Chemical Equilibria

Why did the color stop changing?

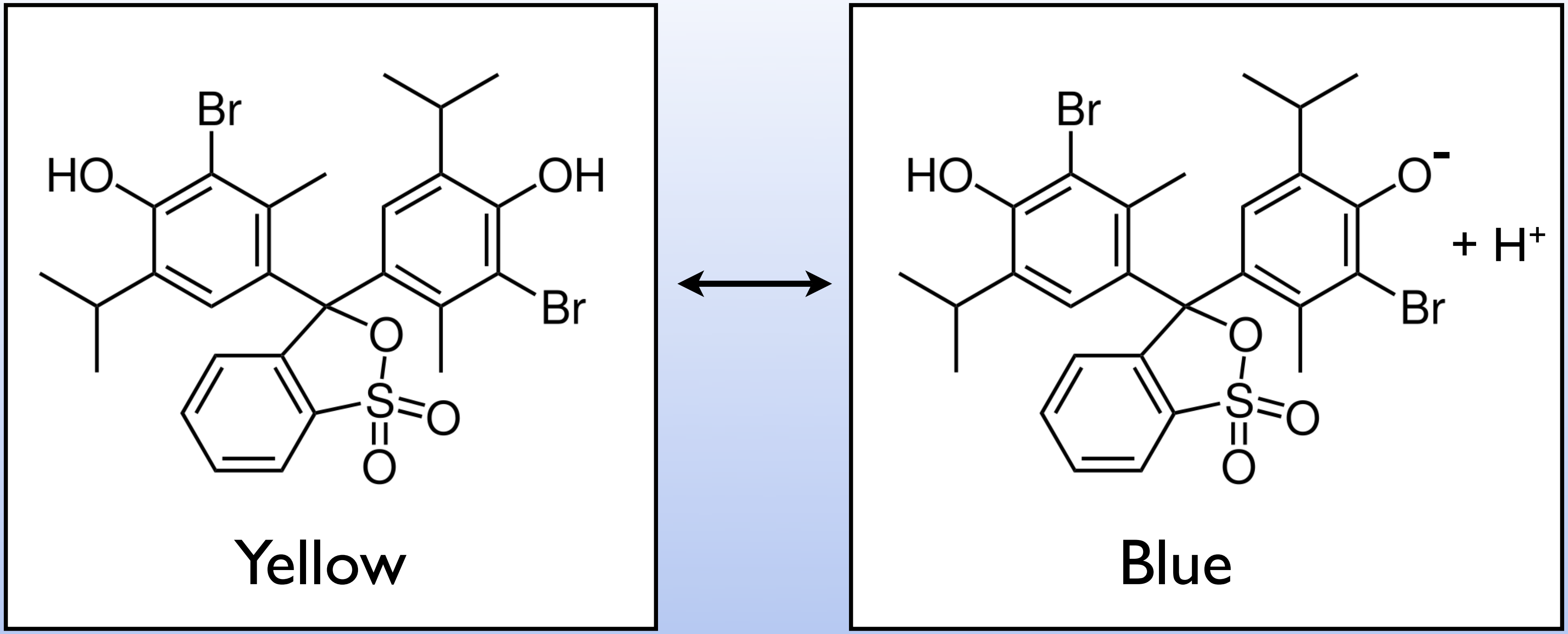
A. the reactants were all converted to products

B. the reaction came to equilibrium

C. the forward and backward reaction rates are the same

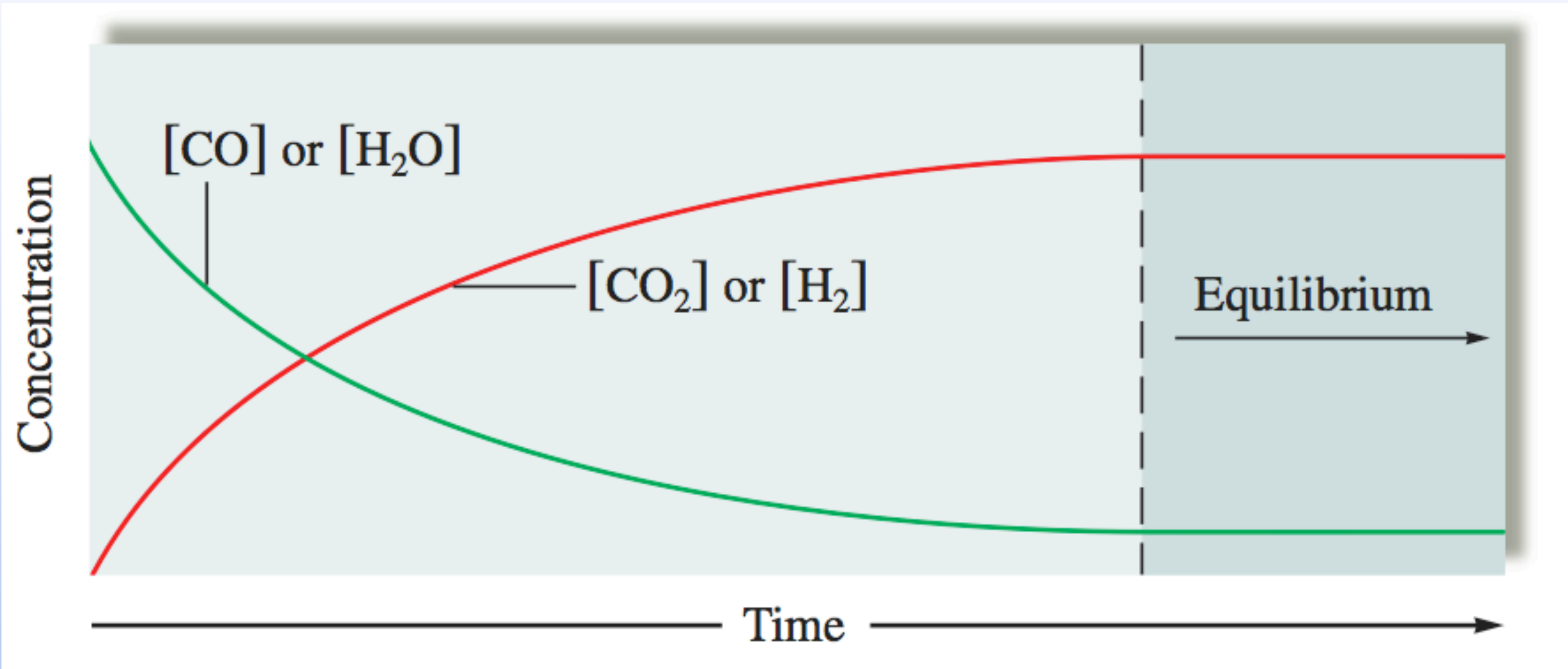
D. B & C

E. all of the above



During the reaction the ratio of yellow to blue changes

$$H_2O + CO \longrightarrow H_2 + CO_2$$



At equilibrium the ratio of the molecules stops changing

it is critical you remember your stiochiometery!

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

Imagine you start out with
10 mole of H_2 and 1 moles of N_2

At equilibrium you find you have 1 mole of NH_3
How many moles of H_2 are there at equilibrium?

A. 5 moles H_2

B. 7 moles H_2

C. 8.5 moles H_2

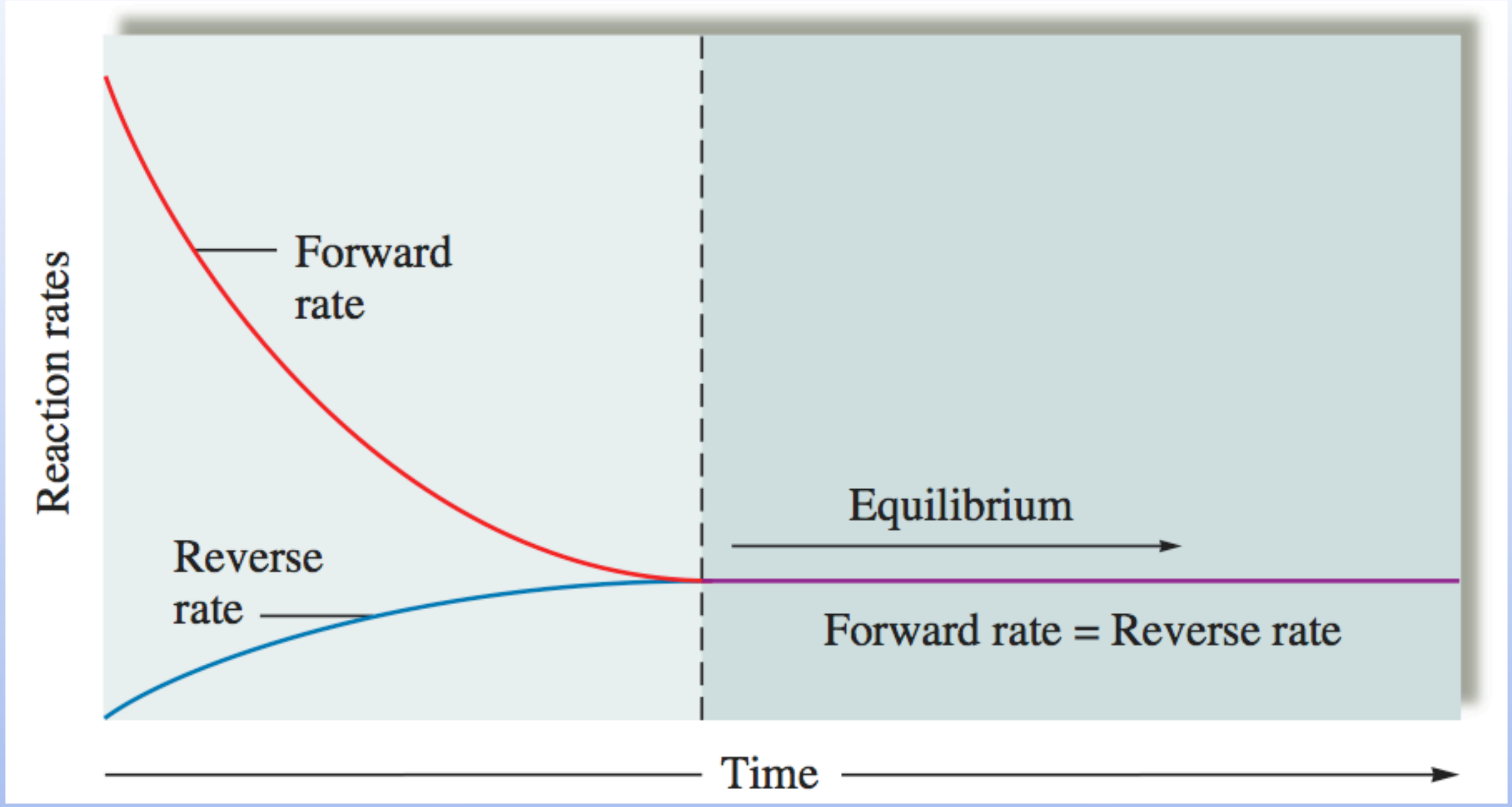
D. 9.5 moles H_2

Keeping it straight (R)ICE diagram

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

Compound	Initial	Change	Equilibrium

What is happening? Reaction has not stopped



Equal reaction rates forward and backwards

The key idea

The ratios of the molecules stops changing
We discover the ratio is a constant

We'll give the ratio a name

K

The equilibrium constant
It has to do with equilibrium
It is a constant

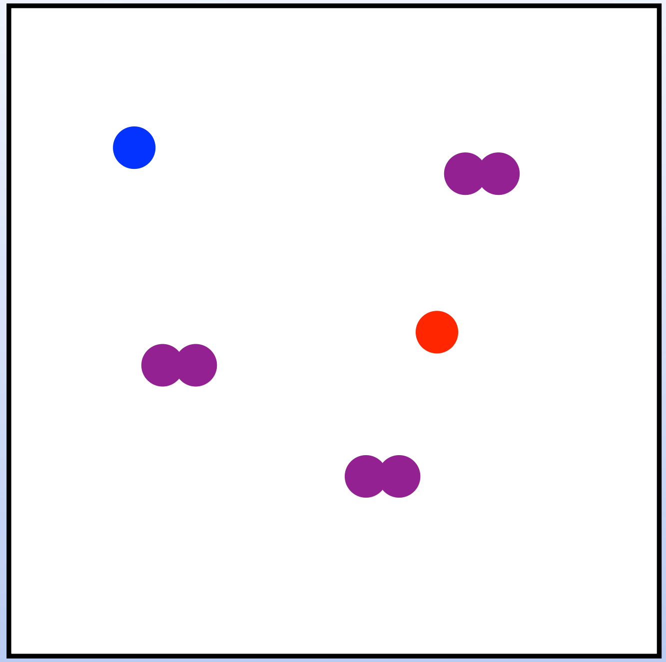
Let's Look an example

$$A + B \longleftrightarrow AB$$

Initially 4A and 4B

Equilibrium

What is the ratio at equilibrium?

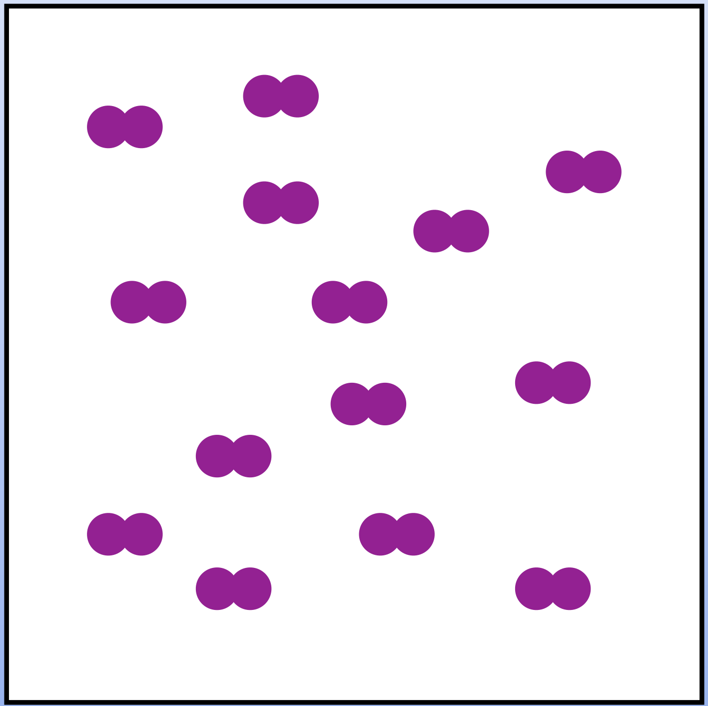


$$\frac{\#AB}{\#A \times \#B}$$

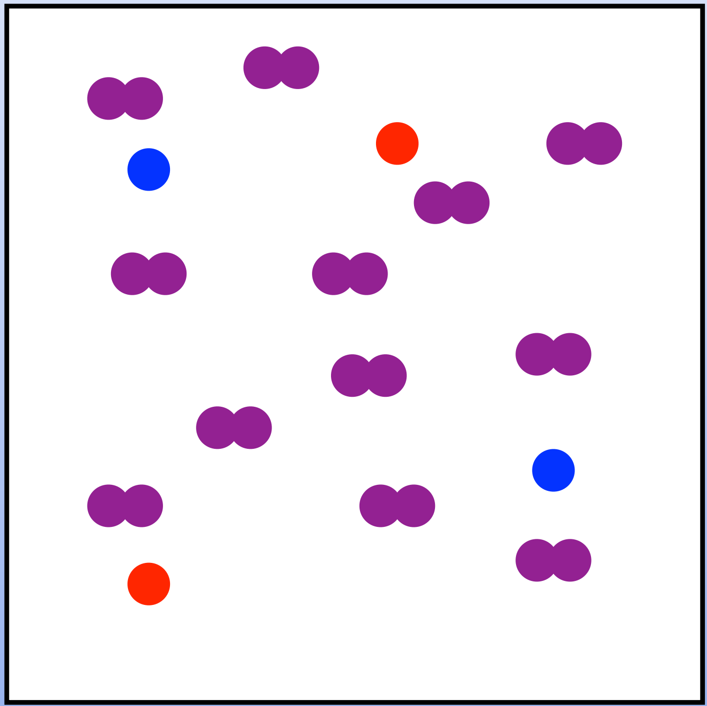
Let's Look an example

$$A + B \longleftrightarrow AB$$

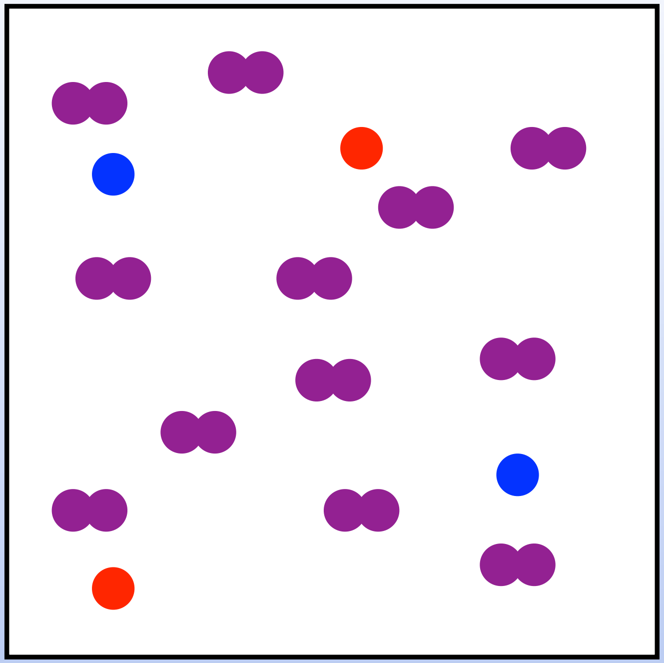
Initially 14AB



Equilibrium



What is the ratio at equilibrium?



$$\frac{\#AB}{\#A \times \#B}$$

How do we write K for a reaction?
First concentrations

$$jA + kB \longleftrightarrow \ell C + mD$$

How do we write K for a reaction?
Pressures

$$j\text{A} + k\text{B} \longleftrightarrow l\text{C} + m\text{D}$$

Why are there sometime “standard pressures”

You can only leave it out if the pressure has the same units as the standard pressure

What is the expression for the equilibrium constant for this reaction?

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

A. $(P_{NH3})/(P_{N2})(P_{H2})$

B. $(P_{N2})(P_{H2})/(P_{NH3})$

C. $(P_{NH3})^2/(P_{N2})(P_{H2})^3$

D. $(P_{N2})3(P_{H2})/2(P_{NH3})$

K depends on $\Delta_r G°$

You need to be able to use a table to find $\Delta_r G°$
from $\Delta_f G°$ or
from $\Delta_f H°$ to find $\Delta_r H°$ and $S°$ to find $\Delta_r S°$

Interpreting K and $\Delta_r G°$

Pure **Products** (in standard state)
are Lower in Free Energy

Pure **Reactants** (in standard state)
Lower in Free Energy

For a particular reaction

$\Delta_r H° = 10 \text{ kJ mol}^{-1}$ and $\Delta_r S° = 20 \text{ J K}^{-1} \text{ mol}^{-1}$

Assuming $\Delta_r H°$ and $\Delta_r S°$ don't change with temperature does this reaction favor the products or the reactants at 400K?

A. Products

B. Reactants

C. There is no way to know without a balance equation

$$2H_2O(g) \longleftrightarrow 2H_2(g) + O_2(g)$$

What is K for this reaction at 298K

A. extremely small

B. extremely large

C. approximately one

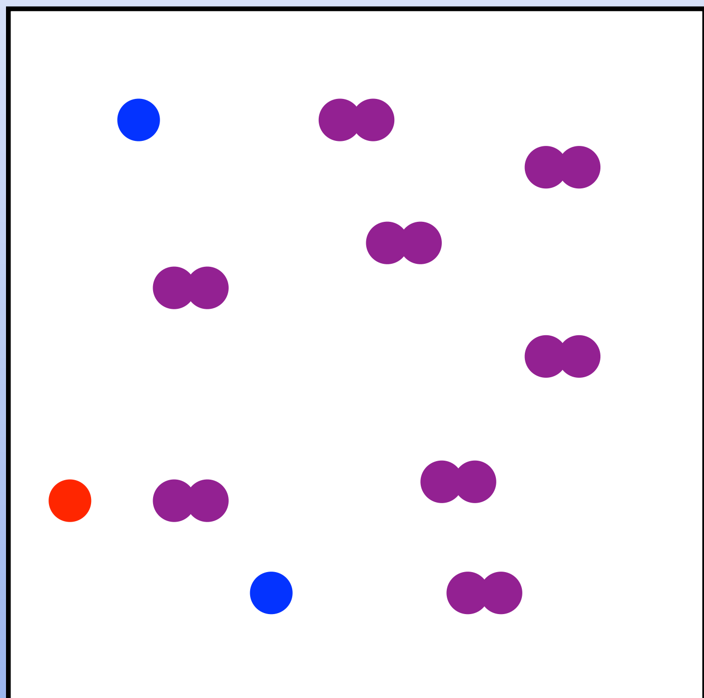
$$2H_2O(g) \longleftrightarrow 2H_2(g) + O_2(g)$$

What is K for this reaction at 298K given that $\Delta_r G° = +113.4$ kJ mol^{-1}

Back to our simple reaction

$A + B \longleftrightarrow AB$

Equilibrium?



From before we had
K = 3

Is this system at equilibrium?

This the reaction quotient Q

Q is just like K but

the concentrations or pressures in the expression

are what you have right now

At 313 K, $\Delta_r G°$ = +41 kJ mol^{-1} for this reaction

$$2H_2S(g) \longleftrightarrow H_2(g) + S_2(g)$$

You find the following partial pressures at 313K

H_2 is 1 atm, S_s is 1 atm, H_2S = 2 atm

How will this reaction proceed?

A. move toward the products

B. move towards the reactants

C. the reaction is at equilibrium

At 313 K, $\Delta_r G°$ = +41 kJ mol^{-1} for this reaction

$$2H_2S(g) \longleftrightarrow H_2(g) + S_2(g)$$

You find the following partial pressures at 313K

H_2 is 1 atm, S_s is 1 atm, H_2S = 2 atm

$K = 2.2 \times 10^{-3}$ for this reaction (at some T)

$$2HI(g) \longleftrightarrow H_2(g) + I_2(g)$$

You start with a partial pressure of 1atm of HI
what are the partial pressures at a constant P of 1atm and constant T