Why did the color stop changing?

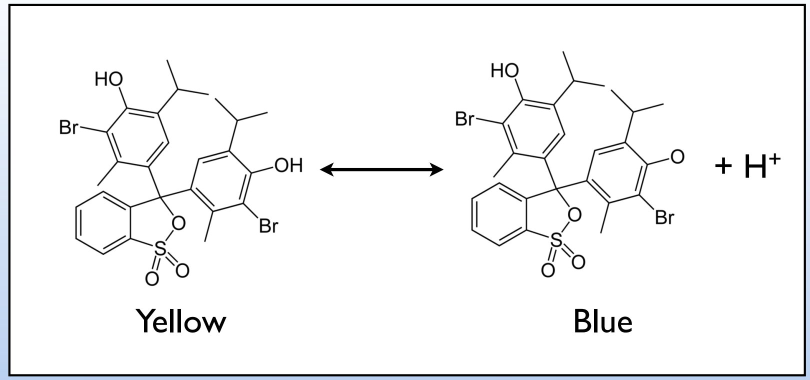
A. the reactants were all converted into products

B. the reaction came to equilibrium

C. the forward and backward reaction had the same rate

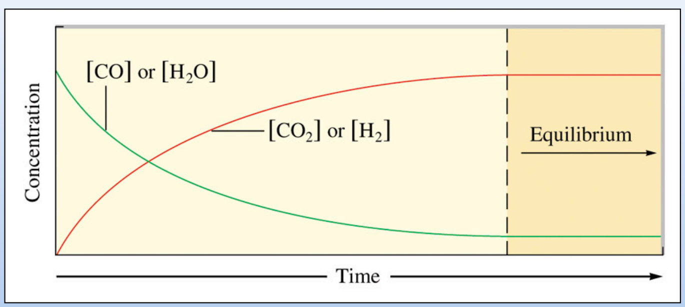
D. B & C

E. all of the above

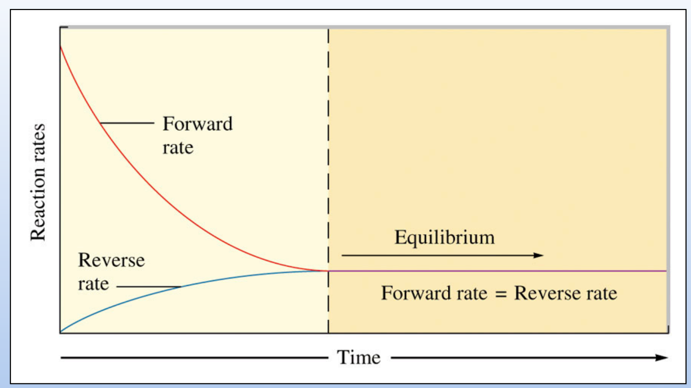


What is changing is the ratio of the yellow form to the blue form

$H_2O + CO \longleftrightarrow H_2 + CO_2$



At equilibrium the ratio of the molecules stops changing



Key Idea

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

We'll give the ratio a name

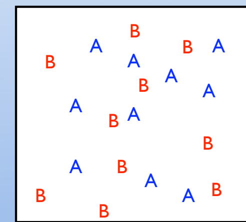
K

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

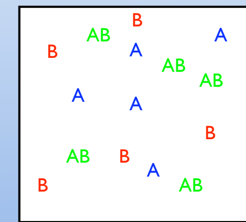
Let's look at a simple reaction between two molecules

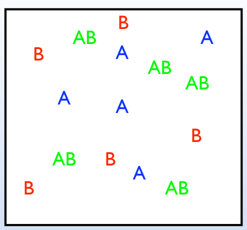
$$A + B \longrightarrow AB$$

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



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

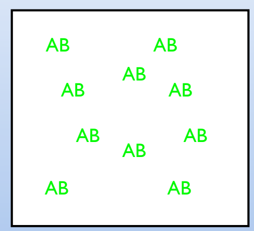




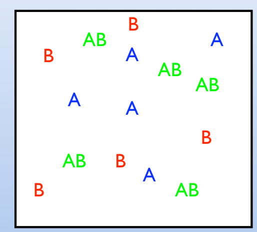
Ratio of Products to Reactants $\dfrac{\#AB}{\#A \ \times \ \#B} = \dfrac{5}{(5)\times(5)} = \dfrac{1}{5}$

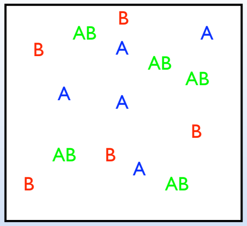
$$A + B \longrightarrow AB$$

Let's start with
10 molecules of AB



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





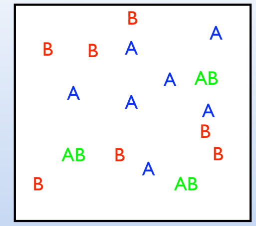
Ratio of Products to Reactants $\dfrac{\#AB}{\#A \times \#B} = \dfrac{5}{(5)\times(5)} = \dfrac{1}{5}$

Same Ratio Starting from Different initial conditions!

At equilibrium the ratio will always be the same

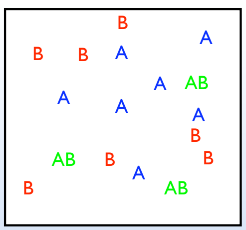
Let's Look at a new condition

7 A, 7B, 3 AB



A. equilibrium

B. not at equilibrium



Ratio of Products to Reactants $\dfrac{\#AB}{\#A \times \#B} = \dfrac{3}{(7)\times(7)} = \dfrac{3}{49}$

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 right K for a reaction?

Concentrations

$jA + kB \longleftrightarrow lC \quad + mD$

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

Pressures

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

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

$$K = \frac{\text{Products}}{\text{Reactants}} = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

How do we know K?

$$\Delta_R G^\circ = -RT \ln K$$

$\Delta_R G^\circ < 0$ $K > 1$ favors products

$\Delta_R G^\circ > 0$ $K < 1$ favors reactants

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

$\Delta T = iK_b m_{solute}$ $P_{solvent} = X_{solvent}P^\circ$

$\Delta T = -iK_f m_{solute}$ $\Delta P = -iX_{solute}P^\circ$

$\Pi = iMRT$ 1 atm = 760 Torr

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

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