# Rainbow Lab

## Equilibrium: An Application of Le Chatelier's Principle

(Adapted from AP Investigation 13: Can we make the colours of the rainbow?)

**Introduction**:

The main challenge is to investigate Le Chatelier's Principle by testing several systems at equilibrium and then selecting specific ones to produce the colours of the rainbow based on Le Chatelier's Principle. An additional challenge involves selecting which reaction system to use for which colour in producing the rainbow while trying to only use a given "stress" once.

**Learning Intentions**:

Use Le Chatelier's Principle to design a set of conditions that will optimize a desired outcome: producing the colours of the rainbow.

B3 – apply Le Chatelier's Principle to the shifting of equilibrium.

**Materials**:

| | | | |
|---|---|---|---|
| beakers | test tube racks | ice | distilled water |
| graduated cylinders | test tubes | hot plates | stirring rods |

In addition to the above materials, you will have the following reagents available to you for each reaction.

Solutions containing **copper** must be disposed of in the proper jar and may not be poured down the sink.

**Important: you may only combine materials within a given station. You may not transfer the reagents to another tray.**

**Procedure**:

Possible equilibrium systems for your use are described in the materials section. You will need to investigate some or all of them and make predictions. Know that in some cases the applied stress may simply reinforce the current colour of the equilibrium system and produce no observable changes.

Be sure to use small quantities of reagents, add these reagents dropwise with stirring, and use hot plates or ice baths to heat or cool your samples should you wish.

Be sure to **keep detailed records**, including a **step-by-step procedure**, a list of **materials used**, all **data and observations**. You need to clearly indicate the **reactant and product species** in each system, the **stress ion** you applied, and the resulting **colour**.

Once you have completed all your investigations and decided which stations to test and which reagents will contain the stress ion, you will prepare your rainbow display. You may be asked to produce the display for your teacher. (Take a picture of you and your partner with the rainbow display!)

**Analysis:**

1. For each equilibrium system studied, identify:
    - the equilibrium reaction
    - the reagent added
    - the ion that caused the stress

2. For each equilibrium shift, explain using Le Chatelier's Principle:
    - How the stress ion affects collisions
    - How the reaction rate is affected
    - How the equilibrium shifts
    - What color you should see

**STATION 1**: The equilibrium reaction is: $HB(aq) \leftrightarrow H^+(aq) + B^-(aq)$

Yellow blue

**Materials**: bromothymol blue, 0.10M HCl, 0.10M NaOH, 0.10M NaCl, glassware

**Guidelines**:

- To create the equilibrium system, add 1mL of bromothymol blue indicator to 25mL of water. Transfer this mixture into test tubes.

- To shift the equilibrium, you can choose to add 0.10M HCl, 0.10M NaOH, and/or 0.10M NaCl dropwise, mixing after each addition. Do not use any other chemicals for station 1.

**Clean Up**: All solutions can be washed down the sink with lots of water.

Remember that there are 3 possibilities:

1. You increase the concentration of one of the species in the equilibrium.
2. You decrease the concentration of one of the species in the equilibrium through a secondary reaction.
3. None of the ions react, acting as spectator ions, and the equilibrium does not shift. If you see the color lighten, it is due to a dilution of the solution, not an equilibrium shift.

**STATION 2**: The equilibrium reaction is: $Fe^{3+}$ (aq) + $SCN^-$ (aq) ←→ $FeSCN^{2+}$ (aq)

Orange/yellow red

**Materials**: 0.10M KSCN, 0.20M $Fe(NO_3)_3$, 0.10M $KNO_3$, 0.20M $FeCl_3$, solid KSCN, a sodium phosphate ($Na_2HPO_4$, $NaH_2PO_4$, or $Na_3PO_4$ depending on what is available), glassware

**Guidelines**:

- To create the equilibrium system, add about 20mL of 0.10M KSCN into your beaker. Add 20 mL of water and 5 drops of 0.20M $Fe(NO_3)_3$. Transfer this mixture into test tubes.

- To shift the equilibrium, you can choose to add 0.10M $KNO_3$ dropwise, 0.20M $FeCl_3$, solid KSCN, and/or a sodium phosphate a few crystals at a time, mixing after each addition. Do not use any other chemicals for station 2.

**Clean Up**: All solutions can be washed down the sink with lots of water.

Remember that there are 3 possibilities:

1. You increase the concentration of one of the species in the equilibrium.
2. You decrease the concentration of one of the species in the equilibrium through a secondary reaction.
3. None of the ions react, acting as spectator ions, and the equilibrium does not shift. If you see the color lighten, it is due to a dilution of the solution, not an equilibrium shift.

**STATION 3**: The equilibrium reaction is: $Cu^{2+}(aq) + 4NH_3(aq) \leftrightarrow [Cu(NH_3)_4]^{2+}(aq)$

Light blue dark blue

**Materials**: 0.50M $CuSO_4$, concentrated $NH_3$ (probably 6M), 1.0M HCl, glassware, fume hood

**Guidelines**:

- To create the equilibrium system, take 25mL of 0.50M $CuSO_4$ and add concentrated $NH_3$ dropwise to observe the formation of a precipitate. Transfer this mixture into test tubes.

- To shift the equilibrium, it would be best to do your experiment in the fume hood. You can choose to add 1.0M HCl or concentrated $NH_3$ dropwise, mixing after each addition. Do not use any other chemicals for station 3.

**Clean Up**: Copper solutions should be placed in the designated waste container. Wash all glassware with lots of water.

Remember that there are 3 possibilities:

1. You increase the concentration of one of the species in the equilibrium.
2. You decrease the concentration of one of the species in the equilibrium through a secondary reaction.
3. None of the ions react, acting as spectator ions, and the equilibrium does not shift. If you see the color lighten, it is due to a dilution of the solution, not an equilibrium shift.

# **STATION 4**: The equilibrium reaction is:

$[Cu(H_2O)_6]^{2+}$ (aq) + $4Cl^-$ (aq) ←→ $[CuCl_4]^{2-}$(aq) + 6 $H_2O$ (l)

Blue green

**Materials**: solid $CuCl_2$ , concentrated HCl (probably 6M or higher), water, glassware

**Guidelines**:

- To create the equilibrium system, add about 2g $CuCl_2$ to 25mL of water.
- To shift the equilibrium, it would be best to do your experiment in the fume hood. You can choose to add concentrated HCl and/or water dropwise, mixing after each addition. Do not use any other chemicals for station 4.

**Clean Up**: Copper solutions should be placed into the designated waste container. Wash all glassware with lots of water.

Remember that there are 3 possibilities:

1. You increase the concentration of one of the species in the equilibrium.
2. You decrease the concentration of one of the species in the equilibrium through a secondary reaction.
3. None of the ions react, acting as spectator ions, and the equilibrium does not shift. If you see the color lighten, it is due to a dilution of the solution, not an equilibrium shift.

**STATION 5**: There are 2 equilibrium reactions that are linked to each other through a common ion:

Equation 1: soda water equilibrium

$CO_2(g) \leftrightarrows CO_2(aq) + H_2O(l) \leftrightarrows H_2CO_3\ (aq) \leftrightarrows HCO_3^-\ (aq) + H^+\ (aq) \leftrightarrows CO_3^{2-}\ (aq) + H^+\ (aq)$

Equation 2: methyl red indicator

$HM\ (aq) \leftrightarrows H^+\ (aq) + M^-\ (aq)$

Red yellow

**Q**: What is the common ion in both equilibrium systems?

Note: If the concentration of that ion increases in one system, it also increases in the other system. You will need to look at the shift in equilibrium in BOTH reactions and predict what you would see.

**Materials**: methyl red, cold soda water, syringe, Luer Lock valve, glassware

**Guidelines**:

- To create the equilibrium system, add 20mL of cold soda water to a beaker and add 1mL of methyl red indicator.
- Draw 10mL of the mixture up into a large syringe with a Luer Lock valve.
- Invert the syringe and depress the piston to expel gas and then close the stopcock on the Luer Lock valve.
- To shift the equilibrium, change the pressure of the system by pulling the piston back and holding it (takes muscle!). Are you increasing or decreasing the pressure inside the system when you pull the piston back? When you push the piston forward? Which way did the equilibrium shift in each reaction?
- Do not use any other chemicals for station 5.

**Clean Up**: All solutions can be washed down the sink with lots of water. Rinse the syringe, Luer Lock, and all glassware with lots of water.

Remember that there are different possibilities:

1. For the gases in your system, you increase the pressure of the system and the equilibrium shifts to decrease the pressure by producing fewer moles of gas.
2. For the gases in your system, you decrease the pressure of the system and the equilibrium shifts to increase the pressure by producing more moles of gas.
3. For the solution, you increase the concentration of one of the species in the equilibrium.
4. For the solution, you decrease the concentration of one of the species in the equilibrium through a secondary reaction.
5. For the solution, none of the ions react, acting as spectator ions, and the equilibrium does not shift. If you see the color lighten, it is due to a dilution of the solution, not an equilibrium shift.