Electrochemistry **Name**_____

Balancing Redox Reactions using the Half-Reaction Method

Read from **Lesson 1 Part c:** Balancing Redox Reactions in the **Chemistry Tutorial** Section**, Chapter 18** of **The Physics Classroom.**

Step-by-Step Method: Balancing Redox Reactions

Step 1: Identify Oxidation and Reduction

- Assign oxidation numbers to all atoms.
- Determine which species is **oxidized** and which is **reduced**.
- Write separate **half-reactions** for each process.

Step 2: Balance Each Half-Reaction

- **Balance all elements except H and O** using coefficients.
- **Balance oxygen** by adding H_2O.
- **Balance hydrogen** by adding H^+ (acidic). (Do this also for basic solutions – there is an additional next step.)
- **For a basic solution:**
  - Neutralize H^+ by adding an equal number of OH^- ions to both sides.
  - Combine H^+ and OH^- to form H_2O.
  - Simplify by canceling water molecules if they appear on both sides.
- **Balance charge** by adding electrons (e^-).
- Verify with an **atom count** and **charge count**.

Step 3: Equalize Electron Transfer

- Multiply each half-reaction by an integer so that both involve the same number of electrons.
- Apply the multiplier to every term in the equation.

Step 4: Combine and Simplify

- Add the two half-reactions.
- Cancel out identical species on both sides (e.g., electrons, H^+, H_2O).
- Confirm that both **mass and charge** are balanced.

Example 1: **$MnO_4^- + Cl^- \rightarrow Mn^{+2} + Cl_2$ (*in an acidic solution*)**

Oxidation states:

Reactants: Mn +7, O −2 in $KMnO_4$; Cl −1

Products: Mn +2; Cl 0 in Cl_2.

Step 1: (Half reactions) $MnO_4^- \rightarrow Mn^{+2}$ and $Cl^- \rightarrow Cl_2$

Step 2: (Balance mass and charge)

$Cl^- \rightarrow Cl_2$ becomes

$2\ Cl^- \rightarrow Cl_2 + 2\ e^-$

$MnO_4^- \rightarrow Mn^{+2}$ becomes

$8\ H^+ + MnO_4^- \rightarrow Mn^{+2} + 4\ H_2O$

$5e^- + 8\ H^+ + MnO_4^- \rightarrow Mn^{+2} + 4\ H_2O$

Step 3: (multiply to get 10 e- transferred in each half reaction)

$[2\ Cl^- \rightarrow Cl_2 + 2\ e^-] \times 5$

$10\ Cl^- \rightarrow 5\ Cl_2 + 10\ e^-$

$[5e^- + 8\ H^+ + MnO_4^- \rightarrow Mn^{+2} + 4\ H_2O] \times 2$
$10e^- + 16\ H^+ + 2\ MnO_4^- \rightarrow 2\ Mn^{+2} + 8\ H_2O$

Step 4: Combine and Simplify
$10\ Cl^- \rightarrow 5\ Cl_2 + 10\ e^-$
$+ 10e^- + 16\ H^+ + 2\ MnO_4^- \rightarrow 2\ Mn^{+2} + 8\ H_2O$

$10\ Cl^- + 16\ H^+ + 2\ MnO_4^- \rightarrow 5\ Cl_2 + 2\ Mn^{+2} + 8\ H_2O$

Example 2: **$MnO_4^- + CN^- \rightarrow MnO_2 + CNO^-$ (*in a basic solution*)**

Step 1: (Half reactions) $MnO_4^- \rightarrow MnO_2$ and $CN^- \rightarrow CNO^-$

Step 2a: (Balance mass and charge)
$MnO_4^- \rightarrow MnO_2$ becomes
$3\ e^- + 4\ H^+ + MnO_4^- \rightarrow MnO_2 + 2\ H_2O$

$CN^- \rightarrow CNO^-$ becomes
$H_2O + CN^- \rightarrow CNO^- + 2\ H^+ + 2\ e^-$

Step 2b: (Neutralize H^+ with OH^-, simplify water molecules.):

$3\ e^- + 4\ H^+ + \mathbf{4\ OH^-} + MnO_4^- \rightarrow MnO_2 + 2\ H_2O + \mathbf{4\ OH^-}$
$3\ e^- + \mathbf{4\ H_2O} + MnO_4^- \rightarrow MnO_2 + 2\ H_2O + \mathbf{4\ OH^-}$
$3\ e^- + 2\ H_2O + MnO_4^- \rightarrow MnO_2 + 4\ OH^-$

$\mathbf{2\ OH^-} + H_2O + CN^- \rightarrow CNO^- + 2\ H^+ + \mathbf{2\ OH^-} + 2\ e^-$
$\mathbf{2\ OH^-} + H_2O + CN^- \rightarrow CNO^- + \mathbf{2\ H_2O} + 2\ e^-$
$2\ OH^- + CN^- \rightarrow CNO^- + H_2O + 2\ e^-$

Step 3: (multiply to get 6e- transferred in each half reaction)
$[3\ e^- + 2\ H_2O + MnO_4^- \rightarrow MnO_2 + 4\ OH^-] \times 2$
$6\ e^- + 4\ H_2O + 2\ MnO_4^- \rightarrow 2\ MnO_2 + 8\ OH^-$

$[2\ OH^- + CN^- \rightarrow CNO^- + H_2O + 2\ e^-] \times 3$
$6\ OH^- + 3\ CN^- \rightarrow 3\ CNO^- + 3\ H_2O + 6\ e^-$

Step 4: Combine and Simplify
$6\ e^- + 4\ H_2O + 2\ MnO_4^- \rightarrow 2\ MnO_2 + 8\ OH^-$ becomes $H_2O + 2\ MnO_4^- \rightarrow 2\ MnO_2 + 2\ OH^-$

$6\ OH^- + 3\ CN^- \rightarrow 3\ CNO^- + 3\ H_2O + 6\ e^-$

$H_2O + 2\ MnO_4^- \rightarrow 2\ MnO_2 + 2\ OH^-$
$+3\ CN^- \rightarrow 3\ CNO^-$ becomes **$3\ CN^- + H_2O + 2\ MnO_4^- \rightarrow 3\ CNO^- + 2\ MnO_2 + 2\ OH^-$**

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Questions

Balance the following equations using the half-reaction method. Show all work.

1. $I_2 + OCl^- \rightarrow \ + IO_3^- + Cl^-$ *(in an acidic solution)*

2. $Mn^{+2} + BiO_3^- \rightarrow Bi^{+2} + MnO_4^-$ *(in an acidic solution)*

3. $Al(OH)_3 + BrO^- \rightarrow AlO_4^{2-} + Br_2$ *(in a basic solution)*

4. $NO_2^- + Cr \rightarrow NH_3 + Cr(OH)_4^-$ *(in a basic solution)*