Can We Make the Colors of the Rainbow?
An Application of Le Châtelier's Principle

Challenge

What is Le Châtelier's principle? How and why does it work? The central challenge is to investigate this principle by testing several systems at equilibrium and then selecting specific ones to produce the colors of the rainbow based on specific applications of Le Châtelier's principle. Several systems produce similar colors so not all students will have the same results.

Materials Per Group:

Small beakers
25 mL graduated cylinder
Test tube rack & test tubes
Glass stirring rods
Distilled water wash bottle
Ice water bath
Hot water bath

Materials (per tray)					
Tray 1	**Tray 2**	**Tray 3**	**Tray 4**	**Tray 5**	**Tray 6**
Concentrated Bromothymol Blue indicator	0.1M KSCN	0.25M $CuSO_4$	$CuCl_2 \bullet 2H_2O$ (s)	$CoCl_2 \bullet 6H_2O$ (s)	Concentrated Methyl Red indicator
1.0M HCl	0.2M $Fe(NO_3)_3$	Concentrated NH_3	12M HCl	95% ethanol	0.1M HCl
1.0M NaOH	KSCN (s)	1.0M HCl		12M HCl	0.1M NaOH
$NaHCO_3$	$Fe(NO_3)_3$ (s)			0.1M $AgNO_3$	0.1M NaCl
	Na_2HPO_4 (s)				
	0.1M KNO_3				

Procedure

Possible equilibrium systems for your use are described below. You will need to investigate them before the lab and make a prediction about what color they will be in your rainbow and how you will stress the equilibrium to make the color you desire possible. Know that in some cases the applied stress may simply reinforce the current color of the equilibrium system and thus produce no observable changes.

Be sure to use small quantities of reagents, add these reagents dropwise with stirring, and use the hot and cold water baths to heat or cool your samples. Keep detailed written records— you need to clearly state the stressor you applied and the resulting color. Note the safety precautions given for some of the reagents.

Pre-lab Investigation

Investigate each of the six equilibrium reactions given below and:

- Write a balanced chemical equation for the equilibrium, indicating the colors of the products and reactants and whether it is endothermic or exothermic (when relevant). For indicators (such as BTB) you may write the name of the indicator rather than the chemical formula in your equation.
- Plan which reaction you will use for each color of the rainbow. Your goal is to use a <u>different</u> reaction for each of the six colors: red, orange, yellow, green, blue, purple.
- Describe the stress you will use to achieve the desired color change in the system.

Tray 1: Bromothymol Blue Equilibrium

Bromothymol Blue is an acid-base indicator you may be familiar with from biology. You will be given a concentrated solution of the indicator that you can dilute with distilled water to your desired color. You will be provided with 1.0M HCl, 1.0M NaOH and sodium bicarbonate ($NaHCO_3$).

1. Equilibrium expression:

2. Color this system will be used to make:

3. How will you make this color? Justify using LeChâtelier's principle.

4. Description of results during lab:

Tray 2: Complex Ion Equilibria with Iron (III) Nitrate and Potassium Thiocyanate

An equilibrium system can be formed in solution with iron (III) nitrate and potassium thiocyanate. The ion that forms is the $FeSCN^{2+}$ complex ion. To create the equilibrium mixture, add about 20 mL of 0.10 M KSCN solution to a beaker and then add 20 mL of distilled water and 5 drops of $Fe(NO_3)_3$ solution. You will have 0.10M $NaNO_3$ (*aq*), solid $Fe(NO_3)_3$, solid KSCN, and solid Na_2HPO_4 to work with.

5. Equilibrium expression:

6. Color this system will be used to make:

7. How will you make this color? Justify using LeChâtelier's principle.

8. Description of results during lab:

Tray 3: Complex Ion Equilibria with Copper (II) Sulfate

An equilibrium system can be formed in solution with copper (II) sulfate and ammonia. To create the equilibrium mixture, take 15 mL 0.25 M $CuSO_4$ and add concentrated ammonia to observe the production of a precipitate. Continue adding the ammonia until the precipitate disappears (this will take a fairly large amount of ammonia). Investigate the shifts that can be observed by applying a stress to small amounts of this solution in the test tubes provided. You will have hydrochloric acid and your original reagents to work with.

9. Equilibrium expression:

10. Color this system will be used to make:

11. How will you make this color? Justify using LeChâtelier's principle.

12. Description of results during lab:

Tray 4: Complex Ion Equilibria with Copper (II) Chloride

An equilibrium system can be formed in a solution with copper (II) chloride in water. To create the equilibrium mixture, add about 2 grams of copper (II) chloride to 25 mL of water. Investigate the shifts that can be observed by applying a stress to small amounts of this solution in the test tubes provided. You will have concentrated HCl (**USE WITH EXTREME CAUTION**) and water.

13. Equilibrium expression:

14. Color this system will be used to make:

15. How will you make this color? Justify using LeChâtelier's principle.

16. Description of results during lab:

Tray 5: Complex Ion Equilibria with Cobalt (II) Chloride

To create this equilibrium mixture, add 2 grams of cobalt (II) chloride hexahydrate to 25 mL of 95% ethanol in a 100 mL beaker. There is a small amount of water dissolved in the ethanol. Investigate shifts that can be observed by applying a stress to small amounts of this solution in the test tubes provided. You will have concentrated HCl (**USE WITH EXTREME CAUTION**), 0.1M silver nitrate (avoid contact with skin!), and water.

17. Equilibrium expression:

18. Color this system will be used to make:

19. How will you make this color? Justify using LeChâtelier's principle.

20. Description of results during lab:

Tray 6: Methyl Red Equilibrium

To create the equilibrium mixture, place 20 mL of distilled water in a beaker and add 1 mL (about 10 drops) of methyl red indicator. Investigate the shifts that can be observed by applying a stress to small amounts of this solution in the test tubes provided. You will be provided with 0.1M HCl, 0.1M NaOH, and 0.1M NaCl.

21. Equilibrium expression:

22. Color this system will be used to make:

23. How will you make this color? Justify using LeChâtelier's principle.

24. Description of results during lab:

Take a picture of your rainbow and paste it here: