Objectives:
1. To make predictions of which way equilibria will shift when certain stresses are applied.
2. To make predictions of what will be observed when certain stresses are applied to systems at equilibrium.
3. To test the predictions made.

PART 2-EQUILIBRIUM INVOLVING THE THIOCYANATOIRON (III) ION

Information Needed:
1. The equilibrium equation involved is:
   \[ \text{Fe}^{3+}(aq) + \text{SCN}^{-}(aq) \rightleftharpoons \text{FeSCN}^{2+}(aq) \]
   - pale rust
   - clear
   - dark red

2. The Cl\(^-\) ion reacts with the Fe\(^{3+}\) ion to decrease its concentration in solution.
   The reaction is: \( \text{Fe}^{3+}(aq) + 4\text{Cl}^{-}(aq) \rightarrow \text{FeCl}_{4}^{-}(aq) \). The FeCl\(^-\) does not interfere with the original equilibrium.

3. The Fe\(^{3+}\) ion reacts with the OH\(^-\) ion to produce the precipitate Fe(OH)\(_3\).
   This decreases the [Fe\(^{3+}\)] in solution.

4. In this equilibrium, a darkening would indicate a shift to the ____________

Procedure:
1. Fill in the prediction columns in the table on the next page.

2. To check the predictions do Part II - Procedures 1-8 on pages 209-210 in the Heath Lab Manual. NOTE HAZARD ON TOP LEFT MARGIN OF P. 210. Fill in the rest of the chart while you are doing the experiment.
\[
\text{Fe}^{3+}(\text{aq}) + \text{SCN}^{-}(\text{aq}) \rightleftharpoons \text{FeSCN}^{2+}(\text{aq})
\]

**Pale rust**

**Clear**

**Dark red**

<table>
<thead>
<tr>
<th>Test Tube</th>
<th>Active Ion</th>
<th>Predicted Shift</th>
<th>Predicted Observation</th>
<th>Actual Observation</th>
<th>Reason for the Shift (increase or decrease of [Fe(^{3+})] or [SCN(^-)])</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Cl(^-)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>C</td>
<td>Fe(^{3+})</td>
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<td></td>
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<tr>
<td>D</td>
<td>SCN(^-)</td>
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<td></td>
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<tr>
<td>E</td>
<td>OH(^-)</td>
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</table>

**PART 3 - EQUILIBRIUM INVOLVING THE COBALT (II) COMPLEXES**

**Information Needed:**
1. The equilibrium equation involved is:

\[
\text{Co(H}_2\text{O)}_6^{2+}(\text{aq}) + 2\text{Cl}^-\text{(aq)} \rightleftharpoons \text{Co(H}_2\text{O)}_4\text{Cl}_2\text{(aq)} + 2\text{H}_2\text{O(l)}
\]

2. The reaction as written is endothermic (ie. Heat is on the left side)

3. In this case, the "active ion" in HCl is the Cl\(^-\) ion. (H\(^+\) is a spectator)

4. Read the "Hazards" for part III in the left margin of page 210.

5. Instead of a bunsen burner, use a hot-plate in procedure 5.

**Procedure:**

1. Read procedures 1-6 on Part III on page 210. Fill in the prediction columns in the table on the next page:
2. Follow steps 1-6 on Part III on page 210 of the Heath Lab Manual. Be careful with the heating. Make sure you wear goggles throughout this part of the experiment! Fill in the "Actual Observations" Column on the chart above.

PART 4 - EQUILIBRIUM INVOLVING THE CHROMATE AND DICHROMATE IONS

Information Needed:

1. The equilibrium equation involved is:

\[
2\text{CrO}_4^{2-}(aq) + 2\text{H}^+(aq) \rightleftharpoons \text{Cr}_2\text{O}_7^{2-}(aq) + \text{H}_2\text{O}(l)
\]

2. HCl\(\text{aq}\) contributes H\(^+\) to this equilibrium

3. NaOH\(\text{aq}\) reduces the [H\(^+\)] by reacting with it. (H\(^+\) + OH\(^-\) \rightarrow H_2O)

4. Ba(NO\(_3\))\(_2\) is used as a test for chromate (CrO\(_4\)\(^{2-}\)). The Ba\(^{2+}\) ion forms a precipitate with CrO\(_4\)\(^{2-}\) but not with Cr\(_2\)O\(_7\)\(^{2-}\). So when barium nitrate is added to one of these solution, a cloudiness would indicate that some CrO\(_4\)\(^{2-}\) is present in the solution. The more the cloudiness, the more CrO\(_4\)\(^{2-}\) is present.
**Procedure:**

1. Read procedures 1-9 on Part IV on page 210-211. Fill in the prediction columns in the following chart. **Omit procedure 4**!

\[ 2\text{CrO}_4^{2-}(aq) + 2\text{H}^+(aq) \rightleftharpoons \text{Cr}_2\text{O}_7^{2-}(aq) + \text{H}_2\text{O}(l) \]

<table>
<thead>
<tr>
<th>Step</th>
<th>Stress</th>
<th>Predicted Shift (L or R)</th>
<th>Predicted Observations</th>
<th>Actual Observations</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>Oh⁻</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>H⁺(HCl)</td>
<td></td>
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<tr>
<td>5</td>
<td>Oh⁻</td>
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<td>What colour?</td>
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<tr>
<td>6</td>
<td>H⁺(HCl)</td>
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<td>What colour?</td>
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<td>7</td>
<td>H⁺</td>
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<td>Will it be cloudy?</td>
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<td>8</td>
<td>Oh⁻</td>
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<td>What colour?</td>
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<td>Will it turn cloudy?</td>
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<tr>
<td>9</td>
<td>CrO₄²⁻</td>
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<tr>
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<td>Ba(NO₃)₂</td>
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<td>as a test for</td>
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<tr>
<td></td>
<td>chromate</td>
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</tbody>
</table>
Procedure
1. Read the "Hazard" warning on the margins of Part IV on pages 210-211.

2. Do procedures 1-3 on Part IV and record the results in the table above.

3. **Omit procedure 4!**

4. Carry out procedures 5-9 on Part IV on page 211 and record the results in the table above.

Questions for this Experiment
1. How did your observed results in Part 2, compare with the predicted ones?

   _______________________________________________________________

   If there were any differences, explain why here. _______________________

   _______________________________________________________________

2. Write out the equilibrium equation for the reaction in Part 2.

   _______________________________________________________________

3. Predict the effect of adding FeBr₃(aq) to this equilibrium. _____________

   _______________________________________________________________

4. Explain, using LeChatelier’s Principle, why the addition of NaOH(aq) caused the colour of the solution to get lighter. Be detailed.

   _______________________________________________________________

   _______________________________________________________________

5. Write out the equation for the equilibrium reaction in **Part III**.

   _______________________________________________________________

6. Is this reaction **endothermic** or **exothermic**? ________________________
7. $\text{Ag}^+(\text{aq})$ is known to form a precipitate with $\text{Cl}^-$ ions. Predict the effect of adding aqueous silver nitrate to this equilibrium. ______________________________

_____________________________________________________________

8. Paper soaked in CoCl$_2$ and dried could be used as a test for ________________________

9. Write out the equation for the equilibrium in Part IV.

_____________________________________________________________

10. Explain, using LeChatelier’s Principle, why the solution turned orange when HCl was added to the Na$_2$CrO$_4$ solution. Refer to the equation in #9.

_____________________________________________________________

_____________________________________________________________

11. Explain, using LeChatelier’s Principle, why the solution turned yellow when NaOH was added to the Na$_2$Cr$_2$O$_7$ solution. Refer to the equation in #9.

_____________________________________________________________

_____________________________________________________________

12. Explain why the solution was cloudy in Step 5. _________________________

_____________________________________________________________

_____________________________________________________________

13. Explain, using LeChatelier’s Principle, why the cloudy colour disappeared in step 6, when the HCl was added. Be detailed!

_____________________________________________________________

_____________________________________________________________

14. Explain why there was a little bit of cloudiness in the second part of step 9, when Ba(NO$_3$)$_2$(aq) was added to the K$_2$Cr$_2$O$_7$(aq) solution. (Cr$_2$O$_7^{2-}$ does not form a precipitate with Ba$^{2+}$) ____________________________

_____________________________________________________________

_____________________________________________________________