Redox reactions between metals and metal oxides (thermite process)

Die hier beschriebenen Experimente eignen sich sehr gut zur Darstellung der unterschiedlichen Affinität verschiedener Metalle im Hinblick auf Sauerstoff. Je weniger edel ein Metall ist, desto höher ist seine Affinität zu Sauerstoff und desto mehr Wärmeenergie wird bei der Oxidation freigesetzt

Chemistry > Industrial Chemistry > Metallurgy

Difficulty level	Group size	Preparation time	Execution time
easy	2	10 minutes	10 minutes

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General information

Application

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Thermite reactions have many uses. Thermite is not an explosive. It operates by exposing a very small area to extremely high temperatures. This can be useful to cut through metal or weld metal.

Thermite may be used for repair by welding in-place of thick steel sections. It can be used for quickly cutting or welding rail tracks, without requiring complex or heavy equipment.

Thermite hand grenades and charges are typically used by armed forces in both an anti- material role and in the partial destruction of equipment. For example it can be used for the emergency destruction of cryptographic equipment when there is a danger that it might be captured by enemy troops.

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Other information (1/2)

Prior knowledge

The less noble a metal is, the higher its affinity to oxygen. Therefore the more thermal energy is released during oxidation.

Scientific principle

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.

Other information (2/2)

Learning objective

The objective of this experiment is to gain better knowledge of redox reactions between metals and metal oxides.

The students will learn what thermites are.

They will observe the thermite process between aluminium and iron oxide.

Tasks

- The students will perform and observe the reduction of copper oxide with iron.
- They will also observe the reduction of iron oxide with aluminium, which is a thermite process.

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Safety instructions

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For this experiment the general instructions for safe experimentation in science lessons apply.

For H- and P-phrases please consult the safety data sheet of the respective chemical.

Theory

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Thermite is a pyrotechnik composition of metal powder and metal oxide. When ignited by heat, thermite undergoes an exothermic redox reaction. Most varieties are not explosive. They can however, create brief bursts of heat and high temperature in a small area.

Thermites have diverse compositions. In this experiment the one that includes aluminium and iron oxide is observed. This is also the most common composition. It produces more heat and it is easier to ignite.

The chemical equation that describes this reaction is:

$$Fe_2O_3 + 2Al -> Al_2O_3 + 2Fe + thermalenergy$$

Here, elemental aluminium reduces the iron oxide, because aluminium forms stronger and more stable bonds with oxygen than iron.

The products are aluminium oxide, elemental iron, and a large amount of heat. The reactants are commonly powdered and mixed with a binder to keep the material solid and prevent separation.

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Equipment

Position	Material	Item No.	Quantity
1	Retort stand, h = 750 mm	37694-00	1
2	Right angle boss-head clamp	37697-00	1
3	Universal clamp	37715-01	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	Hammer, engineers, 200 g	40320-00	1
13	Teclu burner, DIN, natural gas	32171-05	1
14	Safety gas tubing, DVGW, sold by metre	39281-10	1
15	Hose clip f.12-20 diameter tube	40995-00	2
16	Lighter f.natural/liquified gases	38874-00	1
17	Test tube holder, up to d 22mm	38823-00	1
18	Crucible tongs, 200 mm, stainless steel	33600-00	1
19	Spoon, special steel	33398-00	1
20	Copper-II oxide,powder 100 g	30125-10	1
21	Iron-III oxide, red 500 g	48114-50	1
22	Iron powder xtra pure 1000 g	30068-70	1
23	Aluminium, granulated 250 g	30919-25	1
24	Hydrochloric acid 37 %, 1000 ml	30214-70	1
25	Water, distilled 5 l	31246-81	1
26	Quartz sand, coarse, 1000 g	CHE-881318041	1

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Setup and procedure

Setup Part 1

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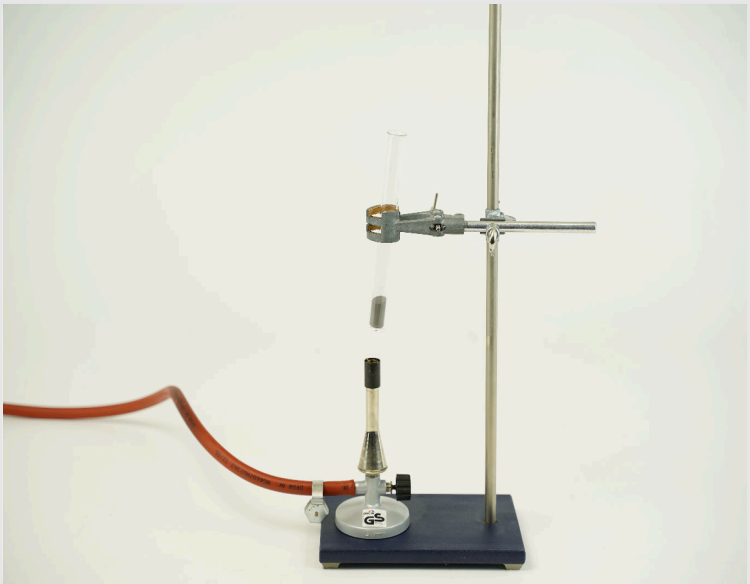

Reduction of coppper oxide with iron

- Set up the experiment shown in figure left
- Take a retort stand and fix the test tupe with a clamp
- Put 3 g of copper (III) oxide and 1.5 g of pure iron powder in the test tube.
- Heat a mixture of 3 g of copper (III) oxide and 1.5 g of pure iron powder in a refractory test tube.
- Let the reaction product cool in the test tube.

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Procedure Part 1

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- Pour the solid 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.

Setup Part 2

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

- The experiment must be performed behind a safety shield, under a closed exhaust, or outdoors.
- The reaction involving fire is particulary impressive in a darkened room.
- Mix 10 g of granulated aluminium with 20 g of red iron (III) oxide throughly 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.

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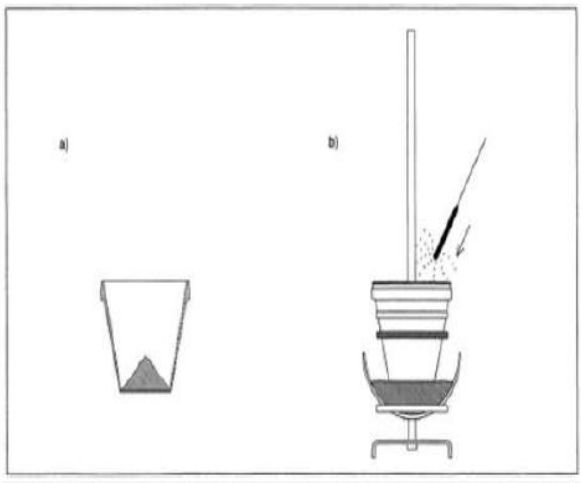
Procedure Part 2



- Place the flower pot onto an iron basin that is filled with fine sand.
- 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.
- 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.
- Approach it with a magnet.

Evaluation

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Evaluation (1/3)

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Reduction of copper oxide with iron

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.

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

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.

Evaluation (2/3)

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Complete the reactions that take place during the experiment!

Reduction of copper oxide with iron

$Al_2O_3 + 2Fe$

$3Cu + Fe_2O_3$

$3CuO + 2Fe- >$ ____ $+thermal\ energy$

Reduction of iron oxide with aluminium (thermite process)

$Fe_2O_3 + 2Al- >$ ____ $+thermal\ energy$

Check

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Evaluation (3/3)

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After the first reaction (copper oxide and iron) the product is

- red in colour.
- black-brown in colour.

Slide	Score / Total
Slide 15: Reaction equation	0/2
Slide 16: Summary of the reaction	0/4

Total Score 0/6

Show solutions Retry

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