LE CHÂTELIER'S PRINCIPLE

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- Henry Louis Le Châtelier
- Karl Ferdinand Braun

- examined what would happen to a system already at equilibrium if the system or surroundings were disturbed

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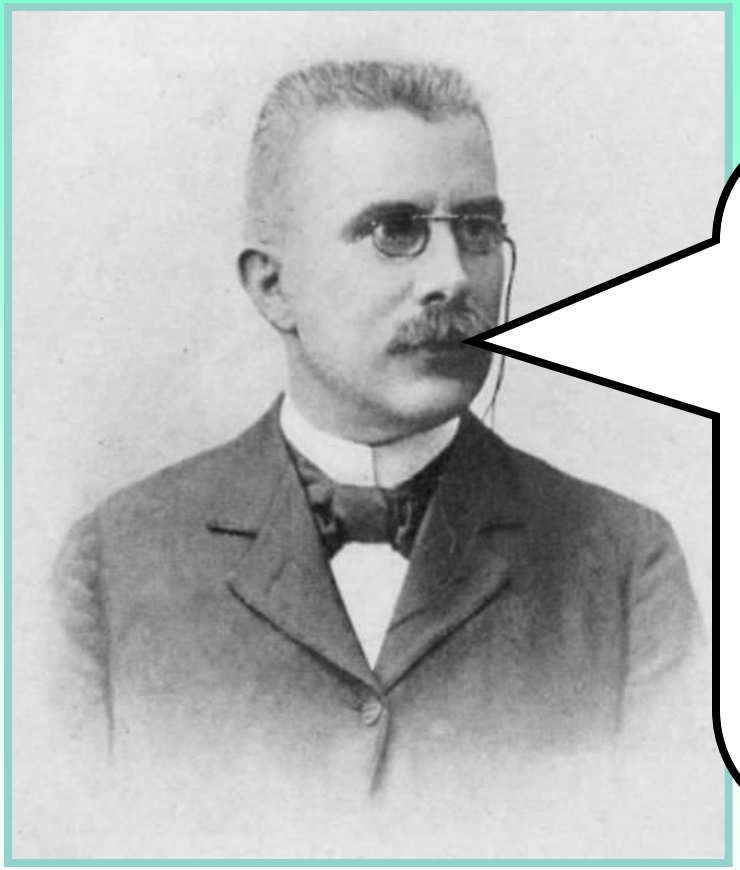

If an outside influence upsets an equilibrium, the system undergoes a change in the direction that counteracts the disturbing influence, and, the system reaches a new state of equilibrium.

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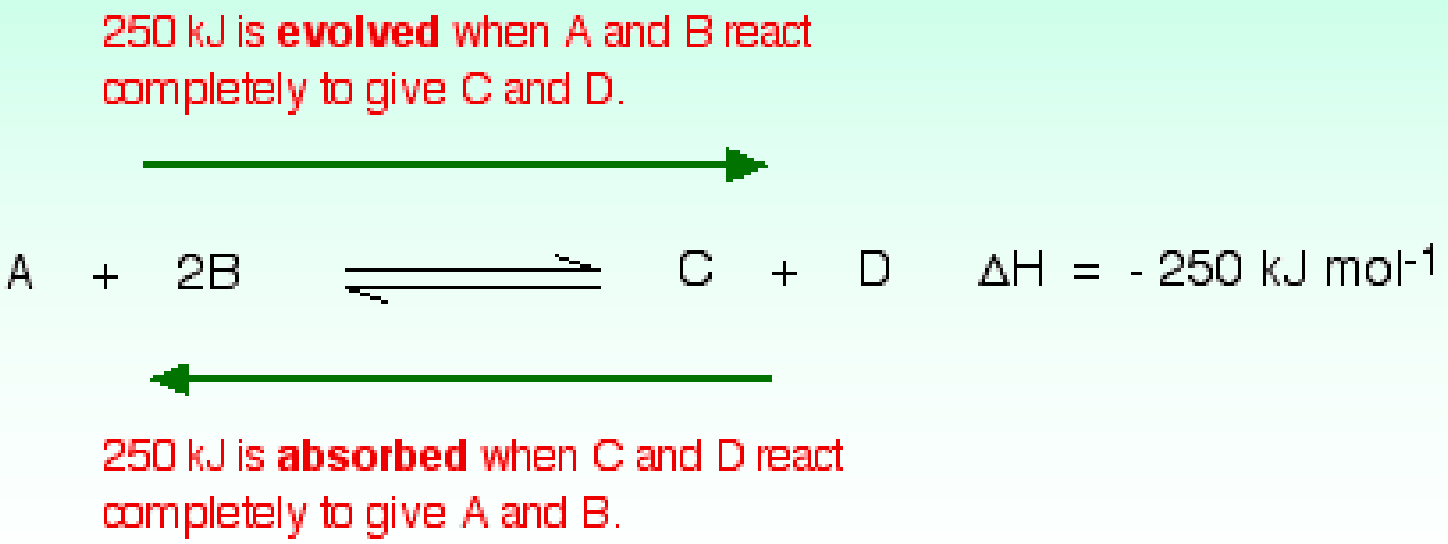
- disturbances to the equilibrium are said to shift to the right (forward) or to the left (backward)



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Factors Affecting Equilibrium

1. concentration of reactants / products
2. Pressure
3. Addition of inert gases
4. Presence of catalysts
5. Temperature

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1. Concentration

$$2\ HI_{(g)} <====> H_{2(g)} + I_{2(g)}$$

Given the equilibrium above, if more HI is added to the system, how will the reaction rates respond to achieve a new equilibrium?

Equilibrium shifts to the right to increase concentration of products and offset the added HI.

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1. Concentration

$$2\ HI_{(g)} <====> H_{2(g)} + I_{2(g)}$$

What happens to the equilibrium if H_2 is removed from the system?

Equilibrium shifts to the right to restore the H_2 that was lost.

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1. Concentration

The equilibrium will always shift to consume the substance that is added or to replace a substance that is removed.

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1. Concentration

Example #1

$$Cu(H_2O)_4^{2+}{}_{(aq)} + 4\ Cl^-_{(aq)} \text{ <===> } CuCl_4^{2-}{}_{(aq)} + 4\ H_2O$$

1. What happens when Cl^- is added?

   Equilibrium shifts to the right

2. What happens when $CuCl_4^{2-}$ is removed?

   Equilibrium shifts to the right

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1. Concentration

Example #2

$$Cu(H_2O)_4^{2+}{}_{(aq)} + 4\ Cl^-{}_{(aq)} \text{ <===> } CuCl_4^{2-}{}_{(aq)} + 4\ H_2O$$

What happens when Ag^+ ions are added?

(Hint: examine your solubility rules)

$Ag^+{}_{(aq)} + Cl^-{}_{(aq)} \rightarrow AgCl_{(s)}$

Equilibrium shifts to the left

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2. Pressure

- pressure is changed if volume is changed

- pressure changes have limited effect on liquids or solids

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2. Pressure

$$2\ NO_{2(g)} <====> N_2O_{4(g)} + \text{energy}$$

Given the equilibrium above, if the pressure on the system is increased, how will the reaction rates respond to achieve a new equilibrium?

Equilibrium shifts to the right to consume particles and relieve pressure in the system.

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2. Pressure

The equilibrium will always shift to relieve an increase in pressure or to fill up space when pressure is decreased.

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2. Pressure

Example #3

$$3\ H_{2(g)} + N_{2(g)} \text{ <===> } 2\ NH_{3(g)}$$

What happens if the volume of the system is reduced?

Equilibrium shifts to the right

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2. Pressure

Example #4

$$H_{2(g)} + I_{2(g)} \text{ <===> } 2\ HI_{(g)}$$

What happens if the volume of the system is increased?

Nothing. Both reaction directions are equally affected.
(# of moles reactants = # of moles products)

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3. Addition of inert gases

Example #5

$$3\ H_{2(g)} + N_{2(g)} \text{ <====> } 2\ NH_{3(g)}$$

What happens if neon gas is added?

Nothing. A gas that cannot react with the chemicals in the system will not change the equilibrium position of the system.

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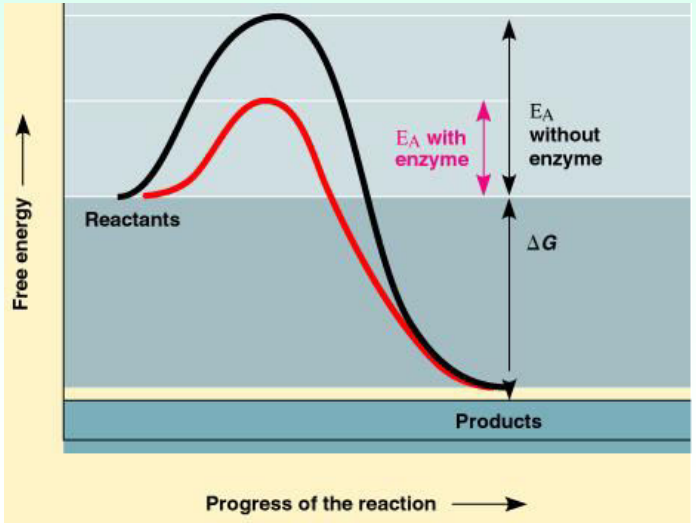
4. Presence of catalysts

Example #6

$$3\ H_{2(g)} + N_{2(g)} \text{ <===> } 2\ NH_{3(g)}$$

What happens when a catalyst is added?

Nothing. Catalysts speed up both the forward and reverse reactions, so the equilibrium will not change.



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5. Temperature

Example #7:

$$2\ NO_{2(g)} \text{ <====> } N_2O_{4(g)} + \text{energy}$$

How does the system compensate when the temperature is increased?

Equilibrium shifts to the left.

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5. Temperature

Example #8:

$2\ SO_{3(g)} + \text{energy} <====> 2\ SO_{2(g)} + O_{2(g)}$

How does the system compensate when the temperature is decreased?

Equilibrium shifts to the left.