

Extraction of iron by the blast furnace process

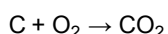
Aims of the experiment

- To learn about industrial-scale processes
- To learn about the extraction of metals
- To learn about the conversion of substances
- To learn about practical redox reactions

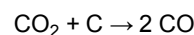
Principles

Iron is one of the most commonly-used metals today. However, it does not occur on the Earth in its elemental form. To obtain elemental iron, its oxides and sulfides must first be converted in an industrial-scale process. This is achieved with the help of a blast furnace. The blast furnace process was used in China as long ago as in the Han dynasty (200 B.C. to 220 A.D.). In this process, iron ores are converted to elemental iron by reduction. Today, a blast furnace is used for this purpose, which consists of a 75 m high steel jacket lined with a 1.5 m thick layer of refractory material (firebricks). The blast furnace is fed in turn with sinter (= iron ore and limestone) and then with coke. The limestone is needed to channel siliceous impurities in the iron ore, also known as gangue, out of the furnace.

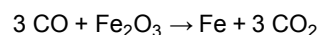
The reaction in a blast furnace takes place by way of a counter-current method. Nozzles are located in the lower part of the furnace through which hot air at about 1200 °C is blown under pressure. This flows upwards through the descending iron ore and coke mixture. The oxygen contained in the air is thus able to react with the coke.



This is an exothermic reaction in which energy is released. This energy results in temperatures of up to 2000 °C. The carbon dioxide (CO₂) produced then reacts on rising with the glowing coke to instantaneously form carbon monoxide (CO).

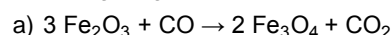


The carbon monoxide rising further is able to reduce the iron oxides.

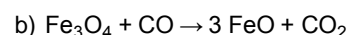


However, this reaction takes place in partial reactions.

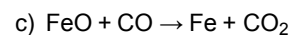
Initially iron-containing magnetite is formed.



This is then reduced to iron(II) oxide.



Finally elemental iron is formed.



Elemental carbon at the interface between coke and sinter also acts as a reducing agent.

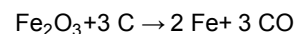


Fig. 1 Set-up of the experiment

CO₂ then rises further and meets the next layer of coke in the furnace. Here it is reduced again to CO and, when it meets a layer with iron ore, is able to reduce this again to iron. The gases that rise out of the furnace are called blast furnace gas. They are used in a recycling process in hot blast stoves in order to heat the air supply fed to the lower part of the blast furnace. This is done by igniting the CO contained in the blast furnace gas, which is present in a proportion of about 30%.

The crude iron produced in this process sinks to the bottom together with the slag, which has formed from the gangue and the limestone. The slag is less dense compared with the crude iron and for this reason they can both be skimmed off in turn via different tapholes. A schematic representation of the whole blast furnace process with the various temperature areas can be seen in Fig. 2.

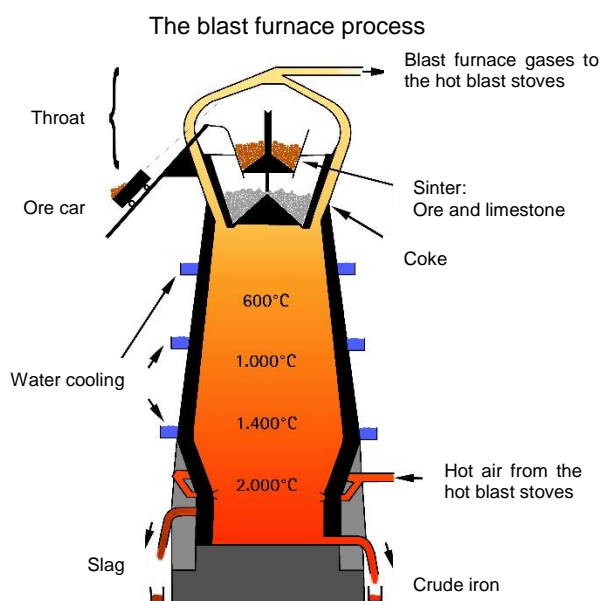


Fig. 2: Schematic representation of the blast furnace process

In this experiment, the industrial blast furnace process is to be simulated using a miniature blast furnace. For this purpose, activated charcoal will be used as the carbon component. The iron ore to be used is haematite (Fe₂O₃) which will be applied in a single layer. Air will be introduced into the apparatus using a compressor. The reaction product will be tested for magnetism at the end of the experiment.

Risk assessment

The substances used in the experiment are not hazardous. However, very high temperatures of 600 °C will be reached on the outer wall. Internal temperatures of over 1000 °C are possible. It is possible that the glowing mass will bubble and vibrate during the experiment. Volcano-like effects might also be observed.

Equipment and chemicals

1 Blast furnace model.....	661 541
1 Mini compressor, electric.....	664 752
1 High current power supply.....	521 55
1 Stand base, V-shaped, small	300 02
1 Stand rod 25 cm, 10 mm Ø	301 26
1 Bosshead S.....	301 09
1 Universal clamp 0...120 mm.....	301 72
1 Heat-resistant cover plate, ceramic fibre	667 104
1 Tube connector PP, T-shaped, 8 mm Ø.....	665 23ET10
1 Rubber tubing 7 mm Ø, 1 m.....	667 180
1 Tubing clamp after Hofmann, 30 mm	667 176
1 Bunsen burner, universal	656 016
1 Crucible tongs, 200 mm	667 035
1 Pocket balance JE120, 120 g: 0.1 g.....	667 7931
1 Wooden turnings, 200 pcs.....	661 083ET20
1 Magnet with hole	510 15
1 Peroxide of iron, 250 g	671 8810
1 Activated charcoal, granulated, 500 g	670 2020
1 Wood charcoal, small pieces, 500 g.....	672 2490
Additionally recommended:	
1 Glass rod 300 mm x 8 mm Ø	665 213

Set-up and preparation of the experiment

Set-up of the apparatus

1. The apparatus is set up as shown in Fig. 1.
2. For the electrical supply, the compressor is connected to the high current power supply.
3. A piece of tubing must be connected to the foot of the blast furnace model to connect this to the mini compressor.
4. For better air control, a T-piece with a short piece of tubing and a tubing clamp after Hofmann should be inserted between the compressor and the blast furnace.
5. In continuous operation, the compressor should be operated at a voltage of 6 - 8 V.

Preparation of the blast furnace model

1. With the glass shaft removed, fill the base body of the blast furnace model with granulated activated charcoal up to just below the air inlets.
2. Wrap the glass shaft with the sealing tape and place it onto the base body.

Note: The sealing tape must not cover the air inlets.

3. Carefully tighten the locking screws of the base body.

Note: Avoid over-tightening the screws to prevent the glass shaft from breaking.

4. Place the blast furnace model prepared in this way onto the heat-resistant cover plate and secure the glass shaft using a universal clamp and a bosshead S on a stand rod. Fix the stand rod in the stand base.

Performing the experiment

1. Using a Bunsen burner, heat a piece of wood charcoal held in crucible tongs until it fully glows.
2. Let the glowing wood charcoal fall into the glass shaft, preferably so that it comes to rest near an air inlet.

Note: If the wood charcoal does not come to rest near an air inlet, push it in front of the air inlet with a glass rod.

3. Immediately switch on the compressed air supply. The wood charcoal should then continue to distinctly glow.
4. Carefully pour granulated activated charcoal onto the glowing wood charcoal. However, this must not completely cover the wood charcoal.

5. Wait until the glow has spread also to the activated charcoal. Then fill the glass shaft to its widest point with activated charcoal.
6. Pour about 25 g of iron ore (haematite) onto the activated charcoal. When doing so, take care to ensure that the iron ore is evenly distributed. If this is not the case, use a glass rod to assist.
7. Then cover the ore layer again with a 1 cm layer of activated charcoal.
8. Adjust the compressed air supply using the tubing clamp so that the glow spreads out further.
9. Attempt to light the escaping carbon monoxide gas (CO) with a burning wooden turning.
10. In the course of the experiment, the glow spreads further and further and the ore/activated charcoal layer slowly sinks to the bottom.
11. When the charge has almost reached the upper edge of the base body, the experiment can be terminated.
12. Allow the apparatus to cool for 5 - 10 minutes.

Observation

It can be observed during the experiment that the glow in the glass shaft continually spreads and the ore/charcoal layer slowly sinks. Bubbling and vibrating of the mass might occur during this time. Possibly also volcano-like effects can be

observed in the shaft through swirling, glowing ore and charcoal particles.

After the apparatus has cooled down, it can be dismantled. In the mass from the blast furnace model, alongside incompletely burned charcoal and slag, metallic lumps can also be found.

Evaluation

In this experiment, the extraction of iron using the blast furnace process is demonstrated. Apart from incompletely burned charcoal and slag, the reaction product obtained also contains metallic lumps. Both the metallic product and the iron ore used can be examined for any possible magnetism using a magnet.

Results

The metallic lumps from the reaction product are attracted by a magnet. The iron ore used at the start of the experiment, on the other hand, is not attracted. This demonstrates that the iron ore has been reduced at least to magnetite (Fe_3O_4). But metallic iron has also partly been formed.

Cleaning and disposal

The substances used in this experiment are not hazardous. They can be disposed of in accordance with local regulations.