LeChatelier's Principle of Equilibrium

Example #1: Which way will the equilibrium shift if more H_2 is added to this reaction at equilibrium:

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

Answer:

The H_2 amount goes up (by adding it), therefore according to LeChatelier's Principle, the reaction will try and use up the added H_2. It does so by shifting the position of equilibrium to the right. This makes more NH_3 by using up N_2 and H_2

Example #2: Using the same reaction in Example #1, which way will the equilibrium shift if some NH_3 is removed from the reaction when it is at equilibrium.

Answer:

According to LeChatelier's Principle, the chemical system will attempt to replace the lost NH_3. The stress was to remove NH_3, so the opposite is to replace it. The equilibrium position will shift to the right in order to replace some of the lost NH_3.

Example #3: Which way will the equilibrium shift if the system temperature goes up (heat is added):
$2\ SO_2 + O_2 \rightleftharpoons 2\ SO_3 + \text{heat}$

Answer:

Even though heat is not a chemical substance, for the purposes of LeChatelier's Principle, you can treat it as if it has physical existence. Since heat is added, the reaction will shift to try and use up some of the added heat. In order to do this, the reaction must shift to the left.

Example #4: Using the same reaction, which way will the equilibrium shift if heat is removed (that is, the temperature goes down).

Answer:

The reaction will attempt to do the opposite of what the stress was. Since the stress was to remove heat, the reaction will shift to the right to generate more heat (replacing only a part of what was lost).

Pressure Changes and their Effect on Equilibrium.

Remember that a pressure change potentially affecting the position of equilibrium can be accomplished three different ways.

(1) Increasing the volume of the reaction container will reduce the pressure.
(2) Reducing the volume of the reaction container will send the pressure up.
(3) Introducing an inert gas like argon into the reaction container will increase the total pressure.

Important point: the volume changes would affect ONLY the substances in a gaseous state. Liquid and solids would be unaffected by any volume changes. Since the below examples are all 100% gas phase, the position of the equilibrium will be changed, except in one particular circumstance, demonstrated in example #6.

Example #5: The container holding the following reaction (already at equilibrium) has its volume suddenly reduced by half. Which way will the equilibrium shift to compensate?

$PCl_3 + Cl_2 \rightleftharpoons PCl_5$

Answer:

Since the volume went down, this means the pressure went up. The reaction will try to lessen the pressure by shifting to the side with the lesser number of gas molecules. This means a shift to the right because for every PCl_5 molecule made, two molecules are used up. The lesser the total number of gas phase molecules in the container, the lesser the pressure.

Example #6: The container holding the following reaction (already at equilibrium) has its volume suddenly increased. Which way will the equilibrium shift to compensate?

$H_2 + Cl_2 \rightleftharpoons 2HCl$

Answer:

Neither side is favored over the other since both sides have the same number of total molecules (two). No matter which way the reaction shift, the total number of molecules would remain unchanged.

In cases like this, where there is an equal number of molecules on each side, the equilibrium would remain unchanged by the change in pressure (in either direction).

Example #6 is a favorite question to ask on a test. All other examples used would involve a change in the number of gas molecules, therefore showing a shift in the position of the equilibrium. In the above example, the number of gas molecules is the same on each side, so no shift.

You have been warned!

Example #7: The system below is already at equilibrium when some neon is added to the system. What happens to the position of the equilibrium? Does it shift right, left, or no change?

$H_2 + Cl_2 \rightleftharpoons 2HCl$

Answer:

The neon DOES NOT participate in the chemical reactions (forward and reverse) which make the equilibrium. Therefore, the presence of the inert gas has NO EFFECT on the position of the equilibrium. The $[H_2]$, $[Cl_2]$ and $[HCl]$ would all remain unchanged.

Example #8: The system below is already at equilibrium when a catalyst is added to the system. What happens to the position of the equilibrium? Does it shift right, left, or no change?

$PCl_3 + Cl_2 \rightleftharpoons PCl_5$

Answer:

There will be no change in the equilibrium. BOTH (with emphasis on both) the forward and the reverse reactions are speeded up. A catalyst just gets you to equilibrium faster, it doesn't affect the final position of equilibrium like changing the concentration would.

Example #9: Which way would the equilibrium shift if the pressure is increased?

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

Answer:

You should think of the pressure being increased by reducing the volume, not by adding an inert substance or heating the system up.

The position of the equilibrium would shift to the side with the lesser number of molecules. The shift would be to the right.

Which direction will the reaction shift due to the change? R / L / NC

$N_2 + 3H_2 \rightleftharpoons 2NH_3$ + heat

a. remove NH_3 gas
b. decrease pressure
c. add N_2 gas
d. increase temperature

$2SO_2 + O_2 \rightleftharpoons 2SO_3$ + heat

e. increase SO_2 concentration
f. increase temperature
g. remove O_2

CO_2 + C + heat $\rightleftharpoons$ 2 CO

h. increase temperature
i. increase CO concentration
j. decrease pressure

$H_2 + Cl_2 \rightleftharpoons 2HCl$ + heat

k. increase H_2 concentration
l. increase pressure

$N_2 + O_2$ + heat $\rightleftharpoons$ 2NO

m. decrease O_2 concentration
n. add catalyst

$PCl_3 + Cl_2 \rightleftharpoons PCl_5$ + heat

o. increase Cl_2 concentration
p. decrease pressure

$CO_2 + H_2$ + heat $\rightleftharpoons CO + H_2O$

q. decrease pressure
r. add a catalyst

N_2O_4 + heat $\rightleftharpoons 2\ NO_2$

s. decrease pressure
t. remove N_2O_4