# THE THERMITE REACTION



The thermite reaction, a mixture of aluminum powder and iron(III) oxide is known as an aluminothermic reaction, that is, an incendiary mixture of aluminum with another metal such as zirconium, magnesium, titanium, or depleted uranium, which burns at very high temperatures around 2000° to about 3000°C. Such aluminothermic reactions can be explosive and have been used in warfare in incendiary bombs.

The Thermite process was developed by Hans Goldschmidt in 1893.  While investigating what happens when a mixture of a metal oxide and aluminum was applied to carbon-free metals, he found he could create a quality molten steel in small quantities.

At the time, railroad tracks were joined together by the use of nuts, bolts and angle bars (you can see these types of bars between the joints on the sides of rail).  Such joints are maintenance intensive as the nuts and bolts can work loose causing play between each rail in the joint. This is the cause of the "clack-clack clack-clack" sounds you may have heard riding on railroad cars. Jointed rail is also prone to pulling apart as the joints expand and contract with changes in weather along with the battering of the ends of the rails get slammed by the wheels of the trains passing over them, resulting in the bolts within the joint deteriorating from the motion of the rail, cracking  and eventually breaking. Also, nuts tend to work loose and back off the bolts.  If the nuts are not periodically checked and tightened and worn bolts replaced, track failure can occur.

Goldschmidt demonstrated that the thermite process could be used to precision-weld two pieces of metal end to end, including rails. This welding compound was called Thermit® and was used to weld streetcar track for the Essen. Within years, the Thermite® process was established as the worldwide standard for welding streetcar track.  The big railroad companies held back until the end of the 1920s before starting to use Thermit® to make their track safer, more comfortable and faster.

Growing up in the city of Philadelphia, which had an extensive trolley system throughout the city, this author observed repair crews using the thermite reaction to repair cracks in the tracks.

The thermite reaction is written as:

$$Fe_2O_3 + 2\ Al \rightarrow Al_2O_3 + 2\ Fe$$

It is left as an exercise for the reader to calculate the heat of this reaction.

## Safety Precautions

Safety goggles must be worn.

This reaction should be run out of doors on a concrete surface and away from any flammable materials.

A safety shield must be placed between the reaction and the observers.

Observers should be at a minimum distance of 10 yards (10 m) from the reaction.

The apparatus must be assembled so that the molten iron produced will fall into a metal bucket of dry sand. (Plastic buckets can melt and are flammable.)  Never direct the molten iron from the thermite reaction into water or wet sand, an explosion can result.

If you prepare the thermite mixture, prepare it as you need it.  Do not store the mixture for long periods of time.  To the best of this author's knowledge, the thermite mixture is stable in storage, however, in the event of a fire, the thermite mixture, once ignited, cannot be extinguished with water.

Mix the thermite components in a jar with a plastic cap by gently rotating and turning the container. Never grind the mixture in a mortar with a pestle or any abrasive tools.

Do not use a large excess of aluminum powder in the thermite mixture as it may result in an explosion hazard.

The thermite reaction produces a great amount of heat. Although one can observe the molten iron in the bucket of sand from several feet away, once the reaction has concluded, no one should be allowed to get near the apparatus for a minimum of 15 minutes or until the apparatus is cool.

Aluminum powder is flammable, particularly as a dust. Use aluminum powder in a spark free area and away from all flames.

Bigger is not better.

**Figure 1.** Apparatus for the thermite reaction.

## Materials Needed

Iron(III) oxide, $Fe_2O_3$
Aluminum powder, Al, 100 mesh
Magnesium ribbon, Mg
Potassium permanganate, $KMnO_4$
Glycerin, $C_3H_5(OH)_3$
Note: a small amount of gunpowder can be used along with a piece of fuse to allow the experimenter to get to a safe location before the reaction begins.
Dropper
2 clay flower pots, 2 ½ inch diameter
ring stand with support ring to hold the flower pots
metal bucket or large tray
sand
safety shield

## Procedure

The thermite mixture is prepared by mixing 50 g iron(III) oxide, $Fe_2O_3$, with 15 g aluminum powder.

Assemble the apparatus by nesting two clay flower pots together and placing them in a ring on a ring stand. Place a piece of paper in the bottom of the flower pot to cover the drainage hole.

Place a bucket of sand directly below the flower pots.

Add the thermite mixture to the flower pot.

**Figure 2.** The thermite reaction is just starting.

Make a small indentation in the surface of the thermite powder and add a small scoop of potassium permanganate powder. Place a piece of magnesium ribbon, approximately

2.5 cm long (1 inch) into the potassium permanganate so it also extends into the thermite mixture. Insure that all observers are at a safe distance from the reaction. Add 2 or 3 drops of glycerin to the potassium permanganate and move back to a safe distance.

**Figure 3.** The thermite reaction.

**Figure 4.** Molten iron falling from the flower pots into the sand.

**Figure 5.** The reaction is just completed. Note that the inside of the flower pot is glowing red and the reflection of the molten iron is visible in the bucket.

**Figure 6.** The molten iron.

**Figure 7.** The flower pots after the reaction.