Model 1: Oxidation, Reduction and Acid-Base Reactions

These reactions are very common in organic chemistry. In organic chemistry, they are defined in the following ways:

- Oxidation: gain of oxygen or loss of hydrogen to a carbon atom
- Reduction: loss of oxygen or gain of hydrogen to a carbon atom
- Acid-base: transfer of $\text{H}^+$ from an acid to a base

Critical thinking questions

1. Use these definitions to classify the reactions below as oxidation, reduction or acid-base.

(a) \[
\begin{array}{c}
\text{OH} \\
\xrightarrow{\text{Cr}_2\text{O}_7^{2-} / \text{H}^+}
\text{O}
\end{array}
\]

(b) \[
\begin{array}{c}
\text{OH} \\
\xrightarrow{\text{Cr}_2\text{O}_7^{2-} / \text{H}^+}
\text{O}
\end{array}
\]

(c) \[
\begin{array}{c}
\text{H} \\
\xrightarrow{\text{LiAlH}_4}
\text{O}^-
\end{array}
\]

(d) \[
\begin{array}{c}
\text{HO}^- \\
\xrightarrow{\text{[Ag(NH}_3)_2]^+ \cdot \text{OH}^-(aq)}
\text{O}^-
\end{array}
\]

2. Given your answer to Q1, predict the outcome of the following reactions.

(a) \[
\begin{array}{c}
\text{OH} \\
\xrightarrow{\text{Cr}_2\text{O}_7^{2-} / \text{H}^+}
\text{O}
\end{array}
\]

(b) \[
\begin{array}{c}
\text{O} \\
\xrightarrow{\text{Cr}_2\text{O}_7^{2-} / \text{H}^+}
\end{array}
\]

(c) \[
\begin{array}{c}
\text{HO}^- \\
\xrightarrow{\text{[Ag(NH}_3)_2]^+ \cdot \text{OH}^-(aq)}
\end{array}
\]

(d) \[
\begin{array}{c}
\text{H}_3\text{C} \xrightarrow{\text{Cr}_2\text{O}_7^{2-} / \text{H}^+}
\end{array}
\]
Model 2: Addition to a Carbonyl

In Worksheet 8, you looked at the following reaction:

The addition of a nucleophile to a carbonyl carbon is a very general reaction. The C=O bond is very polar and the C end is very easily attacked by a nucleophile.

Critical thinking questions

1. Using the model above, predict the outcome of the following reactions. (*Hint*: LiAlH₄ reacts as if it contains the hydride ion, H⁻)

   ![Reaction 1 Diagram]

2. Based on this, predict the outcome of the reaction below.

   ![Reaction 2 Diagram]

Model 3: Alcohol Addition – Water Elimination

In water, aldehydes and ketones are in equilibrium with hydrates:

![Equilibrium Diagram]

The mechanism for the acid catalysed formation of hydrates is shown below.
Critical thinking questions

1. Why does acid catalyse the reaction?

2. Two \( \text{H}_2\text{O} \) molecules are involved in the reaction. Describe the two ways in which \( \text{H}_2\text{O} \) is reacting.

Aldehydes and ketones can react in a similar way with alcohols to form hemiacetals and acetals, as shown below.

3. Hemiacetal formation follows the same mechanism as hydrate formation, except that an alcohol is the nucleophile instead of water. Add curly arrows to the reaction below to show this.

4. Both hydrate formation and hemiacetal formation are reversible. The steps of the reaction are themselves reversed. Add curly arrows to the reaction below to show this.
5. Acetal formation from a hemiacetal follows a similar mechanism to the first part of this, as shown below. Add curly arrows to the reaction below to show acetal formation.

```
\[
\begin{align*}
\text{HO} & \quad \text{OR} \\
\text{H} & \quad \text{H} \\
\text{OR} & \quad \text{OR} \\
\end{align*}
\]
```

6. Draw the structure of the product(s) formed in the following reactions.

(a) 

```
\[
\begin{align*}
\text{excess CH}_3\text{OH} & / H^+ \\
\end{align*}
\]
```

(b) 

```
\[
\begin{align*}
\text{HO} & \quad \text{OH} \\
\text{H} & \\
\end{align*}
\]
```

(c) 

```
\[
\begin{align*}
\text{H}^+ & \\
\end{align*}
\]
```
Hemiacetals are very important in sugar biochemistry. Circle the hemiacetal in the sugars below and draw the corresponding aldehyde. Do not worry about the stereochemistry. (*Hint:* number the carbon atoms)

(a) β-D-glucopyranose

(b) β-D-mannopyranose