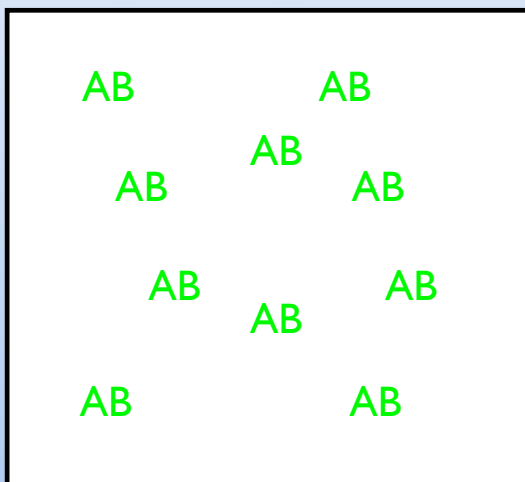


Ratio of Products to Reactants

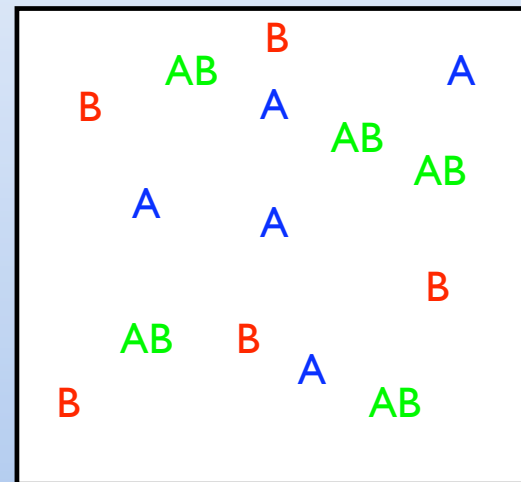
$$\frac{\#AB}{\#A \times \#B} = \frac{5}{(5) \times (5)} = \frac{1}{5}$$

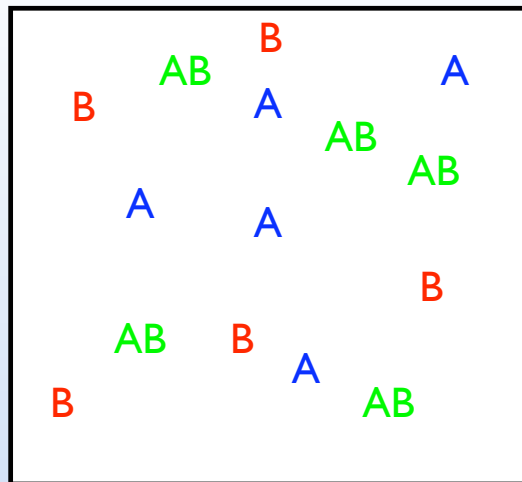


Let's start with
10 molecules of AB



At equilibrium we find
5 A, 5 B, and 5 AB





Ratio of Products to Reactants

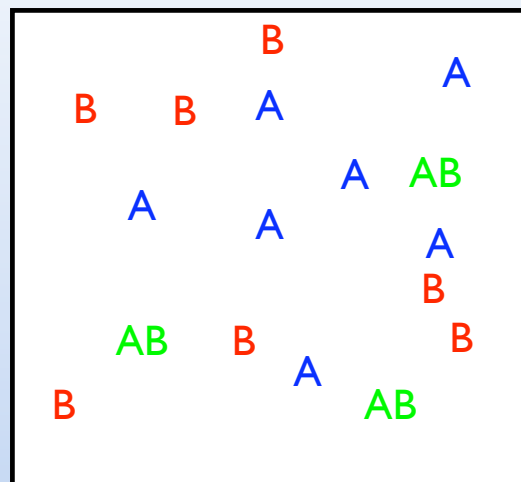
$$\frac{\#AB}{\#A \times \#B} = \frac{5}{(5) \times (5)} = \frac{1}{5}$$

Same Ratio Starting from
Different initial conditions!

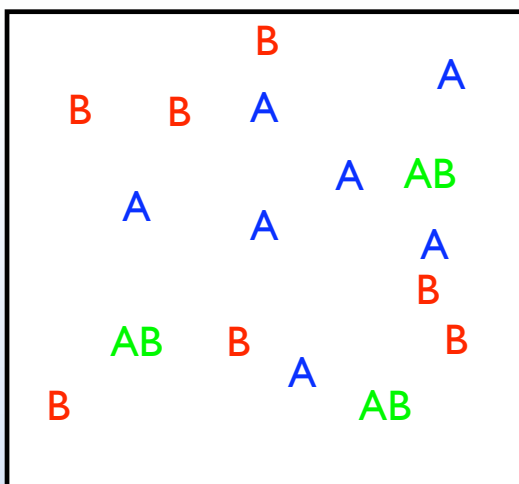
At equilibrium the ratio will
always be the same

Let's Look at a new condition

7 A, 7B, 3 AB



- A. equilibrium
- B. not at equilibrium



Ratio of Products to Reactants

$$\frac{\#AB}{\#A \times \#B} = \frac{3}{(7) \times (7)} = \frac{3}{49}$$

Not equal to 1/5 Therefore not a equilibrium

The ratio at any given instant is called
Q the reaction quotient

At equilibrium when $Q = K$

Direction towards Equilibrium

$Q > K$ "too many" products
reaction proceeds back to reactants

$Q < K$ "too many" reactants
reaction proceeds forward to products

How do we write K for a reaction?

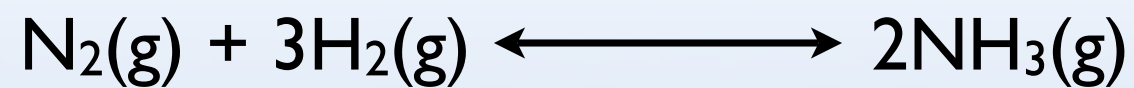
Concentrations



$$K = \frac{\text{Products}}{\text{Reactants}} = \frac{[C]^l [D]^m}{[A]^j [B]^k}$$

Pressures

$$K_p = \frac{\text{Products}}{\text{Reactants}} = \frac{P_C^l P_D^m}{P_A^j P_B^k}$$



$$K = \frac{\text{Products}}{\text{Reactants}} = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$$

How do we know K?

$$\Delta_{\text{R}}G^{\circ} = -RT \ln K$$

$\Delta_{\text{R}}G^{\circ} < 0$ $K > 1$ favors products

$\Delta_{\text{R}}G^{\circ} > 0$ $K < 1$ favors reactants

$$\ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta H_{vap}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\Delta T = iK_b m_{\text{solute}}$$

$$P_{\text{solvent}} = X_{\text{solvent}} P^\circ$$

$$\Delta T = -iK_f m_{\text{solute}}$$

$$\Delta P = -iX_{\text{solute}} P^\circ$$

$$\Pi = iMRT$$

$$1 \text{ atm} = 760 \text{ Torr}$$

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$R = 0.08206 \text{ L-atm K}^{-1} \text{ mol}^{-1}$$