Experiment Three

- Lab one: Parts 1 and 2A
- Lab two: Parts 2B and 3

REDOX Reactions

Halogens used in Parts 2 and 3

- Chlorine: \( \text{Cl}_2(g) \)
- Bromine: \( \text{Br}_2(l) \)
- Iodine: \( \text{I}_2(s) \)

Increasing molecular weight

HALOGENS

\( \text{Cl}_2 = \text{Chlorine} \)

- Exist as diatomic NONPOLAR molecules
- Oxidation state = zero
- Oxidizing agents that react to form halides:
  \( \text{Cl}_2 + 2e^- \rightarrow 2 \text{Cl}^- \)
HALIDES

- Exist as anions in salts
- Salt names end in ide (e.g., sodium bromide…)
- Oxidation state = -1.
- Reducing agents

HALIDES

Cl⁻ in NaCl(s)

Chloride ion

Halogens (Parts 2 and 3)

- The halogens will be provided in water solution.

Chlorine water  Bromine water  Iodine water

Similar in visual appearance

Halides (Parts 2 and 3)

- The halides are provided as sodium salts in water solution.

Sodium halide (s)  Sodium halide (aq)

- The sodium salts of the halides visually look the same in the solid state and in aqueous solution.

Part 2A. Color and Solubility of the Halides and Halogens

- Determine and compare the color and solubility of the halides and halogens in water and hexane.
The color of the halogens is solvent dependent.

Example

- Iodine versus Iodine water (dilute and more concentrated)

Polar (e.g., water) and non-polar (e.g., hexane) liquids are immiscible.

Polar and non-polar liquids form separate phases:

Salts are soluble and dissociate in polar solvents.
Salts are NOT soluble and do not dissociate in non-polar solvents.

“Like attracts like”

Q. A yellow-brown aqueous solution contains an unidentified halogen. If hexane is added to the solution two phases form where the upper phase is pink and the lower phase colorless. Identify the halogen

Answer: Iodine
Part 2B. Reactivity of the Halogens and Halides.

- Collect experimental data on the reactivity of the halogens and halides.

Discussion questions 3 and 4, p.96

OA Strength of Chlorine versus Bromine?

<table>
<thead>
<tr>
<th>Oxidizing agent</th>
<th>Reducing agent</th>
<th># rxns.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl₂</td>
<td>Br⁻</td>
<td></td>
</tr>
<tr>
<td>Br₂</td>
<td>Cl⁻</td>
<td></td>
</tr>
</tbody>
</table>

Table: Oxidizing agents on one side and reducing agents on the other side.

Caution: Check data. Does it make sense?

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<th># rxns.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl₂</td>
<td>No rxn</td>
<td>0</td>
</tr>
<tr>
<td>Br₂</td>
<td>No rxn</td>
<td>0</td>
</tr>
</tbody>
</table>

“These results don’t make sense!”

One combination of halogen and halide should react -- the stronger OA and RA agent!

Interpreting Experiment Results

1) Cl₂ + 2 Br⁻ → 2 Cl⁻ + Br₂
   OA      RA      RA      OA
2) Br₂ + 2 Cl⁻ → 2 Br⁻ + Cl₂
   “Reaction 1) or 2) should occur!”

1) OA strength: Cl₂ > Br₂
2) OA strength: Br₂ > Cl₂
Q. The electronegativity of chlorine = 3.0 and bromine = 2.8. Based strictly on electronegativity values, will \( \text{Br}_2(\text{aq}) + \text{NaCl}(\text{aq}) \) react?

- List the Oxidizing and reducing agent species and indicate the comparative strength

<table>
<thead>
<tr>
<th>Oxidizing Agent</th>
<th>Reducing Agent</th>
</tr>
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<tbody>
<tr>
<td>( \text{Cl}_2 )</td>
<td>( \text{Cl}^- )</td>
</tr>
<tr>
<td>( \text{Br}_2 )</td>
<td>( \text{Br}^- )</td>
</tr>
</tbody>
</table>

Answer: No. \( \text{Br}_2 \) and \( \text{Cl}^- \) are the weaker OA and RA.

Experiment Results

Q. \( \text{Br}_2(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \) reaction or no reaction?

- Add hexane

\( \text{Br}_2(\text{aq}) + 2 \text{NaCl}(\text{aq}) \rightarrow \) no reaction

Interpreting Experiment Results

Q2. Identify the species present in the upper and lower phases upon addition of hexane to the reaction mixture.

\( \text{Br}_2(\text{aq}) + 2 \text{NaCl}(\text{aq}) \rightarrow \) no reaction

Part 3. Analysis of Redox Reactions

- **Identify reactants and spectators** in redox reactions.
  - Non-reactive redox species (K\(^+\), Na\(^+\), NO\(_3^-\)) make good substitutes for an omitted species in tests.

- **Identify products; write a net reaction**
  - Compare properties to known substances
  - Use the *CRC Handbook*

- **Rank the oxidizing or reducing agent strength** of species in the reaction
"Help. I spilled Iodine!"

**Example:** \( \text{I}_2 + \text{SnCl}_2 \rightarrow ? \)

**Analysis of Reaction**

1. Record Observations

**DEMO:** Add tin(II) chloride to iodine spot!

**SnCl\(_2\)(aq) + I\(_2\)(aq) \rightarrow \text{clear and colorless product}**

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2. Design and Interpret Reference Blank Tests

**Reference Blank Test:** \( \text{NaCl(aq)} + \text{I}_2(aq) \rightarrow \text{no reaction} \)

**Conclusion:** “Sn\(^{2+}\) is a reactant”.

**Reference Blank Test:** \( \text{Sn(NO}_3\text{)}\(_2\)(aq) + \text{I}_2(aq) \rightarrow \text{reaction} \)

**Conclusion:** “Cl\(^-\) is a spectator”.

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### 3) Identify OA and RA Reactants

**Q.** Identify the oxidizing and reducing agent reactants:

\[ \text{Sn}^{2+} \text{(aq)} + \text{I}_2 \text{(aq)} \rightarrow \ ? \]

**RA** \hspace{1cm} **OA**

### 4) Identify Products and Write a Net Reaction

**Observation:** Light brown \( \text{I}_2 \text{(aq)} \) color fades.

**Knowledge:** \( \text{Sn}^{2+} \) is the reducing agent.

\[ \text{Sn}^{2+} \text{(aq)} + 2\text{I}^- \text{(aq)} \rightarrow 2\text{I}^- \text{(aq)} + \text{Sn}^{4+} \text{(aq)} \]

### 5) Strength of the Reducing and Oxidizing Agents?

\[ \text{Sn}^{2+} \text{(aq)} + \text{I}_2 \text{(aq)} \rightarrow \text{Sn}^{4+} \text{(aq)} + 2\text{I}^- \text{(aq)} \]

**RA** \hspace{1cm} **OA** \hspace{1cm} **OA** \hspace{1cm} **RA**

**RA strength:** \( \text{Sn}^{2+} > \text{I}^- \) \hspace{1cm} **OA strength:** \( \text{I}_2 > \text{Sn}^{4+} \)

The reactants are the stronger OA and RA.
Q. Identify the reactants in the redox reaction.
\[ \text{CoF}_3(\text{aq}) + K\text{Br}(\text{aq}) \rightarrow ? \]
given OA Strength: \( F_2 > \text{Co}^{3+} > \text{Br}_2 > K^+ \)

* List the species and indicate OA and RA strength:

<table>
<thead>
<tr>
<th>OA</th>
<th>RA</th>
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</thead>
<tbody>
<tr>
<td>( F_2 )</td>
<td>( F^- )</td>
</tr>
<tr>
<td>( \text{Co}^{3+} )</td>
<td>( \text{Co}^{2+} )</td>
</tr>
<tr>
<td>( \text{Br}_2 )</td>
<td>( \text{Br}^- )</td>
</tr>
<tr>
<td>( K^+ )</td>
<td>( K )</td>
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Q. Identify the reactants in the redox reaction.
\[ \text{CoF}_3(\text{aq}) + K\text{Br}(\text{aq}) \rightarrow ? \]
given OA Strength: \( F_2 > \text{Co}^{3+} > \text{Br}_2 > K^+ \)

* Note (circle) all species present in the reaction.

Q. Identify the reactants in the redox reaction.
\[ \text{CoF}_3(\text{aq}) + K\text{Br}(\text{aq}) \rightarrow ? \]
given OA Strength: \( F_2 > \text{Co}^{3+} > \text{Br}_2 > K^+ \)

* Identify which species will react

<table>
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<td>( \text{Br}^- )</td>
</tr>
<tr>
<td>( K^+ )</td>
<td>( K )</td>
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</tbody>
</table>

Answer: \( \text{Co}^{2+}(\text{aq}) + \text{Br}^- \)
Chem 125/126 Exam

**Practice exam questions:**
You should be able to answer all hourly I exam questions upon completion of experiment 3.

**Exams and review notes on Ctools and course web site:**

http://www.umich.edu/~chem125