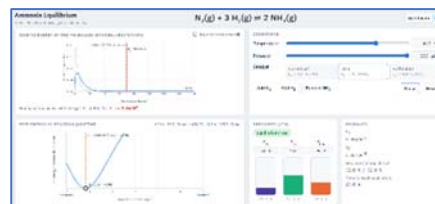


Synthesis of Ammonia

Name _____

Follow the link provided to open the ammonia interactive. This interactive is designed to mimic the industrial process used to produce ammonia. Use the worksheet to guide you through this interactive.



1. You begin with the temperature at 25 °C and a pressure of 1 atm. Under these conditions,
 - a. What fraction of molecules have enough energy to overcome the activation energy?
 - b. Under these conditions, what is the value of K_p ?
Does this favor the reactants or the products?
 - c. Is the reaction proceeding in the forward direction?
 - d. Why are these conditions not feasible for the synthesis of ammonia?
2. Now let's keep the pressure at 1.0 atm, but increase the temperature 450 °C. Note how the increase in temperature affects
 - a. The rate of the reaction
 - b. The fraction of molecules that can overcome the energy of activation.
 - c. The value of K_p .

d. Why are these conditions not feasible for the synthesis of ammonia?

3. Now let's bump the pressure up to about 23.0 atm.

a. Record the value of K_p at this pressure and temperature.

b. If you increase the total pressure, you increase the pressure of each component. Move the pressure back and forth and observe the change in free energy versus the reaction quotient. Does changing the pressure affect K_p ?

c. Now observe how increasing or decreasing the pressure changes Q_p .

i. Which change (an increase or decrease in pressure) causes Q_p to increase?
Which direction does this push the reaction?

ii. Which change (an increase or decrease in pressure) causes Q_p to decrease?
Which direction does this push the reaction?

d. At a temperature of 450 °C, compare the equilibrium percentage of NH_3 in the mixture at 1 atm, at 23.0 atm, and at 300 atm.

Temperature	Pressure	Percent NH_3 at equilibrium
450 °C	1.0 atm	
450 °C	23.0 atm	
450 °C	300 atm	

4. Beginning at equilibrium at 450 °C, select the “remove NH₃” button.

a. Does this change the value of Q_p , K_p , or both?

b. What direction does the reaction proceed as a result of this change?

c. The manufacture of ammonia often cycles the reaction mixture through the catalyst several times, and uses a condenser to remove ammonia as it is formed. Based on Le Chatelier's principle, how does this affect the equilibrium mixture?

5. Now hit the “pause button”, and then “reset” to start at the original settings. Compare the time to completion when the catalyst is iron, ruthenium, or no catalyst. How does the activation energy affect the time to completion? How is this related to the fraction of molecules with energy greater than or equal to the activation energy? (Note: The tail of the Maxwell-Boltzmann graph extends to higher energies than is visible in the graph. If you select “log scale” it will help you visualize this change better.)

Summary:

1. Does an increase in temperature shift the equilibrium by changing Q_p , K_p , or both?
2. This reaction is exothermic. Does an increase in temperature shift the equilibrium toward the reactants (N_2 and H_2), or toward the product (NH_3)?
3. Does an increase in pressure change Q_p , K_p , or both?
4. For this reaction, does an increase in pressure shift the equilibrium toward the reactants (N_2 and H_2), or toward the product (NH_3)?