DISTURBING AN EQUILIBRIUM SYSTEM – Sample Data & ANSWER KEY

System	Disturbance	Observed Change	Direction of Shift
1	Add $Fe(NO_3)_3$ [Reactant]	Darker Red	Right
1	Add KSCN [Reactant]	Darker Red	Right
1	Add NaOH [Removes Fe^{3+}]	Lighter – More Yellow	Left
1	Heat [Exo]	Lighter – More Yellow	Left
1	Cold [Exo]	Darker Red	Right
2	Add HCl	Yellow	Left
2	Add NaOH	Blue	Right
3	Add $CaCl_2$	Green	Left
3	Add C_2H_5OH	Green	Left
3	Heat [Exo]	Green	Left
3	Cold [Exo]	Blue	Right
4	Heat [Endo]	Darker Reddish-Brown	Right
4	Cold [Endo]	Lighter	Left
5	$CaCl_2$	Darker Red & Blue	Right
5	Acetone	Darker Red & Blue	Right
5	Heat [Endo]	Darker Red & Blue	Right
5	Cold [Endo]	Lighter Red	Left

Data Analysis

1. To complete the **fourth column** on the right side of the **data table** (headed **Direction of Shift**), decide whether each disturbance caused the equilibrium system to shift left or right. Record the direction of shift in this column. Consider the equilibrium system:

   A <-----> B
   yellow green

   If a disturbance causes the system to become more yellow, chemists would say that the equilibrium position has shifted to the "left" because the system must have moved to produce more of the yellow molecules shown on the left side of the chemical equation. If the system shifted to the right greener would be observed in the system. The direction of shift is "right".

See Above

2. Use the data table to find all cases where a disturbance was caused by heating.
   a) How does the direction of shift relate to the side of the chemical equation on which the heat term is written?

Increasing the temperature results in a shift away from the heat – to the left (reactants) if the reaction is exothermic and to the right (products) if the reaction is endothermic.

   b) Write a rule which would allow a prediction of how other equilibrium systems would shift when disturbed in this way.

Increasing the temperature results in a shift away from the heat.

3. Use the data table to find all cases where equilibrium systems were disturbed by cooling.
   a) How does the direction of shift relate to the side of the chemical equation on which the heat term is written?

Decreasing the temperature results in a shift towards the heat – to the left (reactants) if the reaction is endothermic and to the right (products) if the reaction is exothermic.

   b) Write a rule which would allow a prediction of how other equilibrium systems would shift when disturbed in this way.

Decreasing the temperature results in a shift towards the heat.

4. Use the data table to examine all cases where a disturbance was caused by increasing the concentration of a substance already present in the equilibrium system. Hint: Adding solid $Fe(NO_3)_3$ to System 1 increases the concentration of $Fe^{3+}_{(aq)}$ and $NO_3^-{}_{(aq)}$ when the solid dissolves. Adding HCl solution to System 2 increases the concentration of both $H^+_{(aq)}$ and $Cl^-_{(aq)}$ in the system.

Write a rule which would explain how the direction of shift relates to the side of the chemical reaction on which the substance with increased concentration is written.

Increasing the concentration results in a shift away from the substance being increased – increasing a reactant shifts right towards the products and increasing a product shifts left towards the reactants.

5. In some cases, the equilibrium system was **disturbed by decreasing the concentration of a substance** in the system. Usually this is done by **adding another substance not involved in the equilibrium** which reacts with a substance in the system, changing it to a different substance. Concentration can also be decreased by **adding another solvent (acetone or alcohol) to dilute the water** in the system. Which systems in this lab were disturbed by the addition of another substance? In each case involving a decrease in concentration, identify the substance that is decreased in concentration, on which side of the equation this substance is found, and which way the equilibrium is observed to shift.

Decreasing the concentration results in a shift towards the substance being decreased – decreasing a product shifts right towards the products and decreasing a reactant shifts left towards the reactant.

6. Consider cases where equilibrium was disturbed by decreasing the concentration of a substance in the equilibrium system.
   a) How does the direction of shift relate to the side of the chemical equation on which the substance with altered concentration is written?

Decreasing a product shifts right towards the products and decreasing a reactant shifts left towards the reactant.

   b) Write a rule which would allow a prediction of how other equilibrium systems would shift when disturbed in this way.

Decreasing the concentration results in a shift towards the substance being decreased.

7. Write a general rule that would cover all of the types of disturbances observed in this experiment. Write the rule so it can be used to predict the effect of any temperature or concentration disturbance on an equilibrium system.

Increasing the concentration results in a shift away from the substance being increased & decreasing the concentration results in a shift towards the substance being decreased. Increasing the temperature results in a shift away from the heat – to the left (reactants) if the reaction is exothermic and to the right (products) if the reaction is endothermic. Decreasing the temperature results in a shift towards the heat – to the left (reactants) if the reaction is endothermic and to the right (products) if the reaction is exothermic.

Questions

1. Explain why no visible changes can be observed when a system is at equilibrium. Express the answer in terms of the rates of the forward and reverse reactions.

At equilibrium, the rate of the forward reaction is equal to the rate of the reverse reactions; therefore, there is no observed change in the system.

2. What effect would each of the following have on the rate of an exothermic reaction? (Answer in terms of the rate of the forward reaction or the rate of the reverse reaction.)
   a) increasing the concentration of a reactant

Increasing the concentration of a reactant results in a shift away from this increase to the right (products).

   b) decreasing the concentration of a reactant

Decreasing the concentration of a reactant results in a shift towards this decrease to the left (reactants).

   c) increasing the temperature of the system

Increasing the temperature results in a shift away from the heat – to the left (reactants) if the reaction is exothermic and to the right (products) if the reaction is endothermic.

   d) decreasing the temperature of the system

Decreasing the temperature results in a shift towards the heat – to the left (reactants) if the reaction is endothermic and to the right (products) if the reaction is exothermic.