Balancing Redox Equations
(Half-Reaction Method)

Learning Goals:

- ☐ I will be able to write balanced chemical equations for oxidation-reduction reactions using the half-reaction method.

Example: Chlorate ions and bromine react in a basic aqueous solution to produce bromate ions and chloride ions. Write the balanced chemical equation for this redox reaction.

Step 1: *Write the unbalanced equation (the "basic" condition is not important at this point).*

$ClO_3^-(aq) + Br_2(l) \rightarrow BrO_3^-(aq) + Cl^-(aq)$

Step 2: *Break the equation into two half-reactions.*

$ClO_3^-(aq) \rightarrow Cl^-(aq)$ $\qquad$ $Br_2(l) \rightarrow BrO_3^-(aq)$

Step 3: *Balance all elements in each half reaction except oxygen and hydrogen.*

$ClO_3^-(aq) \rightarrow Cl^-(aq)$

There is one chlorine on each side of the equation so no need to add any coefficients.

$Br_2(l) \rightarrow \mathbf{2}\ BrO_3^-(aq)$

There are 2 bromine atoms on the reactant side and only one on the product side. Therefore, add coefficient 2 to the product side.

Step 4: *Balance oxygen by adding water molecules*

$ClO_3^-(aq) \rightarrow Cl^-(aq) + \mathbf{3\ H_2O(l)}$

There are 3 oxygen atoms on the reactant side and 0 oxygen atoms on the product side.
Add 3 water molecules to the product side.

$\mathbf{6\ H_2O(l)} + Br_2(l) \rightarrow \mathbf{2}\ BrO_3^-(aq)$

There are 0 oxygen atoms on the reactant side and 6 oxygen atoms on the product side.
Add 6 water molecules to the product side

Step 5: *Balance hydrogen using hydrogen ions.*

$\mathbf{6\ H^+(aq)} + ClO_3^-(aq) \rightarrow Cl^-(aq) + 3\ H_2O(l)$

There are 0 hydrogen atoms on the reactant side and 6 hydrogen atoms on the product side
Therefore, add 6 hydrogen ions to the reactant side

$6\ H_2O(l) + Br_2(l) \rightarrow 2\ BrO_3^-(aq) + \mathbf{12\ H^+(aq)}$

There are 12 hydrogen atoms on the reactant side and 0 hydrogen atoms on the product side.
Therefore, add 12 hydrogen ions to the product side

Step 6: *Balance the charge by adding electrons.*

6 e^- + 6 $H^+(aq)$ + $ClO_3^-(aq)$ → $Cl^-(aq)$ + 3 $H_2O(l)$

Reactant side has +5 charge (+6 and -1)
Product side has -1 charge
Add 6 electrons to the reactant side

6 $H_2O(l)$ + $Br_2(l)$ → 2 $BrO_3^-(aq)$ + 12 $H^+(aq)$ **+ 10 e^-**

Reactant side has no charge
Product side has +10 charge (-2 and +12)
Add 10 electrons to the product side

Step 7: *When the reaction occurs in the* ***basic*** *solution, hydrogen ions cannot be part of the overall equation and must be eliminated from the balanced equation. This step is not done when the reaction occurs in neutral or acidic solution. This step has three sub-steps.*

(a) Add hydroxide ions to both sides of the equation.

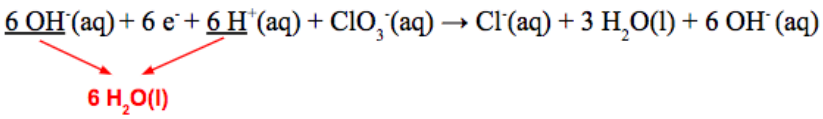
6 OH^- + 6 e^- + 6 $H^+(aq)$ + $ClO_3^-(aq)$ → $Cl^-(aq)$ + 3 $H_2O(l)$ **+ 6 OH^-**

There are 6 hydrogens ions in the equation. Therefore, add 6 hydroxide ions to both sides of the equation.

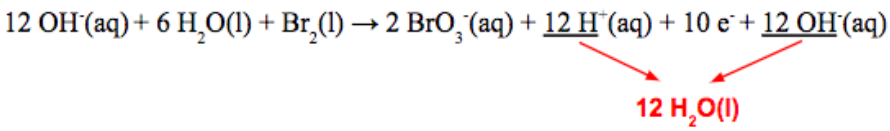
12 OH^- + 6 $H_2O(l)$ + $Br_2(l)$ → 2 $BrO_3^-(aq)$ + 12 $H^+(aq)$ + 10 e^- **+ 12 OH^-**

There are 12 hydrogen ions in the equation. Therefore, add 12 hydroxide ions to both sides of the equation.

(b) Combine hydrogen ions and hydroxide ions to form water molecules.

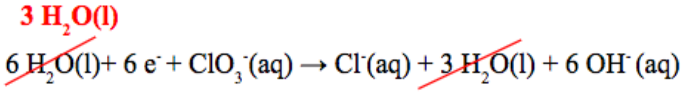


The 6 hydrogen ions and 6 hydroxide ions on the product side are combined to form 6 water molecules.

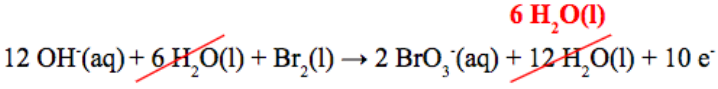


The 12 hydrogen ions and 12 hydroxide ions on the product side are combined to form 6 water molecules.

(c) Reduce the water molecules if necessary.



Three water molecules can be removed from each side. Three water molecules left on the reactant side.



Three water molecules can be removed from each side. Three water molecules left on the product side.

Balanced Reduction Half-Reaction

6 e^- + 3 $H_2O(l)$ + $ClO_3^-(aq)$ → $Cl^-(aq)$ + 6 $OH^-(aq)$

Balanced Oxidation Half-Reaction

12 $OH^-(aq)$ + $Br_2(l)$ → 2 $BrO_3^-(aq)$ + 6 $H_2O(l)$ + 10 e^-

Step 8: *Balance the electron transfer.*

Reduction Half-Reaction X 5

$30\ e^- + 15\ H_2O(l) + 5\ ClO_3^-(aq) \rightarrow 5\ Cl^-(aq) + 6\ OH^-(aq)$

Oxidation Half-Reaction X 3

$36\ OH^-(aq) + 3\ Br_2(l) \rightarrow 6\ BrO_3^-(aq) + 18\ H_2O(l) + 30\ e^-$

$6\ OH^-(aq) + 5\ ClO_3^-(aq) + 3\ Br_2(l) \rightarrow 6\ BrO_3^-(aq) + 5\ Cl^-(aq) + 3\ H_2O(l)$

Multiply the reduction half-reaction by 5 and oxidation half-reaction by 3 to get 30 electrons in each half-reaction.
Add them up. The electrons disappear.
There are 15 water molecules in the reactant side of the reduction half-reaction and 18 water molecules in the product side of the oxidation half-reaction. Therefore, 3 water molecules remain in the product side of the overall reaction.

Step 9: *Check the equation for balance atoms and charge.*

$6\ OH^-(aq) + 5\ ClO_3^-(aq) + 3\ Br_2(l) \rightarrow 6\ BrO_3^-(aq) + 5\ Cl^-(aq) + 3\ H_2O(l)$

21 oxygen atoms	21 oxygen atoms
6 hydrogen atoms	6 hydrogen atoms
5 chlorine atoms	5 chlorine atoms
6 bromine atoms	6 bromine atoms
-11 charge	-11 charge