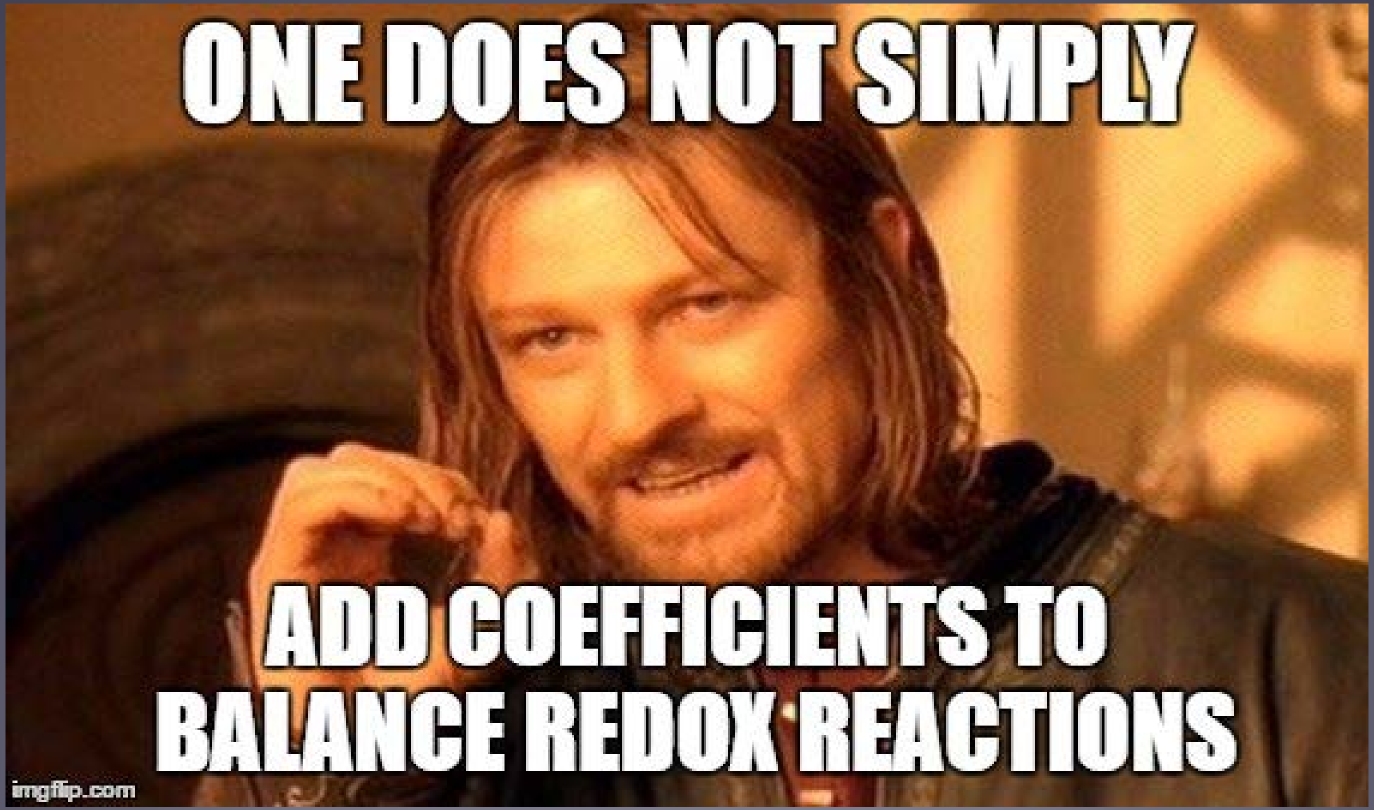
Balancing Redox Reactions



Outcomes:

1-11 Balance redox reactions. Include acidic & basic solutions.

Balancing Redox Reactions:

Balance the following reaction like you would in grade 11...

LEO $\overset{2}{\cancel{1}}e^-$

$$2\,Cu \;+\; Cl_2 \rightarrow 2\,Cu^+ \;+\; 2\,Cl^-$$

$0 \qquad 0 \qquad +1 \qquad -1$

GER $2e^-$

Remember that all redox reactions consist of a **GAIN** and **LOSS** of **ELECTRONS**. The **AMOUNT** of electrons **LOST** must **EQUAL** the amount of electrons **GAINED**.

- Are they equal?

The Half-Reaction Method:

We can separate the entire equation into two **HALF REACTIONS**, balance the **ELECTRONS** lost and gained, then put the new **COEFFICIENTS** into the original equation.

Half-Reactions:

- Show the **OXIDATION** or the **REDUCTION REACTION**.
- An **OXIDATION HALF REACTION** will **PRODUCE** electrons (**LEO**)
- A **REDUCTION HALF REACTION** will **CONSUME** electrons (**GER**)

Example:

LEO

For the reaction: $Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$

0 +1 +2 0

GER

The oxidation half reaction is:

LEO $Cu \rightarrow Cu^{2+} + 2e^-$ x 1

The reduction half reaction is:

GER $2\ Ag^+ + 2\ 1e^- \rightarrow 2Ag$ x 2

Example: Balance the equation $Sn + HNO_3 \rightarrow SnO_2 + NO_2 + H_2O$

Step 1: Assign oxidation numbers to each element to identify which is oxidized and which is reduced.

GER

$$\underset{0}{Sn} + \underset{+1\ +5\ -2}{HNO_3} \rightarrow \underset{+4\ -2}{SnO_2} + \underset{+4\ -2}{NO_2} + \underset{+1\ -2}{H_2O}$$

LEO

Step 2: Write the half reactions, balance elements, then add electrons to balance the charges. Multiply each reaction by the lowest whole number so the electrons lost equal electrons gained.

LEO: $(Sn^{0} \rightarrow Sn^{+4} + 4e^-) \times 1$

GER: $(4N^{+5} + 4e^- \rightarrow 4N^{+4}) \times 4$

Step ~~4~~ 3: Transfer the coefficients into the original reaction.

$$1\ Sn + 4\ HNO_3 \rightarrow 1\ SnO_2 + 4\ NO_2 + 2\ H_2O$$

✓

Step ~~5~~ 4: Balance the remaining elements by inspection then check the equation to see that it is balanced.

Example: Balance the equation $I_2 + Cl_2 + H_2O \rightarrow HIO_3 + HCl$

Step 1: Assign oxidation numbers to each element to identify which is oxidized and which is reduced.

GER

$$\begin{array}{ccccccccc} I_2 & + & Cl_2 & + & H_2O & \rightarrow & \overset{+1\quad -6}{HIO_3} & + & HCl \\ 0 & & 0 & & +1\ -2 & & +1\ +5\ -2 & & +1\ -1 \end{array}$$

LEO

Step 2: Write the half reactions, balance elements, then add electrons to balance the charges. Multiply each reaction by the lowest whole number so the electrons lost equal electrons gained.

LEO: $\left(I_2^{0} \longrightarrow 2I^{+5} + 10e^{-} \right) \times 1$

GER $\left(5\,Cl_2^{0} + \overset{10}{\cancel{2}}e^{-} \longrightarrow \overset{10}{\cancel{2}}Cl^{-1} \right) \times 5$

Step 4: Transfer the coefficients into the original reaction.

$$1\ I_2 + 5\ Cl_2 + 6\ H_2O \rightarrow 2\ HIO_3 + 10\ HCl$$

✓

Step 5: Balance the remaining elements by inspection then check the equation to see that it is balanced.

Try this one… Balance the equation $K_2Cr_2O_7 + FeCl_2 + HCl \rightarrow CrCl_3 + KCl + FeCl_3 + H_2O$

Step 1: Assign oxidation numbers to each element to identify which is oxidized and which is reduced.

GER

$$\overset{+2}{K_2}\overset{-14}{} \underset{+6}{Cr_2}\underset{-2}{O_7} + \underset{+2}{Fe}Cl_2 + HCl \rightarrow \underset{+3}{Cr}Cl_3 + KCl + \underset{+3}{Fe}Cl_3 + H_2O$$

LEO

Step 2: Write the half reactions, balance elements, then add electrons to balance the charges. Multiply each reaction by the lowest whole number so the electrons lost equal electrons gained.

LEO: $(6Fe^{+2} \rightarrow 6Fe^{+3} + 6e^-) \times 6$

GER $Cr_2^{+6} + 6e^- \rightarrow 2Cr^{+3}$

Step 4: Transfer the coefficients into the original reaction.

$$1\,K_2Cr_2O_7 + 6\,FeCl_2 + 14\,HCl \rightarrow 2\,CrCl_3 + 2\,KCl + 6\,FeCl_3 + 7\,H_2O$$

Step 5: Balance the remaining elements by inspection then check the equation to see that it is balanced.

Balancing in Acid/Base Solutions:

Sometimes a redox reaction will occur in an acid or base solution.

We follow the same steps as before, but leave hydrogen and oxygen until the end, and then balance by adding H^+, OH^- or H_2O, according to:

- ***In acid solutions, we add H^+ and H_2O as needed***
- ***In Basic solutions we add OH^- and H_2O as needed.***

<u>Example:</u> Balance the following equation in an **ACIDIC SOLUTION** H^+, H_2O

Step 1: Assign oxidation numbers to each element to identify which is oxidized and which is reduced.

LEO

$$\overset{+12\ \ -14}{\underset{+6\ \ -2}{Cr_2O_7^{2-}}} + \underset{+4\ \ -2}{SO_3^{2-}} \rightarrow \underset{+3}{Cr^{3+}} + \underset{+6\ \ -2}{SO_4^{2-}}$$

GER

Step 2: Write the half reactions, balance elements, then add electrons to balance the charges. Multiply each reaction by the lowest whole number so the electrons lost equal electrons gained.

LEO: $(3S^{+4} \rightarrow 3S^{+6} + \cancel{2}\,6e^-) \times 3$

GER: $Cr_2^{+6} + 6e^- \rightarrow 2Cr^{+3}$

Step 4: Transfer the coefficients into the original reaction.

$$8H^+ + 1\,Cr_2O_7^{2-} + 3\,SO_3^{2-} \rightarrow 2\,Cr^{3+} + 3\,SO_4^{2-} + 4H_2O$$

16 12

Step 5: Balance the remaining elements using H^+ and H_2O

Try this one… Balance the following equation in an **ACIDIC SOLUTION**

Step 1: Assign oxidation numbers to each element to identify which is oxidized and which is reduced.

GER

+6 -8

$$C_2O_4^{2-} + MnO_4^- \rightarrow Mn^{2+} + CO_2$$

+3 -2 +7 -2 +2 +4 -2

LEO

Step 2: Write the half reactions, balance elements, then add electrons to balance the charges. Multiply each reaction by the lowest whole number so the electrons lost equal electrons gained.

LEO: $(5C_2^{+3} \rightarrow 10\ 2C^{+4} + 10\ \cancel{2}e^-) \times 5$

GER: $(2Mn^{+7} + 10\ \cancel{5}e^- \rightarrow 2Mn^{+2}) \times 2$

Step 4: Transfer the coefficients into the original reaction.

28 20

$$16H^+ + 5\,C_2O_4^{2-} + 2MnO_4^- \rightarrow 2\,Mn^{2+} + 10CO_2 + 8H_2O$$

Step 5: Balance the remaining elements using H^+ and H_2O

Example: Balance the following equation in an **BASIC SOLUTION** → OH^-

Step 1: Assign oxidation numbers to each element to identify which is oxidized and which is reduced.

$$\overset{-2\,+1\,-2\,+1}{CH_3OH} + \overset{+7}{MnO_4^-} \rightarrow \overset{+4\;-2}{CO_3^{2-}} + \overset{+6}{MnO_4^{2-}}$$

LEO

GER

Step 2: Write the half reactions, balance elements, then add electrons to balance the charges. Multiply each reaction by the lowest whole number so the electrons lost equal electrons gained.

LEO: $C^{-2} \rightarrow C^{+4} + 6e^-$

GER: $(6Mn^{+7} + \cancel{1}6e^- \rightarrow 6Mn^{+6}) \times 6$

Step 4: Transfer the coefficients into the original reaction.

25 27

6 H2O

~~8 H2O~~

$$8OH^- + \cancel{2H_2O} + 1\,CH_3OH + 6\,MnO_4^- \rightarrow 1\,CO_3^{2-} + 6\,MnO_4^{2-} + \cancel{8H^+ + 8OH^-}$$

$$8OH^- + CH_3OH + 6MnO_4^- \rightarrow CO_3^{2-} + 6MnO_4^{2-} + 6H_2O$$

Step 5: Balance the remaining elements using H^+ and H_2O like in acid solutions, then add OH- to each side to match H+ ions. They will form water, and then cancel any waters on both sides.

Try this one… Balance the following equation in an **BASIC SOLUTION**

Step 1: Assign oxidation numbers to each element to identify which is oxidized and which is reduced.

LEO

$$\underset{+7}{MnO_4^-} + \underset{+3}{C_2O_4^{2-}} \rightarrow \underset{+4}{CO_2} + \underset{+4}{MnO_2}$$

GER

Step 2: Write the half reactions, balance elements, then add electrons to balance the charges. Multiply each reaction by the lowest whole number so the electrons lost equal electrons gained.

LEO: $(C_2^{+3} \rightarrow 2C^{+4} + 2e^-) \times 3$

GER: $(Mn^{+7} + 3e^- \rightarrow Mn^{+4}) \times 2$

Step 4: Transfer the coefficients into the original reaction.

20 16

$$\cancel{8OH^- + 8H^+} + 2MnO_4^- + 3C_2O_4^{2-} \rightarrow 6CO_2 + 2MnO_2 \cancel{+ 4H_2O} + 8OH^-$$

$\cancel{8H_2O}$ $4H_2O$

$$4H_2O + 2MO_4^- + 3C_2O_4^{2-} \rightarrow 6CO_2 + 2MnO_2 + 8OH^-$$

Step 5: Balance the remaining elements using H^+ and H_2O like in acid solutions, then add OH- to each side to match H+ ions. They will form water, and then cancel any waters on both sides.