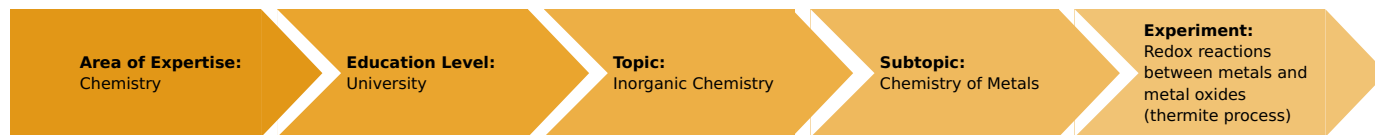


Redox reactions between metals and metal oxides (thermite process) (Item No.: P3110600)

Curricular Relevance



Difficulty



Easy

Preparation Time



10 Minutes

Execution Time



10 Minutes

Recommended Group Size



2 Students

Additional Requirements:

- aluminium foil
- Precision balance, 620 g / 0.001 g

Experiment Variations:

Keywords:

redox reaction, thermite process, metals, welding of iron, aluminothermics, iron, aluminium

Overview

Short description

Principle

The experiments described here are highly suitable for demonstrating the different affinity of various metals in view of oxygen. The less noble a metal is the higher its affinity to oxygen and the more thermal energy is released during its oxidation. The technical importance of the thermite process for the welding of iron parts is that it is relatively easy to produce large amounts of liquid iron and, thereby, to fill wider weld grooves. This is why this process is mainly used for welding thick steel beams, rail tracks, and machine parts.



Fig. 1.

Safety instructions



Concentrated acids are highly caustic. They burn the skin and destroy textile fabrics. For diluting, first add the water, then the acid.

First aid: Rinse the affected skin areas and eyes with the lid gap wide open thoroughly with plenty of water.

Disposal: Solutions must be diluted with water, neutralised (pH 6-8), and flushed away.

During the second experiment (thermite process), there is a risk of a large amount of flying sparks. This is why the experiment should be performed under a closed exhaust or outdoors and with a sufficient safety distance. It is absolutely essential to take suitable fire protection measures and to ensure that observers cannot be injured by the hot sparks.

Copper(II) oxide

H302: Harmful if swallowed.

H410: Very toxic to aquatic life with long-lasting effects.

P260: Do not breathe dust/fumes/gas/mist/vapours/spray.

P273: Avoid release to the environment.

Iron powder

H228: Flammable solid

P370+378: In case of fire: Use ... to extinguish.

Hydrochloric acid, 37%

H290: May be corrosive to metals.

H314: Causes severe skin burns and eye damage.

H335: May cause respiratory irritation.

P234: Keep only in original container.

P260: Do not breathe dust/fumes/gas/mist/vapours/spray.

Ignition sticks

H302: Harmful if swallowed

H332: Harmful if inhaled

P261: Avoid breathing dust/fumes/gas/mist/vapours/spray.

P271: Use only outdoors or in a well-ventilated area.

Equipment

Position No.	Material	Order No.	Quantity
1	Retort stand, h = 750 mm	37694-00	1
2	Right angle boss-head clamp	37697-00	1
3	Universal clamp	37715-00	1
4	Ring with boss head, i. d. = 10 cm	37701-01	2
5	Test tubes 160x16 mm,FIOLAX,100pc	36305-10	1
6	Test tube, 160 x 16 mm, 100 pcs	37656-10	1
7	Test tube rack for 12 tubes, holes d= 22 mm, wood	37686-10	1
8	Mortar with pestle, 150 ml, porcelain	32604-00	1
9	Magnet, d = 10 mm, l = 200 mm	06311-00	1
10	Iron basin,hemispherical, d 160mm	33209-00	1
11	Flower pot, clay, d. approx.12 cm	64123-00	1
12	Ignition sticks for thermite, 50 pcs.	31921-05	1
13	Hammer, engineers, 200 g	40320-00	1
14	Teclu burner, DIN, natural gas	32171-05	1
15	Safety gas tubing, DVGW, sold by metre	39281-10	1
16	Hose clip f.12-20 diameter tube	40995-00	2
17	Lighter f.natural/liquified gases	38874-00	1
18	Test tube holder, up to d 22mm	38823-00	1
19	Crucible tongs, 200 mm, stainless steel	33600-00	1
20	Spoon, special steel	33398-00	1
21	Copper-II oxide,powder 100 g	30125-10	1
22	Iron-III oxide, red 500 g	48114-50	1
23	Iron powder xtra pure 1000 g	30068-70	1
24	Aluminium, granulated 250 g	30919-25	1
25	Hydrochloric acid 37 %, 1000 ml	30214-70	1
26	Water, distilled 5 l	31246-81	1
27	Standard sand,coarse 2500 g	31826-79	1

Tasks

1. Reduction of copper oxide with iron
2. Reduction of iron oxide with aluminium (thermite process, aluminothermics)

Setup and procedure



1. Reduction of copper oxide with iron

Procedure

In accordance with Fig. 2, heat a mixture of 3 g of copper(II) oxide and 1.5 g of pure iron powder in a refractory test tube (DURAN glass, simple design).

**Observation**

The mixture glows and a strong reaction can be observed. The reaction product is black-brown in colour.

Continuation

Let the reaction product cool in the test tube, pour it into a mortar, and grind it with the pestle. Fill a small sample of the black-brown substance into a test tube, add some diluted hydrochloric acid, and heat mildly. For comparison, also treat the initial substances with diluted hydrochloric acid.

Observation

The reaction product shows hardly any magnetic behaviour. Unlike in the case of the initial substances, following the addition of hydrochloric acid a residue with the typical colour of copper remains in the test tube of the reaction product. It is copper.

2. Reduction of iron oxide with aluminium (thermite process, aluminothermics)**Procedure**

The experiment must be performed behind a safety shield, under a closed exhaust, or outdoors (see the safety instructions). The reaction involving fire is particularly impressive in a darkened room. Mix 10 g of granulated aluminium with 20 g of red iron(III) oxide thoroughly in a mortar. Fill this mixture into a flower pot made of baked clay. Ensure that the hole in the bottom of the pot is covered with a piece of aluminium foil. When filling the mixture in, ensure that it forms a little cone (Fig. 3a). Then, place the flower pot onto an iron basin that is filled with fine sand (see Fig. 3b). Secure the flower pot in place on the support stand by way of the iron ring with a boss head. Ignite an ignition stick and plunge the burning tip immediately into the mixture.

Attention: Violent reaction!

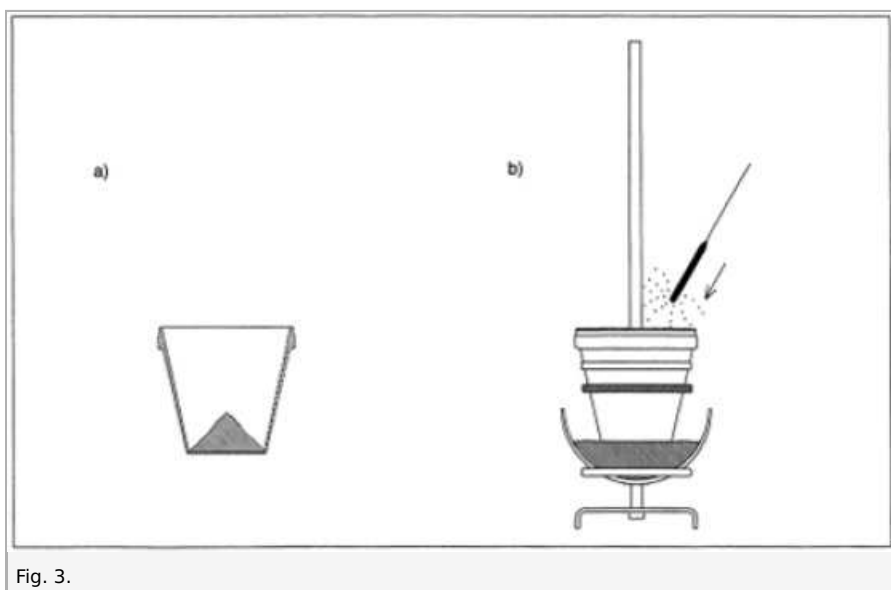


Fig. 3.

Observation

The iron oxide reacts with the granulated aluminium while glowing strongly. Sparks fly and a lot of heat is generated. The flower pot usually ruptures during this process.

Continuation

Let the reaction product cool down or cool it actively by holding it with the flower pot under running water. Separate it as far as possible from the broken clay fragments (if necessary, use a small hammer) and approach it with a magnet.

Observation

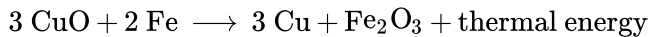
Unlike the initial products, the reaction product is clearly attracted by the magnet.

Theory and evaluation

1. Reduction of copper oxide with iron

Interpretation

Iron is able to reduce copper oxide to copper. During this process, iron as the reducing agent is transformed into iron oxide. Unlike copper, iron oxide is soluble in diluted hydrochloric acid.



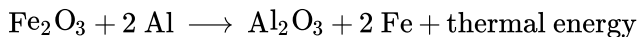
Result

Non-noble metals are able to withdraw oxygen from the oxides of nobler metals, i.e. to reduce them, since they have a higher "affinity" towards oxygen. While giving off energy, they are then transformed into the oxide themselves. This means that the reaction is a redox reaction.

2. Reduction of iron oxide with aluminium (thermite process, aluminothermics)

Interpretation

Aluminium reduces iron oxide to iron. The aluminium itself is oxidised during this process.



The process releases so much thermal energy (852 kJ/mol) that the reaction product melts and flows together to form spherical shapes. In doing so, iron and aluminium oxide mix with each other, but evidence concerning the presence of iron can be provided based on its magnetic properties. The process that takes place during this reaction is used technically in the so-called thermite welding process. It is used predominantly for welding thick iron parts and rail tracks. On the other hand, these "aluminothermic processes" are used for the preparation of metals that are only very difficult to prepare based on their oxides, e.g. chromium, manganese, titanium, silicon, etc.

Notes

The experiments described here are highly suitable for demonstrating the different affinity of various metals in view of oxygen. The less noble a metal is the higher its affinity to oxygen and the more thermal energy is released during its oxidation. The technical importance of the thermite process for the welding of iron parts is that it is relatively easy to produce large amounts of liquid iron and, thereby, to fill wider weld grooves. This is why this process is mainly used for welding thick steel beams, rail tracks, and machine parts.

The aluminothermics experiment can also be performed with the "Thermite process demonstration set" (order no. 36685-00). The set includes all of the necessary equipment and chemicals as well as an experiment description with instructions.