Reactions with Group 1 Elements

The elements of Group 1 consist of: Lithium, Sodium, Potassium, Rubidium, Cesium, and Francium. These elements are called the alkali metals because they react strongly with water and create hydroxide ions and hydrogen gas, leaving a basic solution.

\[ 2M(s) + 2H_2O \rightarrow 2M^+(aq) + 2OH^-(aq) + H_2(g) \ M = \text{Group 1 metal} \]

Group 1 metals are very reactive with oxygen and must be kept away from oxygen in order to not get oxidized. These alkali metals rapidly react with oxygen to produce several different ionic oxides.

Oxides: \( O^{2-} \), peroxides: \( O_2^{2-} \), super oxide: \( O_2^- \).

The usual oxide, \( M_2O \), can be formed with alkali metals generally by limiting the supply of oxygen.

With excess oxygen, the alkali metals can form peroxides, \( M_2O_2 \), or superoxides, \( MO_2 \).

Lithium: Reacts with oxygen to give \( 2Li_2O \), lithium oxide. Reactions are shown below.

\[ 4Li(s) + O_2(g) \rightarrow 2Li_2O(s) \]

Sodium: Reacts with oxygen to form mostly sodium peroxide, \( Na_2O_2 \). \( Na_2O_2 \) along with \( Li_2O_2 \) is used in emergency breathing devices in submarines and spacecrafts. Reactions are shown below.

\[ 2Na(s) + O_2(g) \rightarrow Na_2O_2(s) \]

The rest of the group, K, Rb, Cs, and Fr, forms the superoxides.

\[ M(s) + O_2(g) \rightarrow MO_2(s) \ M= K, \text{Rb}, \text{Cs}, \text{Fr} \]

Metal oxides, peroxides, and superoxides that dissolve in water react with water to form basic solutions.

Oxide ion with water: \( O^{2-}(aq) + H_2O(l) \rightarrow 2OH^-(aq) \)

Peroxide ion with water: \( O_2^{2-}(aq) + 2H_2O(l) \rightarrow H_2O_2(aq) + 2OH^-(aq) \)

Superoxide ion with water: \( 2O_2^-(aq) + 2H_2O(l) \rightarrow H_2O_2(aq) + 2OH^-(aq) + O_2(g) \)

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Reactions with Group 14 Elements

The elements in Group 14 consist of carbon, silicon, germanium, tin, and lead. Carbon is the only nonmetal element of the group 14. Silicon is mostly nonmetallic. Germanium is a metalloid or semi-metal. Tin and lead have mainly metallic properties.
Carbon: Reacts with oxygen to form oxides. The main form of oxides of carbon are carbon monoxide, CO, and carbon dioxide, CO₂.

Carbon dioxide is the primary product of burning organic materials and also a byproduct of respiration. During photosynthesis carbon is combined with water to form carbohydrates.

\[
6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]

Carbon is the building block to many organic compounds.

Carbon dioxide is the only oxide formed when carbon is burned in an excess of air.

The reactions are shown below.

\[
\text{C(s)} + \text{O}_2(g) \rightarrow \text{CO}_2
\]

\[
2\text{C(s)} + \text{O}_2(g) \rightarrow 2\text{CO}
\]

Silicon: Forms only one stable oxide with the empirical formula \( \text{SiO}_2 \), silica. In silica, each Si atom is bonded to four O atoms and each O atom to two Si atoms forming a network covalent solid with a network of \(-\text{Si–O–Si–}\) bonds.

Germanium: Forms germanium dioxide which is covalent network solid similar to silicon dioxide.

Tin: Forms two primary oxides, \( \text{SnO} \) and \( \text{SnO}_2 \). By heating \( \text{SnO} \) in air, it can be converted to \( \text{SnO}_2 \). \( \text{SnO}_2 \) is used as a jewelry abrasive. The reactions are shown below.

\[
\text{Sn(s)} + \text{O}_2(g) \rightarrow \text{SnO}_2(s)
\]

\[
2\text{Sn(s)} + \text{O}_2(g) \rightarrow 2\text{SnO(s)}
\]

Lead: Forms a several forms of oxides. The best known oxides of lead are yellow lead oxide, \( \text{PbO} \), red-brown lead dioxide, \( \text{PbO}_2 \), and red lead, \( \text{Pb}_3\text{O}_4 \). The reactions are shown below.

\[
2\text{Pb(s)} + \text{O}_2(g) \rightarrow 2\text{PbO(s)}
\]

\[
\text{Pb(s)} + \text{O}_2(g) \rightarrow \text{PbO}_2(s)
\]

\[
3\text{Pb(s)} + 2\text{O}_2(g) \rightarrow \text{Pb}_3\text{O}_4(s)
\]

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**Reactions with Group 15 Elements**

The elements in Group 15 consist of: nitrogen, phosphorus, arsenic, antimony, and bismuth. Nitrogen and phosphorus are nonmetallic, arsenic and antimony are metalloids, and bismuth is metallic.

Nitrogen: Forms a series of oxides in which the oxidation state of \( \text{N} \) can have every value ranging from +1 to +5. All these oxides are gases at room temperature except for \( \text{N}_2\text{O}_5 \), which is solid.
Preparation of Oxides of Nitrogen: Reactions are shown below.

\[ \text{N}_2\text{O} \text{NH}_4\text{NO}_3(\text{s}) \xrightarrow{\Delta} \text{N}_2\text{O}(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \]

\[ \text{NO} \ 3\text{Cu}(\text{s}) + 8\text{H}^+(\text{aq}) + 2\text{NO}_3^-(\text{aq}) \rightarrow 3\text{Cu}^{2+}(\text{aq}) + 2\text{NO}(\text{g}) + 4\text{H}_2\text{O}(\text{l}) \]

\[ \text{N}_2\text{O}_3 \ 2\text{NO}(\text{g}) + \text{N}_2\text{O}_4(\text{g}) \xrightarrow{-20^\circ\text{C}} 2\text{N}_2\text{O}_3(\text{l}) \]

\[ \text{NO}_2 \ 2\text{Pb(NO}_3)_2(\text{s}) \rightarrow \Delta \rightarrow 2\text{PbO}(\text{s}) + 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g}) \]

\[ 2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \leftrightarrow 2\text{NO}_2(\text{g}) \]

\[ \text{N}_2\text{O}_4 \ 2\text{NO}_2(\text{g}) \leftrightarrow \text{N}_2\text{O}_4(\text{g}) \]

\[ \text{N}_2\text{O}_5 \ 4\text{HNO}_3(\text{l}) + \text{P}_4\text{O}_{10} \rightarrow \xrightarrow{10^\circ\text{C}} 4\text{HPO}_3(\text{s}) + 2\text{N}_2\text{O}_5(\text{s}) \]