Aluminum (also called Aluminium) is the third most abundant element in the earth's crust. It is commonly used in the household as aluminum foil, in crafts such as dyeing and pottery, and also in construction to make alloys. In its purest form the metal is bluish-white and very ductile. It is an excellent conductor of heat and electricity and finds use in some wiring. When pure it is too soft for construction purposes but addition of small amounts of silicon and iron hardens it significantly.

Facts

- Symbol: Al
- Atomic Number: 13
- Atomic Weight: 26.98154 amu
- Color: Silver
- Melting Point: 933.4 K
- Boiling Point: 2792 K
- Density: 2.70 g/cm$^3$
- Number Oxidation States: 3
- Great reducing agent
- Has 13 electrons, 13 protons, and 14 neutrons
- Metal
- Good conductor
- Resists corrosion
- Non-magnetic
- Stable ion
- Forms dimers
- Group Number: 13

History of Aluminum

Aluminum ranks third on the list of the ten most abundant elements in the earth's crust, while its oxide is fourth among the ten most common compounds in the crust. It is the most abundant metal on the planet. Its name is taken from the Latin alumen for alum. Soft, lightweight and silvery, its existence was proposed by Lavoisier in 1787, it was named by Davy in 1807 and finally isolated by Ørsted in 1825. Before this, it was known for being part of alum, which is used as a mordant to help set dye on fabric. At this time it was known as a very expensive metal. In the late 1800s, two scientists, Charles Martin Hall and Paul L. T. Heroult, found that they could produce aluminum from aluminum oxide through electrolysis and a cryolite (molten mineral) solvent. This allowed the price to decrease and for aluminum to become available for commercial use.
Aluminum on Earth

Aluminum is the third most abundant element found on earth, and the most abundant metal. It makes up 8.1% of the earth's crust by mass, following oxygen and silicon. Naturally, it is found in chemical compounds with other elements like bauxite. It is not easily removed from natural ores because it must first be reduced. To see how alumina, which is used to make aluminum, is extracted from bauxite, read the Bayer Process in the refining aluminum section.

Electron Configuration of Aluminum

To find the electron configuration of an atom, you first need to know the number of electrons that it has. Since aluminum's atomic number is thirteen, it has thirteen electrons. You then split the electrons between the different orbitals. Aluminum's first two electrons fall in the 1s orbital, and the following two electrons go in the 2s orbital. The next six electrons fill the 2p orbital in the second shell (that's ten electrons so far, three more to go). Then electrons 11 and 12 fill the 3s orbital. Finally the last electron occupies the 3p orbital.

The electron configuration for Aluminum is $1s^22s^22p^63s^23p^1$. The ground state electron configuration is $[\text{Ne}]3s^23p^1$.

Oxidation States

Aluminum has three oxidation states. The most common one is +3. The other two are +1 and +2. One +3 oxidation state for Aluminum can be found in the compound aluminum oxide, $\text{Al}_2\text{O}_3$. In $\text{AlO}$, aluminum monoxide, it has a +2 oxidation state, and $\text{AlH}$ has an oxidation state of +1.

Aluminum Compounds

Although it does not seem to be particularly reactive, aluminum is considered an active metal. Its behavior is deceptive because it reacts rapidly with the oxygen in the air to form aluminum oxide ($\text{Al}_2\text{O}_3$), or alumina, which is tightly bound to the metal and exists as a dense coating (unlike the oxides of iron). This coating protects it from further reaction. Clearly, however, this coating is not entirely foolproof since aluminum does not exist in native form.

Alumina is the refractory oxide of aluminum and is found in bauxite and corundum (sapphires and rubies). It has a very high melting point. One of the applications of this compound is used to produce different color light that can be used as a laser beam. It is also used in pottery, dyeing, antacid medicines, and in making chemicals.

Another compound containing aluminum is $\text{Al(OH)}_3$, which is usually formed as a gelatinous precipitate when aluminum compounds are hydrolyzed in water.

Aluminum sulfate, $\text{Al}_2(\text{SO}_4)_3$·$18\text{H}_2\text{O}$ is a very useful aluminum compound, made from the oxide and sulfuric acid. One use of this salt is in the dyeing of cotton fabrics.
Aluminum Reactions

Aluminum is easily oxidized to Al$^{3+}$ such as in this equation:

$$[2\text{Al}_{(s)} + 6\text{H}^+_{(aq)} \rightarrow 2\text{Al}^{3+} + 3\text{H}_2(g)]$$

In the welding of large objects, the thermite reaction is used:

$$[2\text{Al}_{(s)} + \text{Fe}_2\text{O}_3(s) \rightarrow \text{Al}_2\text{O}_3(s) + \text{Fe}(s)]$$

Reactions with Halogens

Aluminum Halides, like the boron halides, are reactive Lewis Acids, meaning that they readily accept a pair of electrons. For example, an important halide complex for the production with aluminum is cryolite, NaAlF$_6$.

$$[6\text{ HF} + \text{Al(OH)}_3 + 3\text{NaOH} \rightarrow \text{Na}_3\text{AlF}_6 + 6\text{H}_2\text{O}]$$

Aluminum Oxide and Hydroxide

Aluminum oxide is often referred to as alumina or when crystallized, corundum. Aluminum oxide is relatively unreactive because the small Al$^{3+}$ ions and the O$^{2-}$ form a very stable ionic lattice in cubic closest structure with the ions occupying small octahedral holes. Aluminum is protected against corrosion due to thin coating of Al$_2$O$_3$ which prevent further oxidation of the aluminum metal.

$$[2\text{Al}_{(s)} + 3\text{H}_2\text{O}_{(l)} \rightarrow \text{Al}_2\text{O}_3(s) + 6\text{H}^+ + 6\text{e}^-]$$

Aluminum hydroxide is amphoteric which means that it can react with acids or bases.

$$[\text{Acid:}\; \text{Al(OH)}_3(s) + 3\text{H}_3\text{O}^+_{(aq)} \rightarrow [\text{Al(H}_2\text{O)}_6]^{3+}_{(aq)}]\]$$

$$[\text{Base:}\; \text{Al(OH)}_3(s) + \text{OH}^-_{(aq)} \rightarrow [\text{Al(OH)}_4]^-_{(aq)}]$$

Refining Aluminum

Most of the aluminum today is produced by the Hall process which uses significant amounts of energy in the form of electricity to electrolyze aluminum metal from a molten salt mixture. The large initial outlay of energy is one important reason why recycling aluminum is such a good and cost-effective idea.

Since aluminum is found in compounds with other elements it needs to be reduced. The Bayer process was invented by Karl Bayer in 1887. It is essentially referring to the refining of bauxite, the most important aluminum ore, to produce alumina. From here, the intermediate alumina must be smelted into metallic aluminum through the Hall-Heroult Process.
References


Problems

1. Write the configuration of Aluminum, assuming that it has lost its valence electrons.
2. What happens to aluminum when it reacts with chlorine?
3. Balance these equations: a) $2\text{Al}(s) \rightarrow \text{Al}^{3+}(aq) + e^-$  
b) $\text{Al}(s) + \text{Pb}^+(aq) \rightarrow \text{Al}^{3+}(aq) + \text{Pb}(s)$
4. What is the electron configuration of Aluminum?
5. What is the process by which alumina is extracted from bauxite?
6. Complete and balance the following reactions.
   1. $\text{Al(OH)}_3 (s) + \text{OH}^-(aq) \rightarrow$
   2. $\text{Al(OH)}_3 (s) + \text{H}^+(aq) \rightarrow$

Solutions

1. $1s^2 \ 2s^2 \ 2p^6$, or $[\text{Ne}]$
2. It forms a dimer.
3. a) $2\text{Al}(s) \rightarrow \text{Al}^{3+}(aq) + 3e^-$
   b) $2\text{Al}(s) + 3\text{Pb}^+(aq) \rightarrow 2\text{Al}^{3+} (aq) + 3\text{Pb}(s)$
4. $1s^2 2s^2 2p^6 3s^2 3p^1$
5. Bayer Process
6.1 $\text{Al(OH)}_3 (s) + \text{OH}^-(aq) \rightarrow [\text{Al(OH)}_4]^-(aq)$
6.2 $\text{Al(OH)}_3(s) + 3\text{H}^+(aq) \rightarrow \text{Al(H}_2\text{O)}_3^{3+}(aq)$
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