The reaction of potassium dichromate (K₂Cr₂O₇) with sulfuric acid (H₂SO₄) and ferrous sulfate (FeSO₄) is a classic redox reaction. Here's a breakdown of the reaction, its components, and the underlying principles:

1. The Overall Reaction (in ionic form):

Cr₂O₇²⁻ (aq) + 14 H⁺ (aq) + 6 Fe²⁺ (aq) → 2 Cr³⁺ (aq) + 6 Fe³⁺ (aq) + 7 H₂O (l)

2. The Role of Each Reactant:

Potassium Dichromate (K₂Cr₂O₇): The Oxidizing Agent

Dichromate ion (Cr₂O₇²⁻) is a strong oxidizing agent. It accepts electrons and is reduced in the process.

The chromium in dichromate has an oxidation state of +6. It's reduced to Cr³⁺, where the oxidation state is +3.

The reduction of chromium from +6 to +3 requires gaining 3 electrons per chromium atom. Since there are two chromium atoms in Cr₂O₇²⁻, the dichromate ion accepts a total of 6 electrons.

Sulfuric Acid (H₂SO₄): The Acidic Medium

Sulfuric acid provides the acidic (H⁺) environment necessary for the reaction to proceed effectively. The dichromate ion's ability to oxidize is heavily dependent on the presence of sufficient hydrogen ions.

H⁺ ions participate directly in the reduction half-reaction of dichromate.

Ferrous Sulfate (FeSO₄): The Reducing Agent

Ferrous sulfate is the reducing agent. Ferrous ion (Fe²⁺) donates electrons and is oxidized in the process.

The iron in ferrous sulfate has an oxidation state of +2. It's oxidized to Fe³⁺, where the oxidation state is +3.

The oxidation of iron from +2 to +3 involves the loss of one electron per iron atom.

3. Half-Reactions:

To understand the electron transfer, we can separate the overall reaction into two half-reactions:

Reduction Half-Reaction (Dichromate is reduced):

Cr₂O₇²⁻ (aq) + 14 H⁺ (aq) + 6 e⁻ → 2 Cr³⁺ (aq) + 7 H₂O (l)

Notice that the equation is balanced both in terms of atoms (2 Cr, 7 O, 14 H on both sides) and charge ( -2 + 14 + (-6) = +6 on both sides).

Oxidation Half-Reaction (Ferrous ion is oxidized):

Fe²⁺ (aq) → Fe³⁺ (aq) + e⁻

This equation is balanced in terms of atoms and charge.

4. Balancing the Redox Reaction:

The number of electrons lost in the oxidation half-reaction must equal the number of electrons gained in the reduction half-reaction. In this case:

The dichromate reduction requires 6 electrons.

The ferrous ion oxidation releases 1 electron per ion.

Therefore, to balance the electron transfer, we need to multiply the oxidation half-reaction by 6:

6 Fe²⁺ (aq) → 6 Fe³⁺ (aq) + 6 e⁻

Now, we can add the balanced half-reactions together:

Cr₂O₇²⁻ (aq) + 14 H⁺ (aq) + 6 e⁻ → 2 Cr³⁺ (aq) + 7 H₂O (l)

6 Fe²⁺ (aq) → 6 Fe³⁺ (aq) + 6 e⁻

-------------------------------------------------------------

Cr₂O₇²⁻ (aq) + 14 H⁺ (aq) + 6 Fe²⁺ (aq) → 2 Cr³⁺ (aq) + 6 Fe³⁺ (aq) + 7 H₂O (l)

The electrons cancel out, leaving us with the balanced redox reaction.

5. The Observations & Color Changes:

This reaction is often used as a demonstration due to its distinct color changes:

Potassium dichromate (K₂Cr₂O₇) solutions are orange. This color is due to the presence of the Cr₂O₇²⁻ ion.

Ferrous sulfate (FeSO₄) solutions are pale green.

Chromium(III) ions (Cr³⁺) are green.

Ferric ions (Fe³⁺) are yellow/brown (depending on concentration and other ions present).

Therefore, as the reaction proceeds:

The orange color of the dichromate solution fades.

The pale green color of the ferrous sulfate diminishes.

The solution turns green (due to Cr³⁺). If enough Fe³⁺ is produced, the solution may also appear yellowish-brown.

6. Complete Molecular Equation (with spectator ions):

While the ionic equation is essential for understanding the electron transfer, a complete molecular equation is:

K₂Cr₂O₇ (aq) + 7 H₂SO₄ (aq) + 6 FeSO₄ (aq) → Cr₂(SO₄)₃ (aq) + 3 Fe₂(SO₄)₃ (aq) + K₂SO₄ (aq) + 7 H₂O (l)

Spectator Ions: K⁺ and SO₄²⁻ are spectator ions. They don't directly participate in the redox reaction (their oxidation states don't change). They are present in the solution to maintain charge balance, but they don't change during the process.

Sulfuric Acid: In this equation, it serves two roles: providing the acidic medium and contributing the sulfate counter-ions to form the sulfate salts of chromium and iron.

In summary, the reaction of potassium dichromate, sulfuric acid, and ferrous sulfate is a redox reaction where the dichromate ion oxidizes the ferrous ion, leading to a noticeable color change. The sulfuric acid provides the acidic environment necessary for the reaction to occur.