What will happen if an equilibrium system is disturbed?

Possible disturbances include a change in concentration of one of the substances, a change of temperature, or a change in the pressure (essentially the concentration) of a gas, or the addition of a catalyst.

The French chemist LeChatelier developed a principle to help chemists predict the effect of a disturbance.

What is LeChatelier's Principle?

When an equilibrium system is subjected to a stress (change), processes will occur to shift the equilibrium to alleviate the stress, until a new equilibrium is established.

Concentration Change:

Consider the following system at equilibrium:

\[
2\text{HI} (g) \rightleftharpoons \text{H}_2 (g) + \text{I}_2 (g)
\]

Now, let's subject the equilibrium to a change: the addition of more \text{HI} (g) to the system.

What substance initially increases in concentration?

What does this affect the amount of collisions?

How does this affect the forward and reverse reaction rates?

If one rate is temporarily greater than the other, we say a shift is taking place, as concentrations are no longer constant. In the case above, shift to the right is taking place because the forward rate is temporarily ________ than the reverse rate.

Therefore, products are being produced faster than they are being used (resulting in a net increase), so during a shift right, we say that products are favoured. This is LeChatelier's 'counteraction' (we added more reactant, but now the product concentration is increasing).

Since products start increasing in concentration, what will happen to the reverse rate?

Concurrently, since the reactant is being used up faster than it is being produced, what starts to happen to the forward rate?

The reverse rate continues to increase and the forward rate continues to decrease until...

In summary:

\[ [\text{HI}] \text{ initially } \text{increased}, \text{ then due to the shift right it decreased but overall is slightly } \text{decreased} \text{ (an initial change is always more drastic than a shift change).} \]

\[ [\text{H}_2] \text{ increased, and } [\text{I}_2] \text{ increased due to the shift right.} \]

So how is it possible that all of \[ [\text{HI}], [\text{H}_2], \text{ and } [\text{I}_2] \text{ increased? Because more } \text{HI} \text{ was added initially, there are more particles in the system, so all the } \text{(concentrations) can do is increase.} \]

Graph the concentration changes that occur throughout the process:

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Sample Problem 2.2.1(a) — Predicting How an Equilibrium System Will Respond to the Addition of Reactants or Product

Some \text{H}_2 \text{ is added to the system below. In what direction will the system shift to restore equilibrium? When equilibrium is restored, how will the concentration of each substance compare to its concentration below the \text{H}_2 \text{ was added?} \]

\[
\text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2\text{HI}(g)
\]

What to Think About

1. Using Le Chatelier's principle, determine if the system will shift to remove some of the added \text{HI}.

2. Infer from Le Chatelier's principle that the shift left produces \text{HI} and \text{I}_2. Notice that Le Chatelier's principle doesn't explicitly state what happens to the concentrations of \text{H}_2 and \text{I}_2, but you can infer what happens from your understanding of the principle.

How to Do It

The system must shift left to remove at least some of the added \text{HI}.

Always use all of the \text{H}_2 added will be removed; the \text{I}_2 will increase.

The \text{[H}_2] \text{ and } [\text{I}_2] \text{ will also increase.}
How is it possible that both rates are now higher compared to the original equilibrium?

Summary using LeChatelier’s Principle:
If an equilibrium is subjected to a change ____________________________, processes occur to counteract the change ____________________________, until a new equilibrium is established ____________________________.

Consider the same system at equilibrium: $2\text{HI}(g) \rightleftharpoons \text{H}_2(g) + \text{I}_2(g)$

Explain what would occur if some $\text{HI}(g)$ is removed from the system.

- HI collisions would ____________________________.
- Forward rate would ____________________________.
- Thus, reverse rate will be temporarily ____________________________ than the forward rate.
- This will cause a shift ____________________________, meaning ____________________________ will be favoured.
- Thus, reverse rate will be temporarily ____________________________. This will cause a shift ____________________________, meaning ____________________________ will be favoured.
- Eventually, the forward rate will start to ____________________________ and the reverse rate will start to ____________________________, until they become balanced.
- At this point, a new ____________________________ has been established.

In summary, $[\text{HI}]$ initially ________________ and $[\text{H}_2]$ and $[\text{I}_2]$ ________________.

Overall slightly ________________, $[\text{HI}]$ ________________, and $[\text{H}_2]$ ________________, $[\text{I}_2]$ ________________.

How is it that all concentrations decrease?

Graph how concentrations change during the process:

Graph how the rates change during the process:

LeChatelier’s Principle: ________________
Le Chatelier's Principle:

What was the initial change? (decrease in HCN(g) "reactant"
What was the ‘counteraction’? shift LEFT, to favor reactant(s) to temporarily produce more N2(g) (to Qf)
Why was it a ‘new’ equilibrium? the new rates are slightly lower, but equal and the concentrations are constant.

Note: The ‘counteraction’ is always the shift that is the result of the initial stress/disturbance.

Conclusion: Increasing the concentration of a substance causes a shift to the opposite side. Decreasing the concentration of a substance causes a shift to the same side.