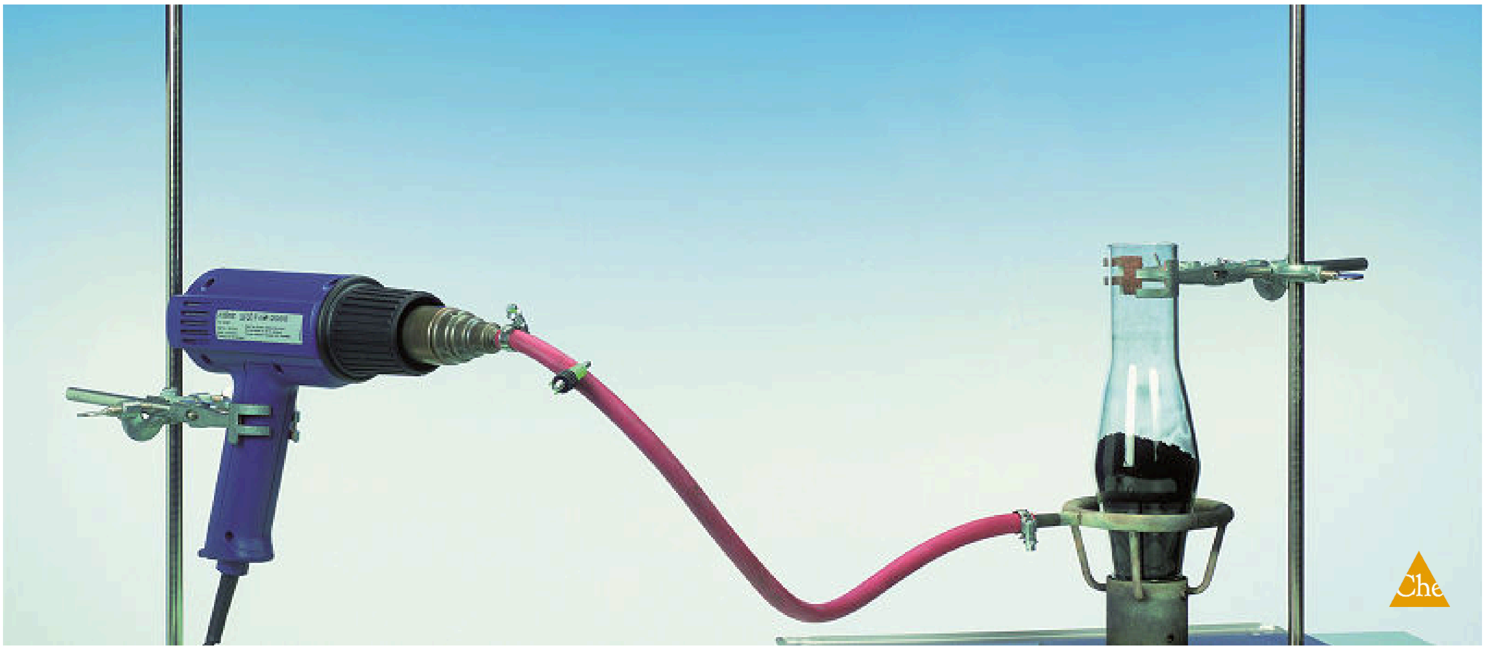
Preparation of iron from oxidic ores (blast furnace process)



The students learn the industrial blast durnace process to produce iron from iron(III) oxide in a model experiment.

Chemistry | Industrial Chemistry | Metallurgy

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

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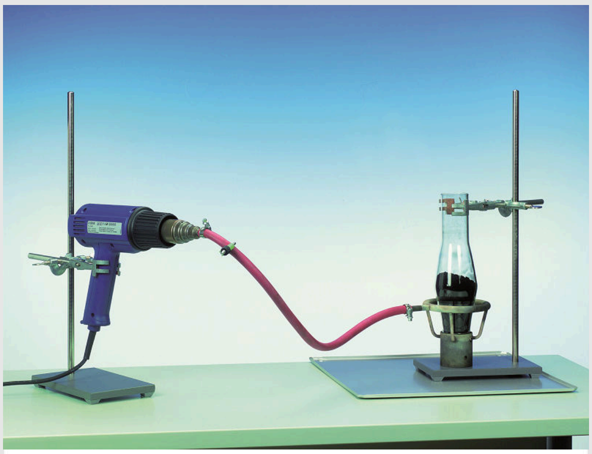
General information

Application



Experimental setup

This is a model experiment to show the industrial blast furnace process to produce iron from iron(III) oxide. During the experiment a furnace gas flame that is approximately 10 to 20 cm high can be ignited at the stack outlet. Cavities form in the burning carbon layer. These cavities collapse over time. Apart from ash and carbon residues, metallic lumps can also be found in the frame after the end of the experiment.

Samples of these lumps lead to the formation of hydrogen when they are treated with hydrochloric acid.

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Other information (1/2)

Prior knowledge

The students should already be familiar with the blast furnace process, the production of iron, reduction and oxidation in theory.

Scientific principle

During the experiment a furnace gas flame that is approximately 10 to 20 cm high can be ignited at the stack outlet. Cavities form in the burning carbon layer. These cavities collapse over time. Apart from ash and carbon residues, metallic lumps can also be found in the frame after the end of the experiment. Samples of these lumps lead to the formation of hydrogen when they are treated with hydrochloric acid.

Other information (2/2)

Learning objective

The students learn the industrial blast furnace process to produce iron from iron(III) oxide in a model experiment.

Tasks

The students are to prepare iron from oxidic ores using the blast furnace process.

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Safety instructions (1/2)

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- For the reduction with hydrogen, the right-angled glass tube must be filled with quartz glass wool as blowback protection. Prior to igniting the hydrogen, perform an oxyhydrogen test until the result is negative!
- During the second experiment (blast furnace model), there is a risk of a large amount of flying sparks. This is why the experiment should be performed under closed exhaust hood 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.
- For the H- and P-phrases please refer to the corresponding safety data sheets.
- The general instructions for safe experimentation in science education apply to this experiment.

Safety instructions (2/2)

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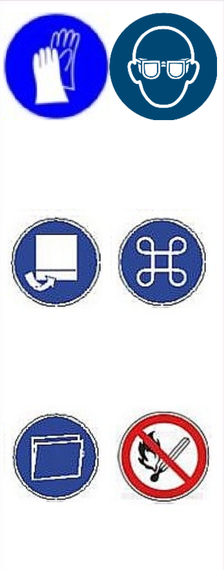

- The reaction leads to the formation of carbon monoxide. It can be burnt at the blast furnace stack. Carbon monoxide is a colourless, odourless, flavourless, toxic, and highly flammable gas. If mixed with air, there is a risk of explosion (lower flammability limit: 12.5%, upper flammability limit: 74%). As a very strong haemotoxin, it leads to oxygen depletion in the organism. In the event of strong poisoning, this lack of oxygen may cause long-term damage.
- Concentrated acids are highly caustic. They burn the skin and destroy textile fabrics. For diluting, first add the water, then the acid (protective glasses, laboratory coat, gloves).
- For the H- and P-phrases please refer to the corresponding safety data sheets.
- The general instructions for safe experimentation in science education apply to this experiment.

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Theory

During the blast furnace process, cavities form in the burning carbon layer. These cavities collapse over time. Apart from ash and carbon residues, metallic lumps can also be found in the frame after the end of the experiment. Samples of these lumps lead to the formation of hydrogen when they are treated with hydrochloric acid.

Due to caking and conglutination in the upper layers that are caused by thermal expansion, the carbon and ore layers cannot always sink down regularly. This leads to the formation of cavities that can collapse and disturb the reaction. In order to avoid this to the largest possible extent, blast furnaces have a typical double-cone shape. It enables the sinking material to expand without caking too much. In the model, this effect is less distinct.
However, cavities can be caused to collapse by briefly interrupting the air supply (by pinching the tubing). The temperatures that can be reached with the model are not sufficient for collecting any liquid iron and slag in the frame. This is also why they cannot be tapped off. As a result, the product is always iron mixed with slag.

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Equipment

Position	Material	Item No.	Quantity
1	Retort stand, h = 750 mm	37694-00	2
2	Support base DEMO	02007-55	1
3	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
4	Right angle boss-head clamp	37697-00	3
5	Universal clamp	37715-01	3
6	Security bolster, 26,5 cm x 36,5 cm, aluminium	39180-01	1
7	Combustion tube, l 300mm, DURAN	37023-01	1
8	Gas washing bottle, 100 ml	36691-00	1
9	Clamp for ground joint, plastic, IGJ29	43615-00	1
10	Teflon sleeve IGJ 29, 10 pcs	43617-00	1
11	Rubber stopper, d = 22/17 mm, 1 hole	39255-01	2
12	Glass tube, straight, l=80 mm, 10/pkg.	36701-65	1
13	Glass tube,right-angled w.tip,10	36701-53	1
14	Test tube, 160 x 16 mm, 100 pcs	37656-10	1
15	Test tube rack for 12 tubes, holes d= 22 mm, wood	37686-10	1
16	Porcelain boats, 10 pcs	32471-03	1
17	Steel cylinder hydrogen, 2 l, full	41775-00	1
18	Reducing valve for hydrogen	33484-00	1
19	Table stand for 2 l steel cylinders	41774-00	1
20	Wrench for steel cylinders	40322-00	1
21	Support,w.closed-circuit pipeline	36688-01	1
22	Rings, ceramic fibre, 5 pcs	36688-08	1
23	Blast furnace stack, DURAN	36688-09	1
24	Hot air blower with adaptor	36688-93	1
25	Pinchcock, width 15 mm	43631-15	1
26	Mortar with pestle, 150 ml, porcelain	32604-00	1
27	Bar magnet, l 150mm	06310-00	1
28	Teclu burner, DIN, natural gas	32171-05	1
29	Safety gas tubing, DVGW, sold by metre	39281-10	1
30	Lighter f.natural/liquified gases	38874-00	1
31	Hose clip f.12-20 diameter tube	40995-00	2
32	Rubber tubing, i.d. 6 mm	39282-00	1
33	Rubber tubing, i.d. 8 mm	39283-00	1
34	Tweezers,straight,blunt, 200 mm	40955-00	1
35	Crucible tongs, 200 mm, stainless steel	33600-00	1
36	Spoon, special steel	33398-00	1
37	Funnel, glass, top dia. 50 mm	34457-00	1
38	Wash bottle, plastic, 500 ml	33931-00	1
39	Beaker, Borosilicate, tall form, 100 ml	46026-00	1
40	Pasteur pipettes, 250 pcs	36590-00	1
41	Rubber caps, 10 pcs	39275-03	1
42	Glass wool 10 g	31773-03	1
43	Hydrochloric acid 37 %, 1000 ml	30214-70	1
44	Sulphuric acid, 95-97%, 500 ml	30219-50	1
45	Iron ore, 500 g	36688-05	1
46	Activated carbon, granular 500 g	30011-50	1
47	Charcoal,small pieces 250 g	30088-30	1
48	Iron-III oxide, red 500 g	48114-50	1
49	Water, distilled 5 l	31246-81	1

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Setup and procedure

Setup and procedure (1/4)

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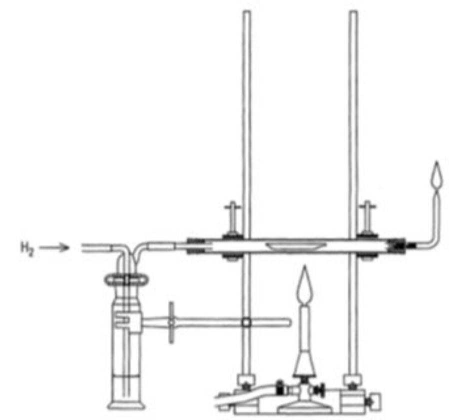
1. Reduction of iron(III) oxide (1/2)

Fill some iron(III) oxide into a porcelain boat and push it into the combustion tube that is secured horizontally on a support stand as shown in Fig. right.

Connect the gas wash bottle, which is filled up to 4 cm high with concentrated sulphuric acid, to one end of the combustion tube. Seal the other end of the tube with a rubber stopper and a right-angled glass tube with a tip. Quartz glass wool in the glass tube ensures protection against blowback.



Experimental setup

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Setup and procedure (2/4)

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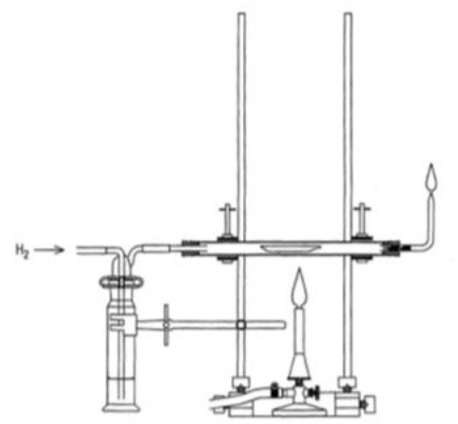
1. Reduction of iron(III) oxide (2/2)

Let a slow flow of hydrogen flow through the apparatus. When this flow is free from oxygen (oxyhydrogen test), ignite the hydrogen that escapes from the tip of the glass tube and heat the iron oxide in the porcelain boat with a burner. The hydrogen flame should not be higher than two centimetres.

After the reaction is over, let everything cool down in a hydrogen flow. Test the cold product by way of a magnet that must be held against the combustion tube. Fill some of the product into a test tube and add a few millilitres of diluted hydrochloric acid (approximately 10%, made from 10 g of concentrated hydrochloric acid and 27 g of water).



Experimental setup

Setup and procedure (3/4)

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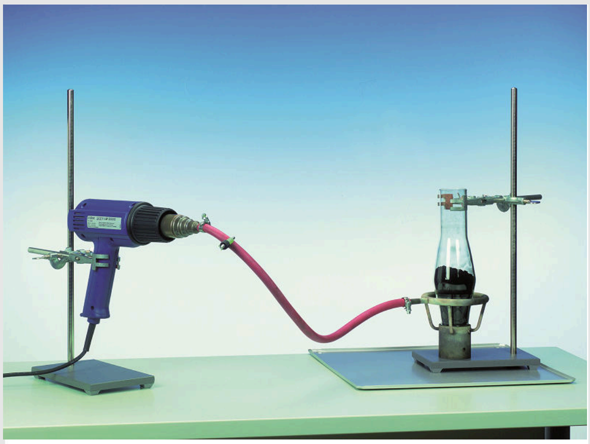
2. Blast furnace model (1/2)

The blast furnace model consists of a metal "frame" with closed-circuit air pipes and the "stack" made of glass that is difficult to melt. The glass cylinder is positioned on the frame on a ring of ceramic fibres. The air supply is ensured via an 8 mm rubber tubing (pinchcock for flow control) and by way of a hot/cold air blower that is fastened to a support stand.

Place the blast furnace model with the second support stand on a safety desk plate as shown in Fig. right.

Remove the glass stack and ignite a piece of charcoal on the burner. When the charcoal glows sufficiently, place it into the frame and switch the air supply on.



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Setup and procedure (4/4)

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2. Blast furnace model (2/2)

Then, pile the activated carbon up around the glowing charcoal until it reaches the rim of the frame. Ensure that the embers are not smothered.

After that, place the stack onto the frame and secure it with a universal clamp at its upper end.

Caution! Hot gases will rise in the stack. Risk of burns. Then, fill some activated carbon carefully into the stack until it is well compacted.

Caution! During this process, carbon dust may be blown out of the stack. Add a layer of 1 to 2 cm of iron ore on top of the activated carbon and cover it with another layer of activated carbon of the same thickness. During the reaction, test from time to time as to whether the gases at the stack outlet can be ignited (use the burner). Ensure a uniform combustion by controlling the air supply accordingly. After the reaction, let the entire system cool down, but leave the stack on the frame. Remove the product with the frame, grind it in a mortar, fill some of it into a test tube and add some diluted hydrochloric acid.

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Evaluation

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Evaluation (1/6)

1. Reduction of iron(III) oxide

After a short period, water condensates at the end of the combustion tube and the hydrogen flame shrinks slightly. The redbrown iron oxide turns black.
Unlike the initial substance, the product is magnetic and reacts with diluted hydrochloric acid under the formation of gas.

Iron(II) oxide is reduced to iron by hydrogen. The iron reacts with hydrochloric acid while hydrogen is formed.

$$Fe_2O_3 + 3H_2 \longrightarrow 2Fe + 3H_2O$$

$$2Fe + 6HCl \longrightarrow 2FeCl_3 + 3H_2$$

Evaluation (2/6)

2. Blast furnace model

If the air supply is adjusted correctly, a furnace gas flame that is approximately 10 to 20 cm high can be ignited at the stack outlet. During the blast furnace process, cavities form in the burning carbon layer. These cavities collapse over time. Apart from ash and carbon residues, metallic lumps can also be found in the frame after the end of the experiment. Samples of these lumps lead to the formation of hydrogen when they are treated with hydrochloric acid.

The following main chemical reactions take place in a blast furnace:

$$C + O_2 \longrightarrow CO_2$$

$$CO_2 + C \longrightarrow 2CO$$

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

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Evaluation (3/6)

2. Blast furnace model

Due to caking and conglutination in the upper layers that are caused by thermal expansion, the carbon and ore layers cannot always sink down regularly. This leads to the formation of cavities that can collapse and disturb the reaction. In order to avoid this to the largest possible extent, blast furnaces have a typical double-cone shape. It enables the sinking material to expand without caking too much. In the model, this effect is less distinct. However, cavities can be caused to collapse by briefly interrupting the air supply (by pinching the tubing). The temperatures that can be reached with the model are not sufficient for collecting any liquid iron and slag in the frame. This is also why they cannot be tapped off. As a result, the product is always iron mixed with slag.

Note: This experiment can only lead to satisfactory results if low-melting iron ores are used, e.g. Mount Nimba iron ore or bog iron.

Evaluation (4/6)

Why is the product of the blast furnace model always iron mixed with slag?

- ○ The temperatures that can be reached with the model are not sufficient for collecting any liquid iron and slag in the frame. This is also why they cannot be tapped off - so the product is always iron mixed with slag.
- ○ The product of the blast furnace reaction is not iron, but copper.
- ○ That is not true. In the normal case, pure iron is extracted. Only when the temperature is too high does t iron mix with slag.

Überprüfen

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Evaluation (5/6)

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Mark the correct statements.

- [ ] Iron(II) oxide is reduced to iron by oxygen. The iron reacts with oxydrochloric acid while hydrogen is formed.
- [ ] After a short period, water condensates at the end of the combustion tube and the hydrogen flame shrinks slightly. The redbrown iron oxide turns black.
- [ ] Iron(II) oxide is reduced to iron by hydrogen. The iron reacts with hydrochloric acid while hydrogen is formed.

Überprüfen

Evaluation (6/6)

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Summary of the experiment

If the air supply is adjusted correctly, a furnace ______ that is approximately 10 to 20 cm high can be ignited at the stack outlet. During the ______, cavities form in the burning carbon layer. These cavities ______ over time. Apart from ash and carbon residues, ______ can also be found in the frame after the end of the experiment. Samples of these lumps lead to the formation of hydrogen when they are treated with ______.

- gas flame
- hydrochloric acid
- blast furnace process
- metallic lumps
- collapse

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Folie	Punktzahl/Summe
Folie 18: Product of the blast furnace model	0/1
Folie 19: Reduction of ironoxide	0/2
Folie 20: Summary of the experiment	0/5

Gesamtsumme 0/8

Lösungen Wiederholen

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