External Changes on Equilibrium

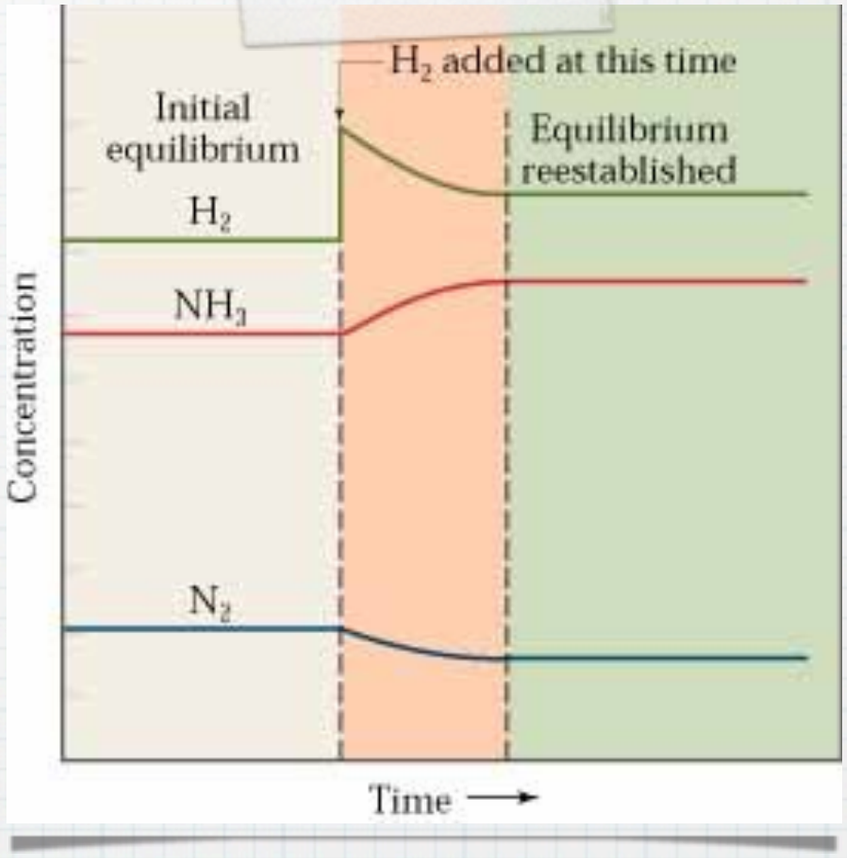
Le Chatelier's Principle

* Temperature, pressure and changes in concentration affect equilibrium
* These factors will make the system undergo an equilibrium shift

* The outcome is governed by **LE CHATELIER'S PRINCIPLE**
* Any change to a chemical reaction at equilibrium causes the reaction to proceed in the direction that reduces the effect of the change

Effects of Concentration Changes

* Addition of a reactant or product causes the reaction to proceed in the direction that consumes the added substance.



$$H_2 + N_2 \rightleftharpoons NH_3$$

Effects of Concentration Changes

* Removal of a reactant or product causes the reaction to proceed in the direction that produces the missing substance.

Concentration Changes

* $CO_{2(g)} + 2\,H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$
    * increase in acidity will cause increase in CO_2
* $2\,SO_{3(g)} \rightleftharpoons 2\,SO_{2(g)} + O_{2(g)}$
    * increase in SO_3 drives reaction to favor SO_2

Concentration Changes

Summary:

-Increased concentration of a product causes a shift to reactant formation.

-Increased concentration of a reactant causes a shift to product formation

-Decreasing reactant causes shift to reactant formation

-Decreasing products causes a shift to product formation

Effects of Temperature Change

* Heat is released in an exothermic reaction and is absorbed in an endothermic reaction.
* Changes in temperature have the same effect as changes in concentration shifts.

Effects of Temperature Change

* $N_{2(g)} + O_{2(g)} + 180.5\ kJ \rightleftharpoons 2NO_{(g)}$

* If the mixture is heated, the equilibrium shifts toward NO.

* If the mixture is cooled, the equilibrium shifts toward N_2 and O_2.

Effects of Temperature Change

* In an endothermic system, an increase in temperature increases K_{eq}

* In an exothermic system, an decrease in temperature causes a decrease in K_{eq}

Effects of Temperature Change Changes

Summary:

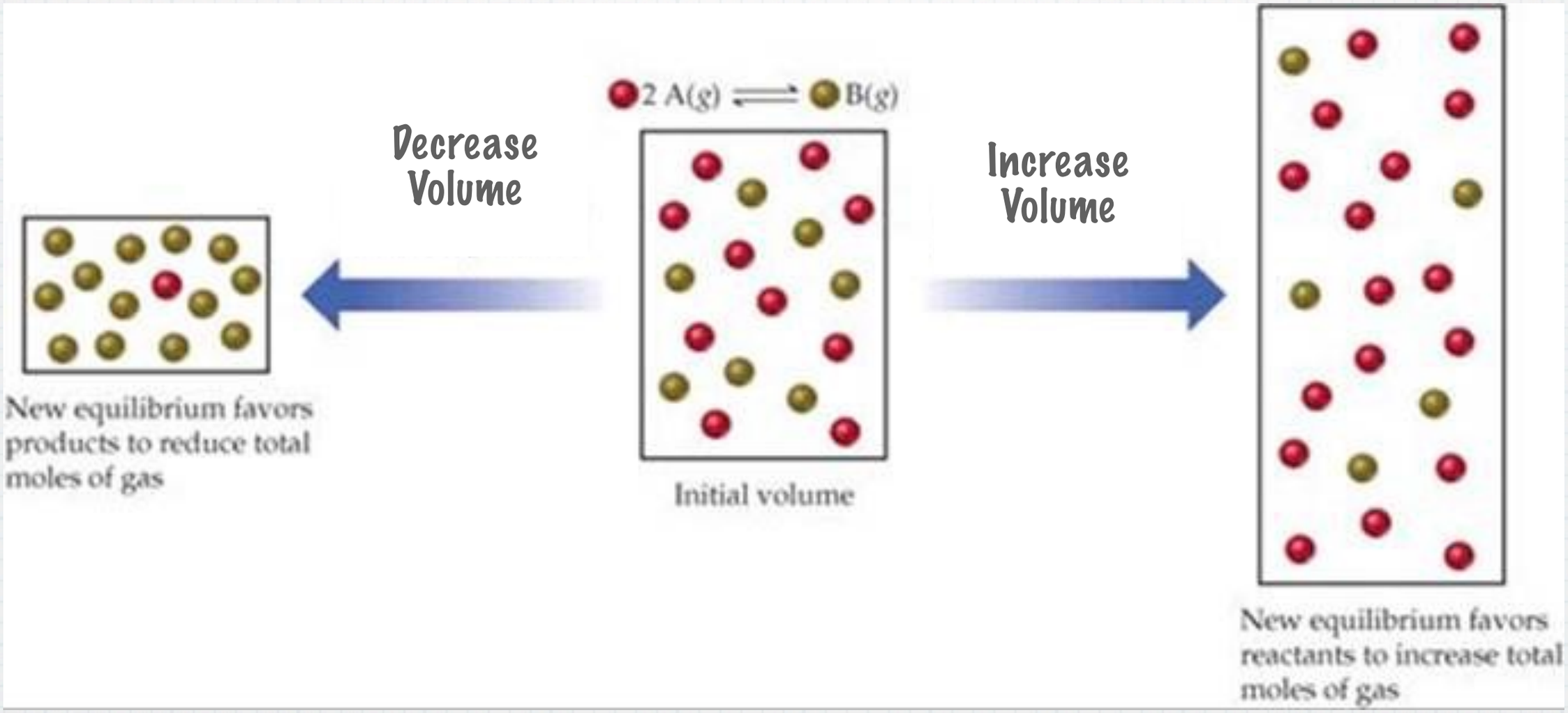
-Temperature increase favours the endothermic side (heat absorbing side)

-Temperature decrease favours the exothermic side (heat producing side)

Effects of Volume and Pressure

* Only applies for gaseous equilibria
* Decrease in volume or an increase in pressure causes reaction to proceed in the direction of fewer number of moles of gaseous reactant or product.
    * These occupy a smaller volume

Effects of Volume and Pressure



Effects of Volume and Pressure

* Example: $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

  * increase in volume drives the reaction to the right
  * decrease in volume drives the reaction to the left

Effects of Volume and Pressure

Summary:

-Pressure increase shifts so the number of particles decreases

-Pressure decrease shifts so the number of particles increases

Changes that do not affect equilibrium

* Adding Catalysts

* Decreases time required for reaction but does not affect the final position of equilibrium lowers activation energy for both forward and reverse processes

Try It

* What happens if:
* $CO_{(g)} + 2\,H_{2(g)} \rightleftharpoons CH_3OH_{(g)} + 35\ kJ$
  * a) temperature is increased?
  * b) pressure is increased?
  * c) $H_{2(g)}$ is added?
  * d) a catalyst is introduced?

Try It

* What happens if:
* $CO_{(g)} + 2\ H_{2(g)} \rightleftharpoons CH_3OH_{(g)} + 35\ kJ$
  * a) temperature is increased? **LEFT**
  * b) pressure is increased? **RIGHT**
  * c) $H_{2(g)}$ is added? **RIGHT**
  * d) a catalyst is introduced? **NOTHING**

Try It

* What happens if
* $NaCl_{(s)} + 3.9\ kJ \rightleftharpoons Na^+_{(aq)} + Cl^-_{(aq)}$
* a) temperature is increased?
* b) pressure is increased?

Try It

* What happens if
* $NaCl_{(s)} + 3.9\ kJ \rightleftharpoons Na^+_{(aq)} + Cl^-_{(aq)}$
  * a) temperature is increased? **RIGHT**
  * b) pressure is increased? **NO CHANGE**

Homework

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