

Chemistry 2000 Slide Set 14: Redox reactions

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Review: Oxidation states

The **oxidation state** of an atom in a molecule is a charge calculated assuming that bonds are purely ionic.

Calculation of oxidation states:

- 1 The sum of the oxidation states in a molecule is equal to the charge.
- 2 In a bond between two identical atoms, the electrons are equally shared.
- 3 In any other bond, we “give” all the shared electrons to the more electronegative atom.

$$\textcircled{4} \left\{ \begin{array}{c} \text{oxidation} \\ \text{state} \end{array} \right\} = \left\{ \begin{array}{c} \text{valence electrons} \\ \text{of neutral atom} \end{array} \right\} - \left\{ \begin{array}{c} \text{electrons in} \\ \text{ionized structure} \end{array} \right\}$$

Example: Determine the oxidation states of all atoms in the sulfate ion.

Answer: Oxidation state of S = 6

Oxidation state of O = -2

Redox reactions

Reduction is a gain of electrons by an atom or set of atoms during a chemical reaction.

Oxidation is a loss of electrons by an atom or set of atoms.

A **redox (reduction-oxidation) reaction** involves oxidation of some atoms and reduction of others.

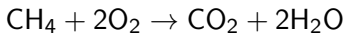
- During a redox reaction, the oxidation states of some atoms increase, while the oxidation states of others decrease.

Redox reactions

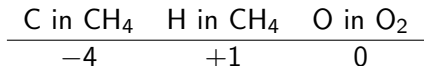
Oxidizing and reducing agents

- If the oxidation state of an atom has increased, it has lost electrons and therefore been oxidized.
A species containing an atom that has been oxidized has caused something else to be reduced and so is a **reducing agent**.
- If the oxidation state of an atom has decreased, it has gained electrons and therefore been reduced.
A species containing an atom that has been reduced has caused something else to be oxidized and so is an **oxidizing agent**.

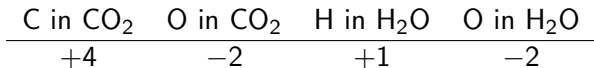
Is the following a redox reaction?



Oxidation states of reactants:



Oxidation states of products:



O has been reduced.

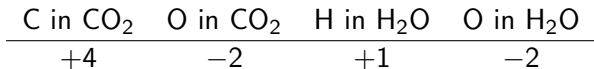
C has been oxidized.

Conclusion: Yes, this is a redox reaction.

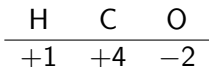
Is the following a redox reaction?



Oxidation states of reactants:



Oxidation states of atoms in product H₂CO₃:

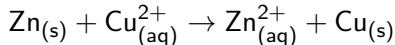


Conclusion: No change in oxidation states, therefore not a redox reaction.

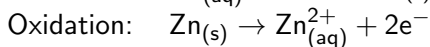
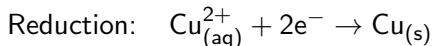
Half-reactions

- A redox reaction can generally be separated into reduction and oxidation **half-reactions**.

Example: For the reaction



the half-reactions are



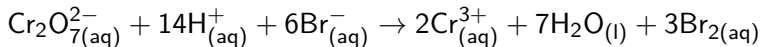
Balancing aqueous redox reactions

- 1 Separate the half-reactions and balance them for all atoms except O and H.
- 2 Balance each half-reaction for O by adding $\text{H}_2\text{O}_{(l)}$.
- 3 Balance each half-reaction for H by adding $\text{H}_{(aq)}^+$.
- 4 Balance each half-reaction for charge by adding electrons.
- 5 Multiply the half-reactions so that each has the same number of electrons, then add them together.
The reaction is balanced for acidic conditions.
- 6 If the reaction occurs in neutral medium, it is OK to have H^+ as a product, but not as a reactant. If the reaction occurs in basic medium, there shouldn't be any H^+ in the overall reaction. In either of these cases, add OH^- to "neutralize" excess H^+ .

Example

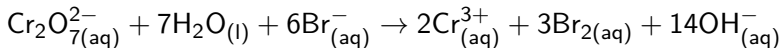
When $\text{Na}_2\text{Cr}_2\text{O}_7$ reacts with KBr in acidic medium, the products are Br_2 and Cr^{3+} . Balance the reaction.

Answer:



Example: Reaction in neutral medium

- If the reaction of the last example had occurred in a neutral (or basic) environment, there would not have been many protons available, so they could not have appeared as reactants.
- To fix this, add equal numbers of hydroxides to **both sides** to neutralize the protons.
- Reaction balanced in neutral (or basic) medium:



Example: Fuel cells

- In a fuel cell, a fuel is oxidized in a controlled manner to produce electricity.
- Common fuel cells use a basic electrolyte.
- Find the half-reactions for the methane fuel cell.

Answer:

