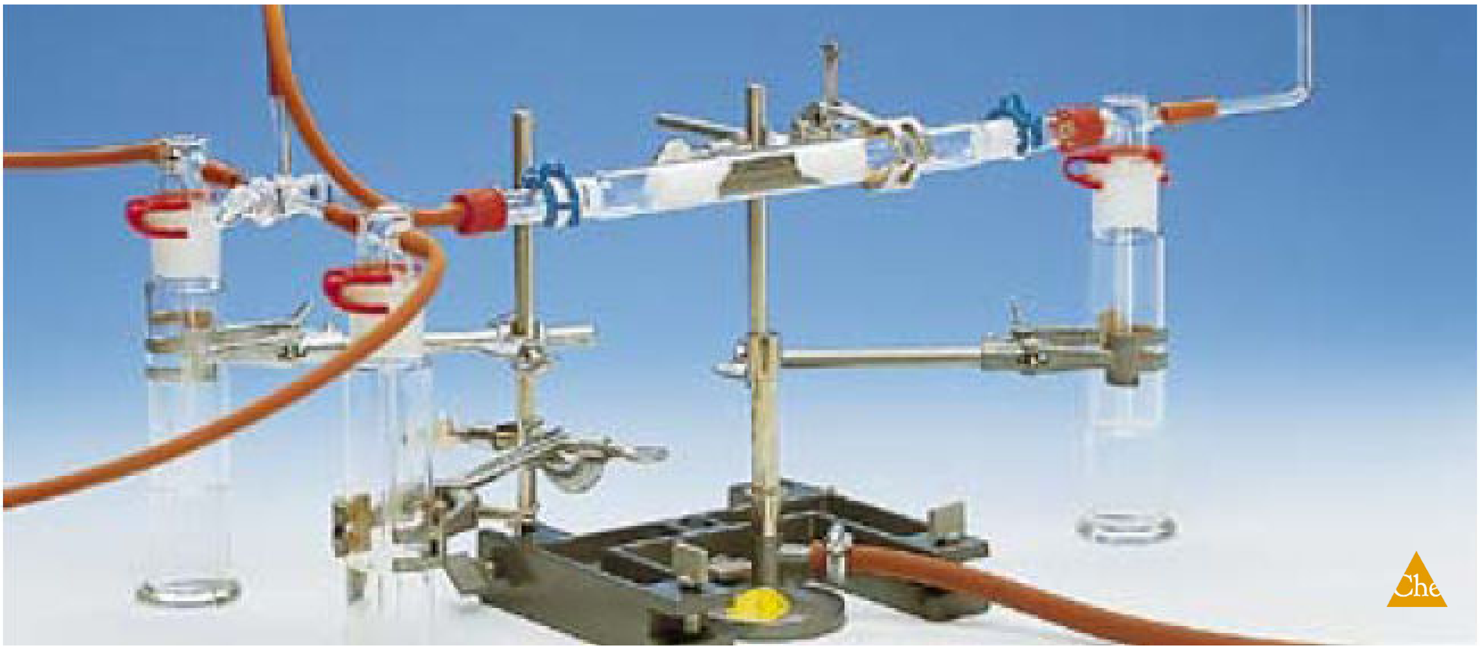
Ammonia preparation from the elements (Haber-Bosch process)



The Haber-Bosch process was the first large-scale technical method for producing nitrogen compounds based on the nitrogen in the air. The setup that is used here can be used to demonstrate the Haber-Bosch process in a simplified manner. The optimum conditions that are necessary for the process cannot be realised with the means that are available at schools or it would be extremely difficult to realise them.

Chemistry > Industrial Chemistry > industrial synthesis

Difficulty level	Group size	Preparation time	Execution time
hard	2	10 minutes	20 minutes

General information

Application

Experimental setup

The Haber process was a big invention. Before its development ammonia had been difficult to produce on an industrial scale. During World War I, this process provided Germany with a source of ammonia for the production of explosives.

The Process is extremely important because it was the first one to mass produce plant fertilizers. It is also one of the first industrial processes developed to use high pressure to create a chemical reaction. Many consider the Haber-Bosch process to be responsible for the Earth's current population explosion. This conclusion is made based on the fact that approximately half of the protein in today's humans originated with nitrogen fixed through this process.

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Other information (1/2)

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Prior knowledge

The Haber- Bosch process is an artificial nitrogen fixation process. This is the main industrial procedure for the production of ammonia today.

Scientific principle

The Haber- Bosch process was the first large- scale technical method for producing nitrogen compounds based on the nitrogen in the air. The formation of ammonia benefits from a falling temperature and rising pressure since it is an exothermic reaction that is accompanied by a decrease in volume. At room temperature, however, the reaction rate would be so small that it could not be measured. In addition, current catalysts are only effective at higher temperatures (approximately 400-500°C). If these temperatures are used at normal pressure, the ammonia yield is approximately 0.1 % by volume. Technical processes, in which the pressure is increased in a continous process, yield approximately 11%.

Other information (2/2)

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Learning objective

The objective of this experiment is to understand how the Huber-Bosch process works. The students should be able to understand the process of converting atmospheric nitrogen to ammonia.

Tasks

- The students should demonstrate the principle of the Haber-Bosch process.
- They should identify the reactions that take place during the process.

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Safety instructions

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There is a danger of explosion if the experiment is performed improperly.

Laboratory glasses should be used.

Gloves should be used.

It is absolutely necessary to flush the apparatus thoroughly with nitrogen and hydrogen prior to the experiment and with nitrogen after the experiment.

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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The Haber- Bosch process is named after its inventors. It is an artificial nitrogen fixation process and is the main industrial procedure for the production of ammonia today.

During this process atmospheric nitrogen is converted to ammonia by reacting with hydrogen under high temperatures and pressures.

$$N_2 + 3H_2 - > 2NH_3$$

This conversion happens at pressures above 10 MPa and between 400 and 500 °C. The gases nitrogen and hydrogen pass over four beds of catalyst, with cooling between each pass in order to maintain an equilibrium constant.

The catalysts are heterogenous which means that they are solid that interact on gaseous reagents.

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Equipment

Position	Material	Item No.	Quantity
1	Support base DEMO	02007-55	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
3	Right angle boss-head clamp	37697-00	5
4	Universal clamp	37715-01	5
5	Lab jack, 160 x 130 mm	02074-00	1
6	Teclu burner, DIN, natural gas	32171-05	1
7	Safety gas tubing, DVGW, sold by metre	39281-10	1
8	Lighter f.natural/liquified gases	38874-00	1
9	Hose clip f.12-20 diameter tube	40995-00	2
10	Combustion tube, 300 mm, quartz, ns	33948-01	1
11	Connecting tube IGJ 19/26-GL 18/8	35678-01	2
12	Gas washing bottle, 100 ml	36691-00	3
13	Clamp f.ground joint,plastic,NS19	43614-00	2
14	Clamp for ground joint, plastic, IGJ29	43615-00	3
15	Teflon sleeve IGJ 19, 10 pcs	43616-00	1
16	Teflon sleeve IGJ 29, 10 pcs	43617-00	1
17	Stopcock,3-way,t-shaped, glass	36731-00	1
18	Glass tubes,right-angled, 10	36701-59	1
19	Glass tube,right-angled w.tip,10	36701-53	1
20	Steel cylinder Nitrogen,2l,filled	41777-00	1
21	Steel cylinder hydrogen, 2 l, full	41775-00	1
22	Reducing valve f.nitrogen	33483-00	1
23	Reducing valve for hydrogen	33484-00	1
24	Table stand for 2 l steel cylinders	41774-00	2
25	Wrench for steel cylinders	40322-00	1
26	Test tube, 160 x 16 mm, 100 pcs	37656-10	1
27	Wash bottle, plastic, 500 ml	33931-00	1
28	Rubber tubing, i.d. 6 mm	39282-00	4
29	Spoon, special steel	33398-00	1
30	Tweezers,straight,blunt, 200 mm	40955-00	1
31	Pasteur pipettes, 250 pcs	36590-00	1
32	Rubber caps, 10 pcs	39275-03	1
33	Glass wool 10 g	31773-03	1
34	Nessler's reagent 100 ml	30171-10	1
35	Water, distilled 5 l	31246-81	1
36	Bead catalyst, 50g	31763-03	1

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Setup and procedure

Setup (1/2)

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Experimental setup

Set the apparatus up under a powerful exhaust hood as shown in the illustration.

Put up the support base with two rods

Fix clamps on the rods as shown in the picture.

Fix the three gas wasching bottle with the clamps.

Connect the two wasching bottles (left side) with tube and a 3-way stopcock.

Connect the 3-way stoppcock and the other wasching bottel with a combustion tube and connection tube.

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Setup (2/2)

Experimental setup

Fill the two gas wash bottle (left side of the picture) and the wash bottle up to one third with distilled water to which Nessler's reagent was added.

Push a strip of catalyst beads of approximately 2 to 3 cm into the middle of the quartz glass combustion tube.

Secure it with two quartz glass wool balls.

Use a piece of rubber tubing to connect the steel cylinders (pressure reducing valves) with hydrogen and nitrogen to the gas wash bottle with hose connectors.

The two gas wash bottles are connected to the hydrogen and nitrogen.

Procedure (2/2)

Experimental setup

Reduce the nitrogen flow and let approximately three times the amount of hydrogen flow through the apparatus. Estimate this amount based on the bubbles in the test tubes with hose connectors.

The gas mixture that leaves the wash bottled at the other end is tested by way of an oxyhydrogen test. Only if this test is negative can the catalyst beads in the reaction tube be heated with the burner.

When a change of colour can be observed in the initial wash bottle, stop the experiment.

To do so, extinguish the burner and interrupt the hydrogen supply. Let nitrogen continue to flow until the reaction tube has cooled down.

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Evaluation

Evaluation (1/3)

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After approximately 5 minutes of the experiment, a change of colour can be observed in the wash bottle at the end of the apparatus.

In the test tube with hose connectors, through which nitrogen or hydrogen flows, no colour can be observed.

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Evaluation (2/3)

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Complete the following reactions!

$N_2 + 3$ ______ $->$ ______

$2K_2[HgI_4] +$ ______ + ______ $->$ ______ $+ 2H_2O + 7KI$

- $2NH_3$
- NH_3
- H_2
- $[Hg_2N]I \cdot H_2O$
- $3KOH$

Überprüfen

Evaluation (3/3)

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In the reaction tube,

- nitrogen reacts with oxygen
- nitrogen reacts with hydrogen

Check

The resulting ammonia

- reacts with hydrogen
- reacts with Nessler's reagent.

Check

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Slide	Score / Total
Slide 14: Reaction scheme	0/5
Slide 15: Multiple tasks	0/2

Total Score 0/7

Show solutions

Retry

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