Qualitative Changes in Equilibrium Systems

Chapter 7.4

Disturbing Equilibrium

- A chemical equilibrium can be disturbed by changes in:

1. Concentration
2. Temperature
3. Pressure/Volume

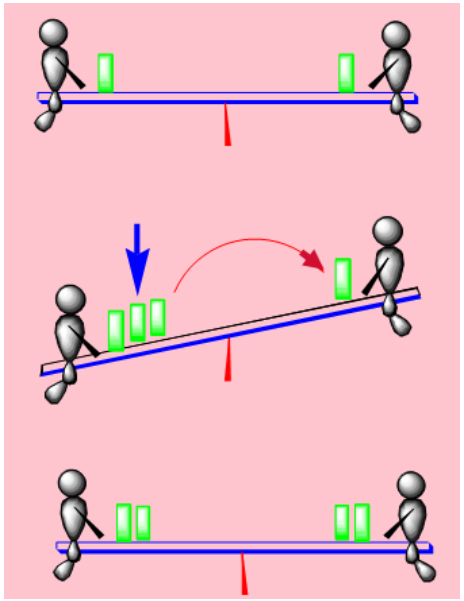
Le Châtelier's Principle

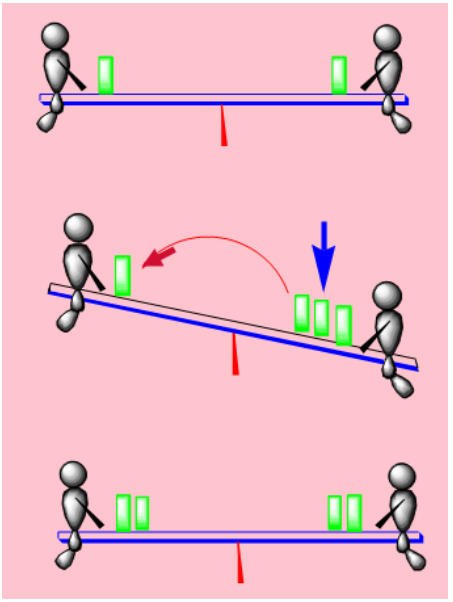
When a chemical system at equilibrium is **disturbed** by a change in a property, the system adjusts in a way that opposes the change

An **equilibrium shift** is a change in concentrations of reactants and products in order to restore a new equilibrium state

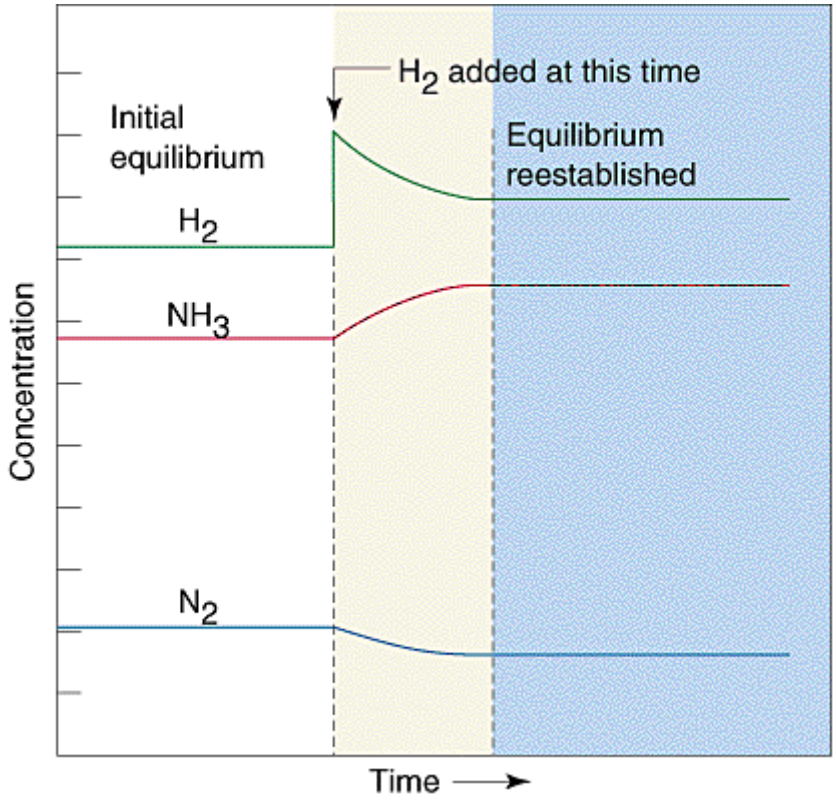
Concentration

- *Increasing* the concentration of a reactant or product causes an equilibrium shift that results in a *decrease* of that reactant or product





$$3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

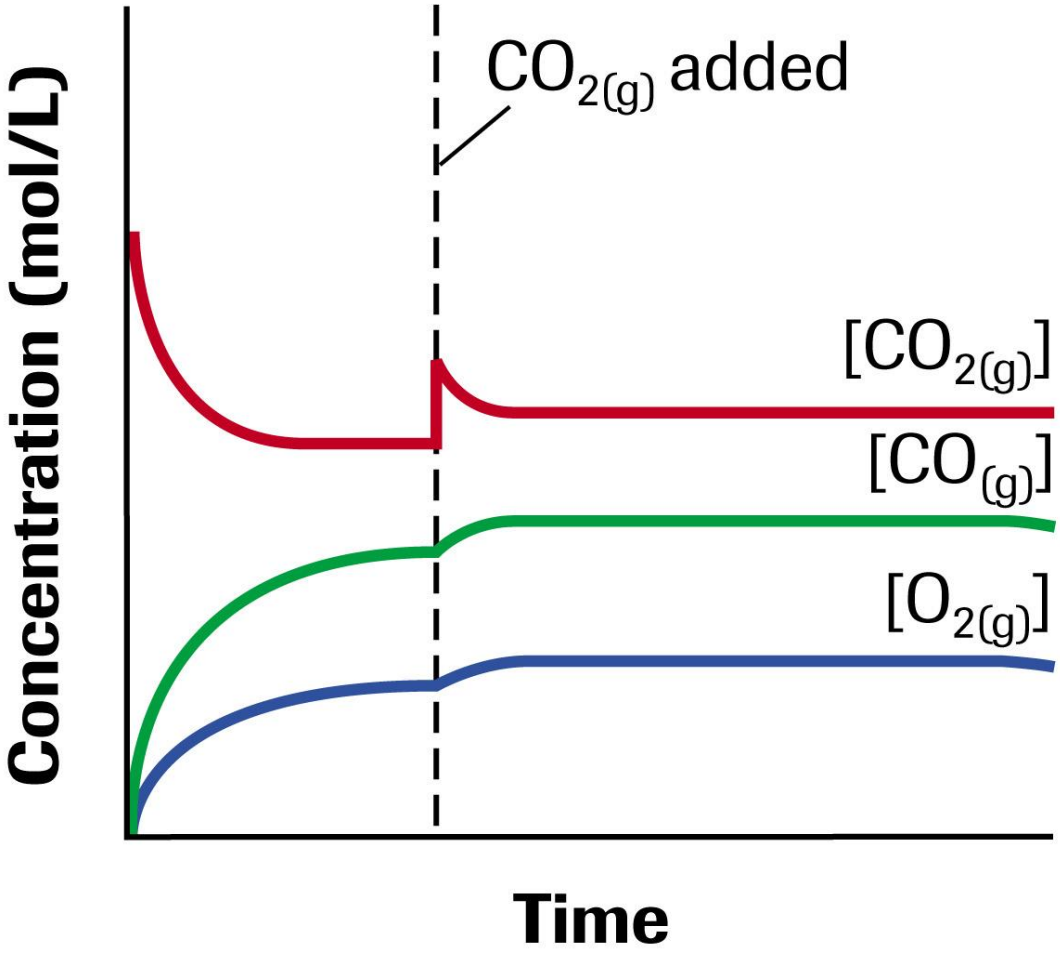


when more reactants, A and/or B is added, the equilibrium shifts to reduce A and B by producing more C and D

$$A + 2B \rightleftharpoons C + D$$

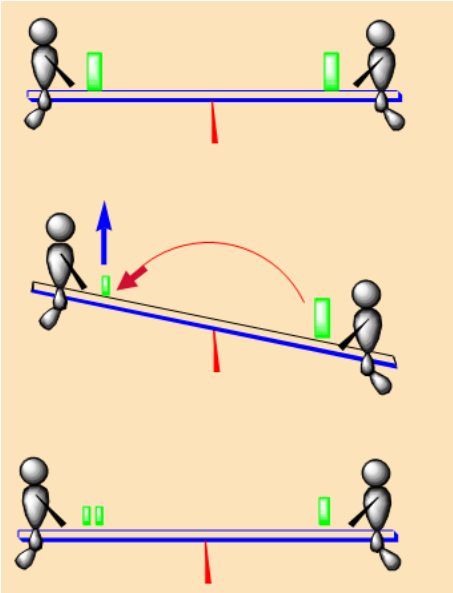
when more products, C and/or D is added, the equilibrium shifts to reduce C and D by producing more A and B

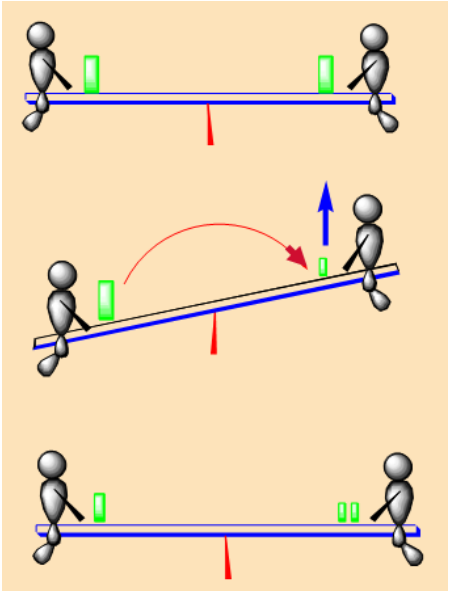
$$2\,CO_{2(g)} \rightleftharpoons 2\,CO_{(g)} + O_{2(g)}$$



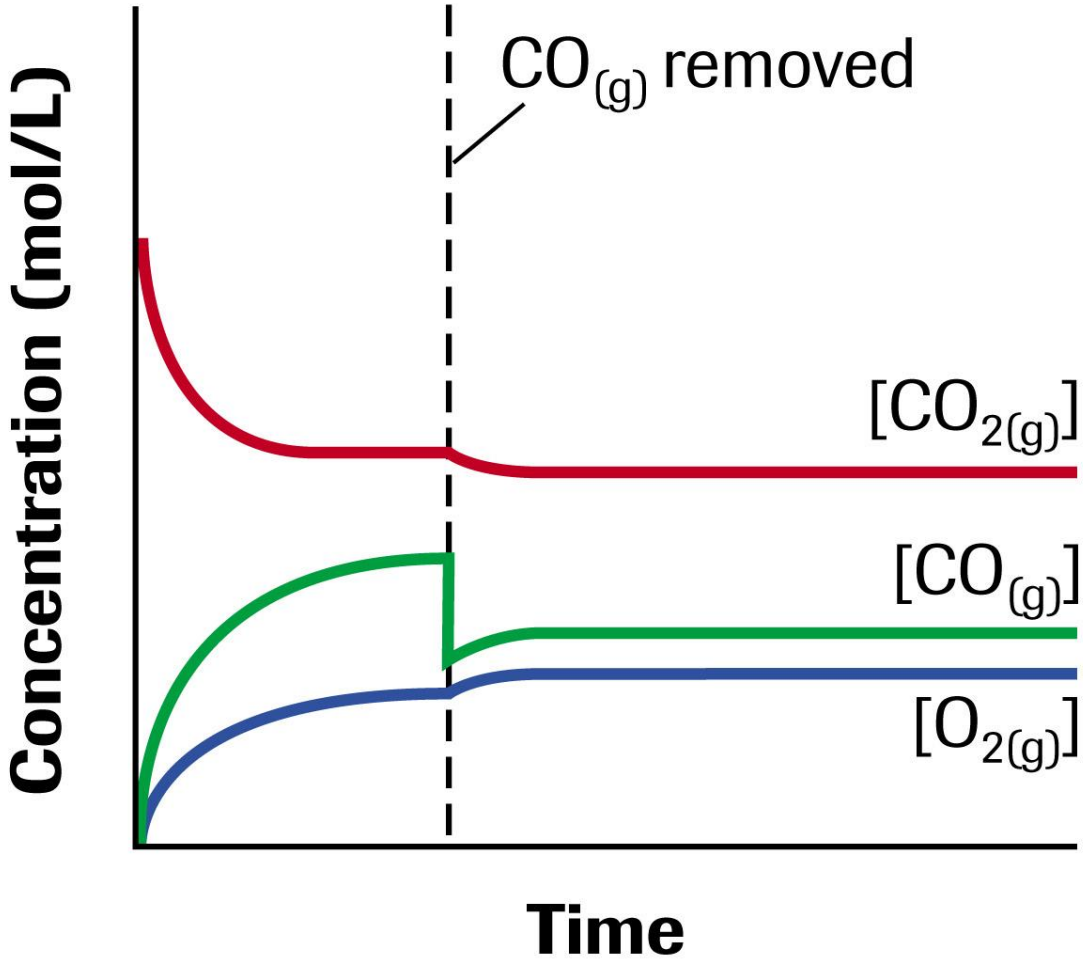
Concentration

- *Decreasing* the concentration of a reactant or product causes an equilibrium shift that results in a *increase* of that reactant or product





$$2\,CO_{2(g)} \rightleftharpoons 2\,CO_{(g)} + O_{2(g)}$$



Practice

- Consider the following equilibrium:

$$SO_{2(g)} + O_{2(g)} \rightleftharpoons SO_{3(g)}$$

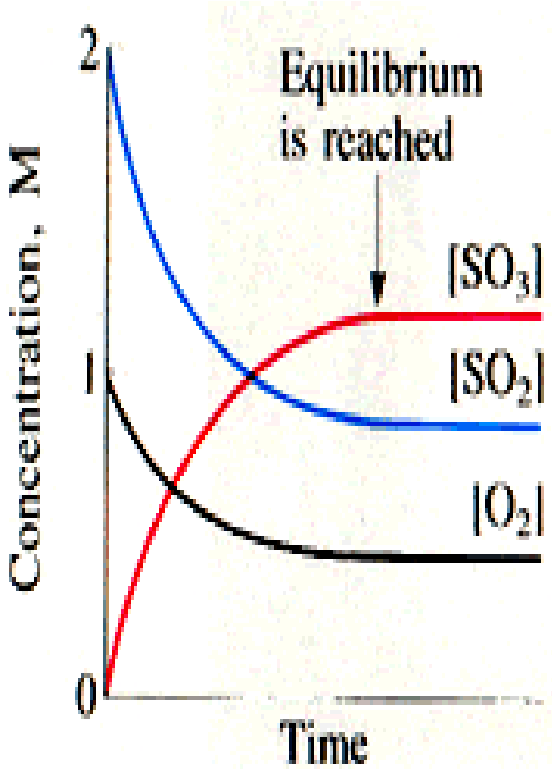
How would the equilibrium shift if:

a) $[SO_{2(g)}]$ increases

b) $[SO_{3(g)}]$ increases

c) $[O_{2(g)}]$ decreases

d) $[SO_{3(g)}]$decreases



Temperature

- In an **exothermic** reaction energy is a product

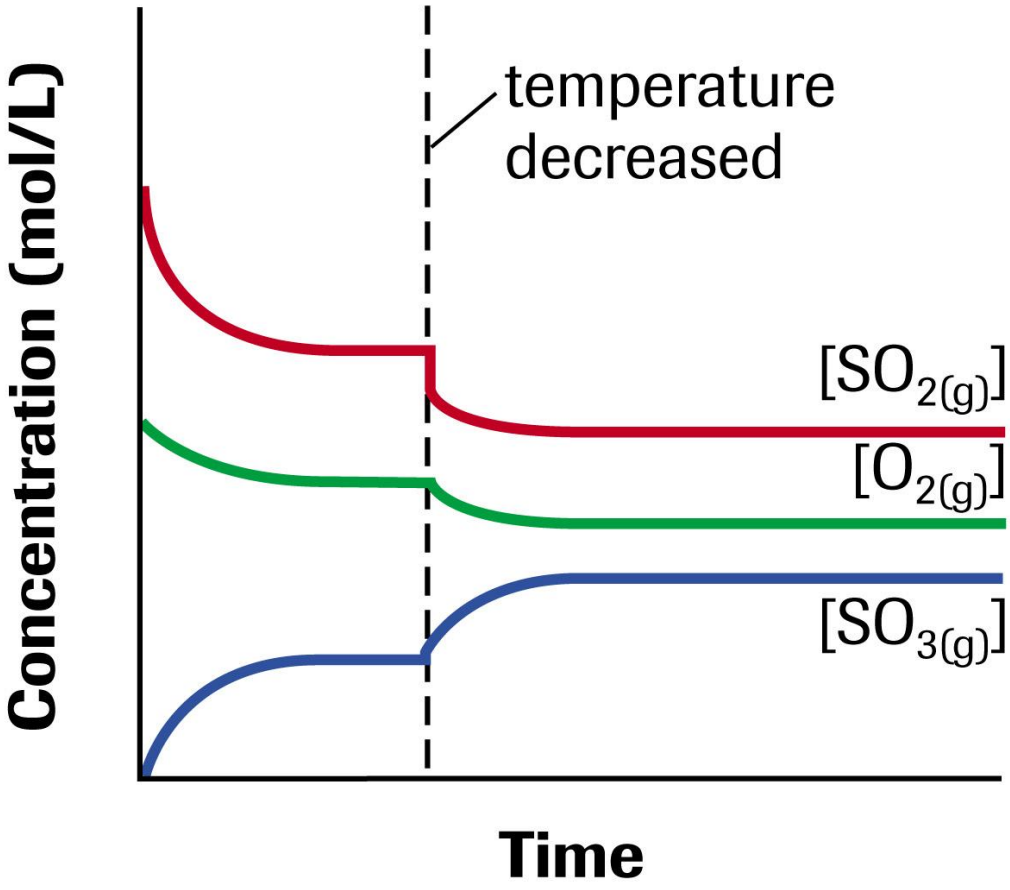
$$A + B \rightleftharpoons C + D + \text{energy}$$

- In an **endothermic** reaction energy is a reactant

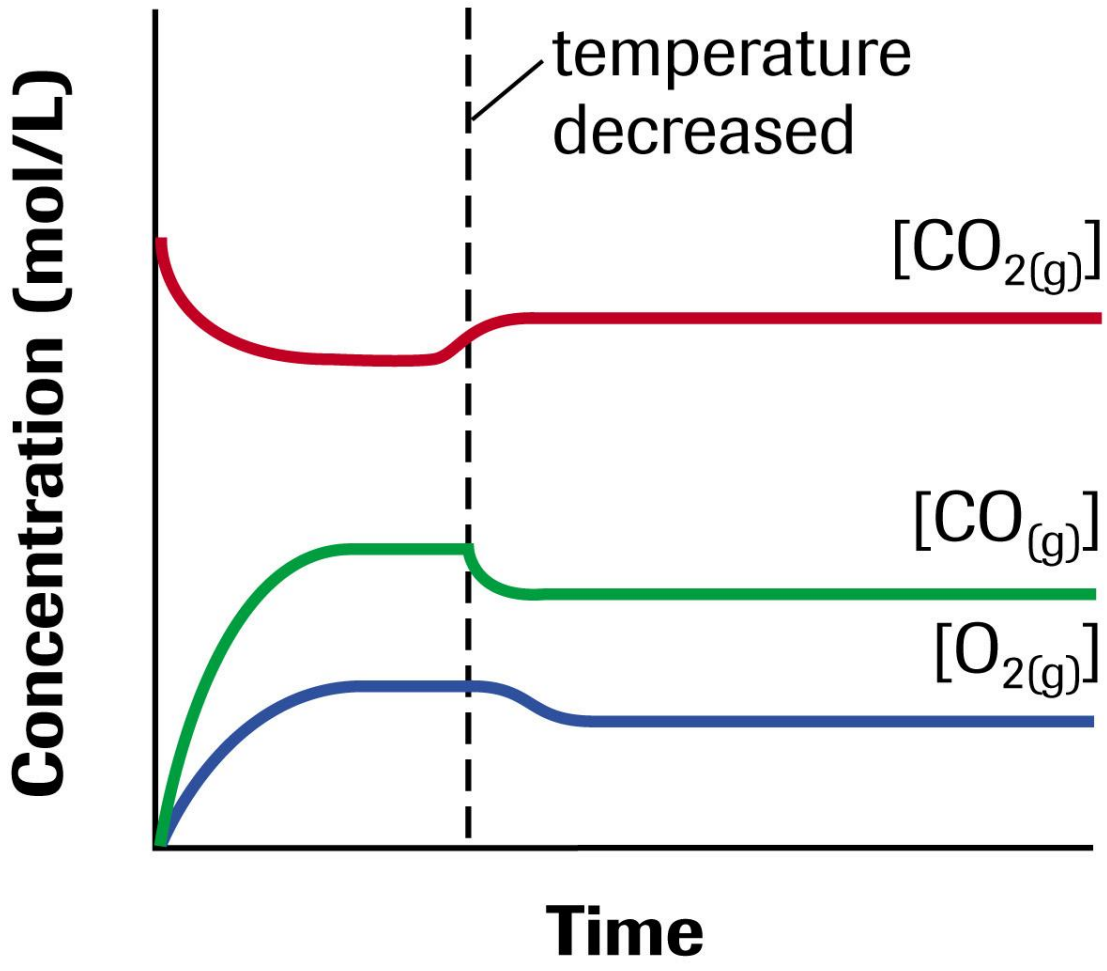
$$\text{energy} + A + B \rightleftharpoons C + D$$

- Heating a chemical system up *increases the energy* which causes an equilibrium shift that results in *decreased energy*
- Cooling a chemical system down *decreases the energy* which causes and equilibrium shift that results in *increased energy*

$$2\,SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\,SO_{3(g)} + \text{energy}$$



$$CO_{2(g)} + \text{energy} \rightleftharpoons 2\,CO_{(g)} + O_{2(g)}$$



Practice

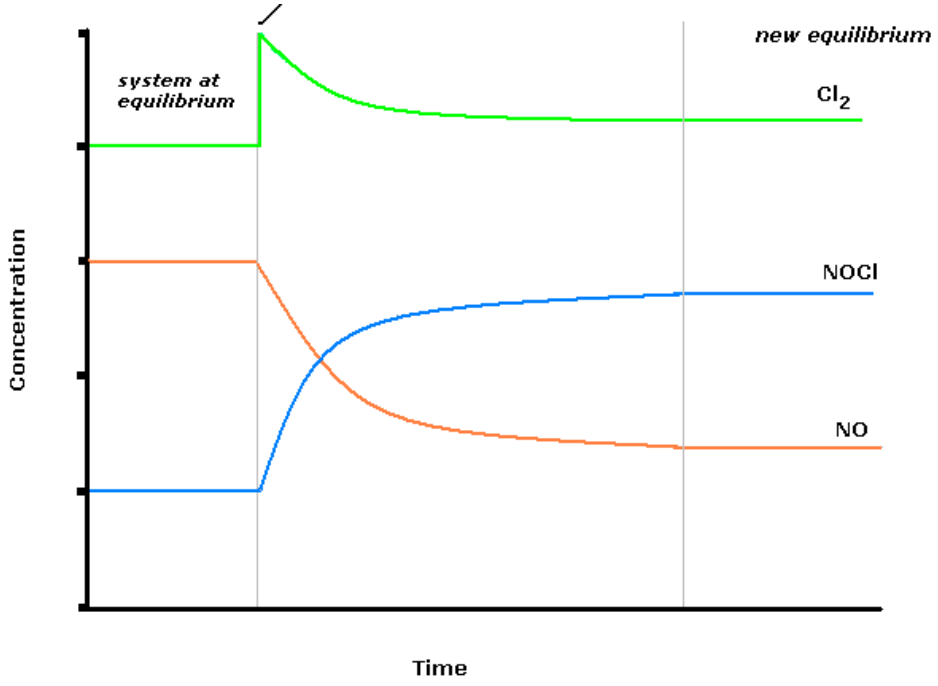
- Consider the following equilibrium:

$$2NO_{(g)} + Cl_{2(g)} \rightleftharpoons 2NOCl_{(g)} \qquad \Delta H = -76\ kJ$$

a) What was the initial disturbance?

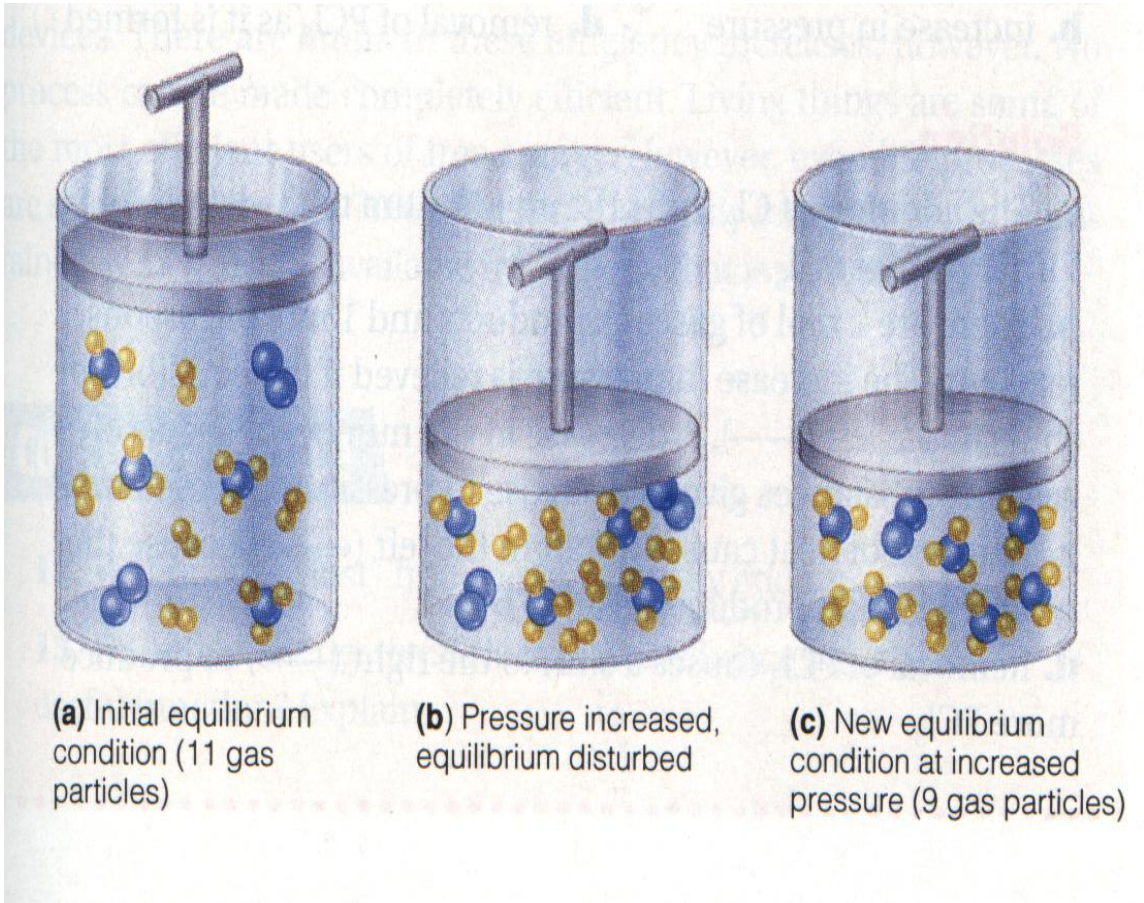
b) How will the equilibrium shift if the reaction vessel is heated?

c) How will the equilibrium shift if the reaction vessel is cooled?



Pressure and Volume

- According to Boyle's law, volume and pressure are inversely proportional
- When the *volume* of a chemical system *decreases* (or it's pressure increases) the equilibrium will shift in the direction that gives the smaller number of gas molecules in order to *make more space*



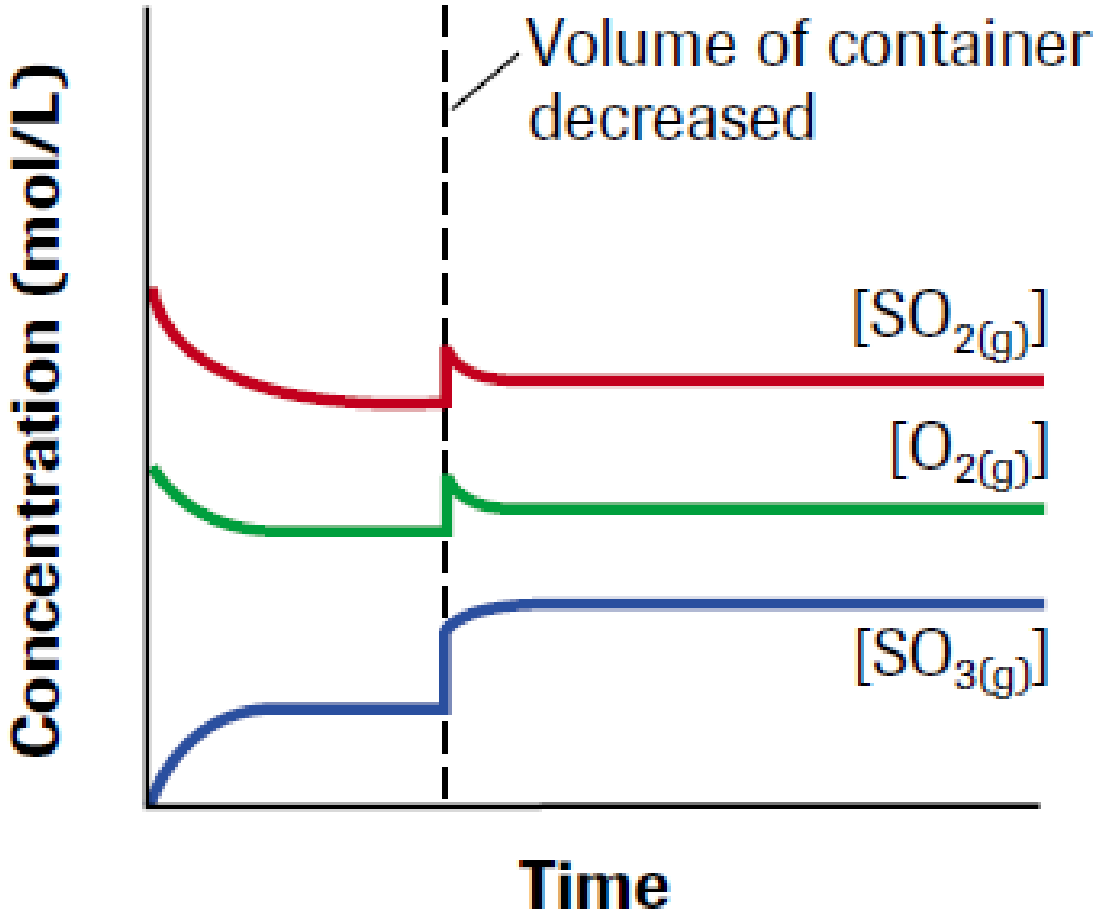
(a) Initial equilibrium condition (11 gas particles)

(b) Pressure increased, equilibrium disturbed

(c) New equilibrium condition at increased pressure (9 gas particles)

$$3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

$$2\,SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\,SO_{3(g)} + \text{energy}$$



***Notice that changes in volume affect concentration

Factors That do not Affect the Equilibrium Position

- Catalysts
- Adding an Inert Gas
- State of Reactants

(read about these in your textbook)

Practice

- Consider the following equilibrium system:

$$N_2O_{4\ (g)} + \text{energy} \Leftrightarrow 2NO_{2(g)}$$

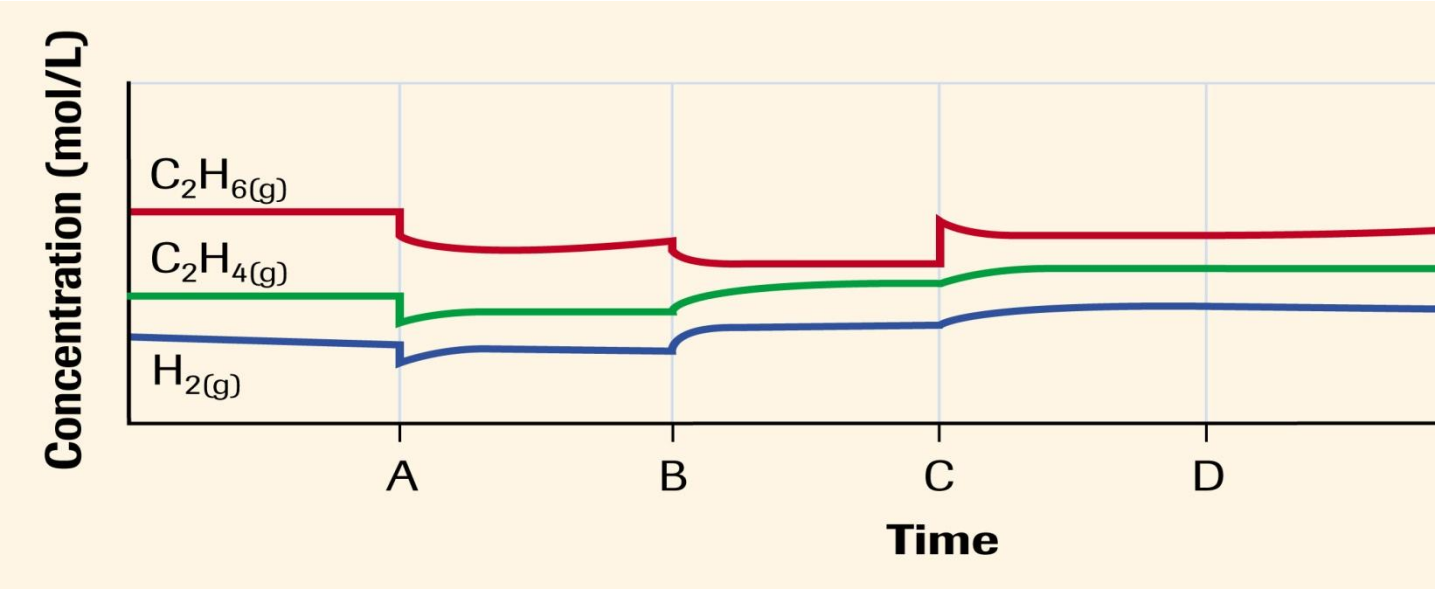
- How will the equilibrium shift if the following disturbances occur:

a) Addition of $N_2O_{4\ (g)}$
b) Addition of $NO_{2(g)}$
c) Removal of $N_2O_{4\ (g)}$
d) Removal of $NO_{2(g)}$
e) Decrease in container volume
f) Increase in container volume
g) Increase in temperature
h) Decrease in temperature

Practice

- Consider the following equilibrium system:

$$C_2H_{4\,(g)} + H_{2\,(g)} \Leftrightarrow C_2H_{6\,(g)} + \text{energy}$$



- What disturbances caused the equilibrium shifts at points A, B, C, and D on the graph?

HOMEWORK

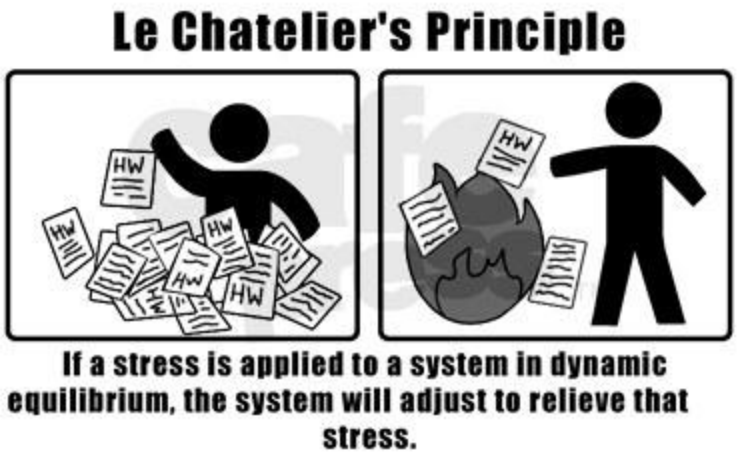
Required Reading:

p. 439-446

(remember to supplement your notes!)

Questions:

p. 446 #1-4



Note: A **smarter** way to relieve homework stress is to see your teacher for extra help!