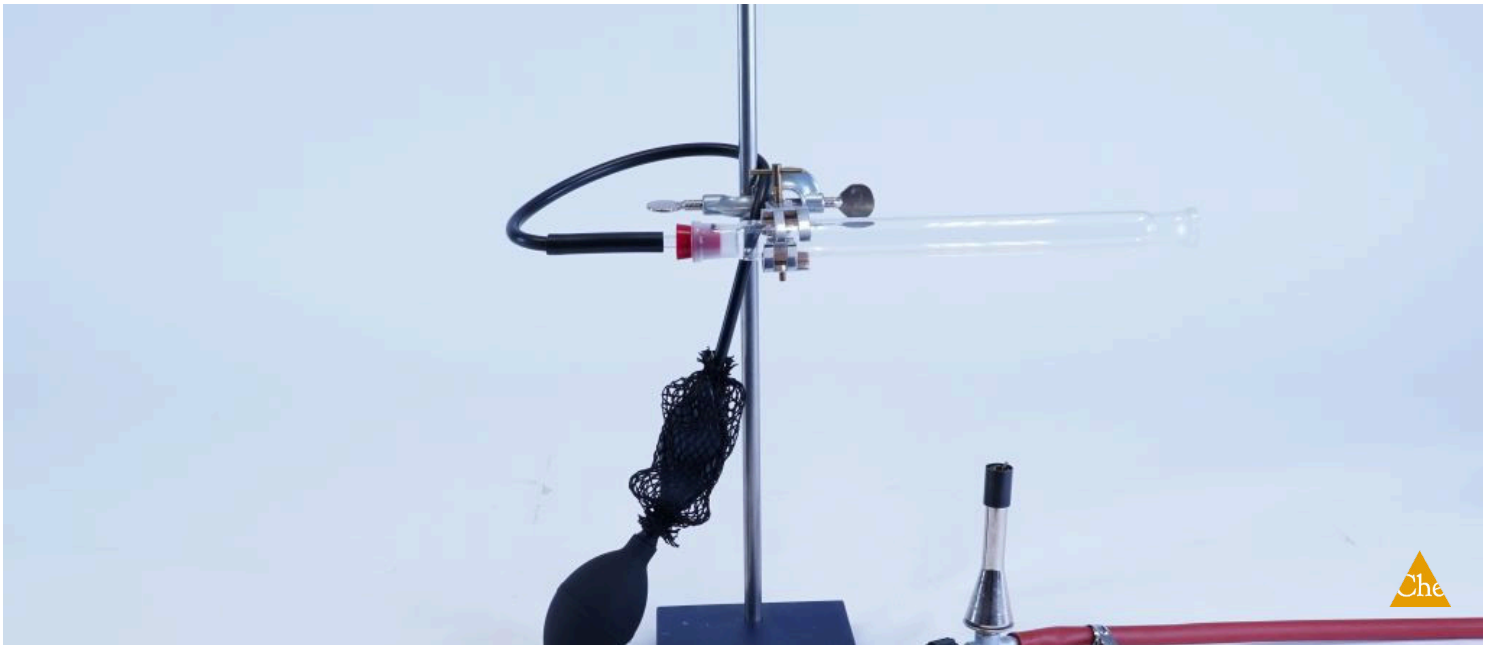
# Binding of nitrogen by base metals



In this experiment, students realize that nitrogen can react not only with very base metals (alkali metals), but also with base metals such as magnesium or calcium.

Chemistry > Inorganic chemistry > Chemistry of metals

| Difficulty level | Group size | Preparation time | Execution time |
|---|---|---|---|
| medium | 1 | 10 minutes | 20 minutes |

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# General information

## Application

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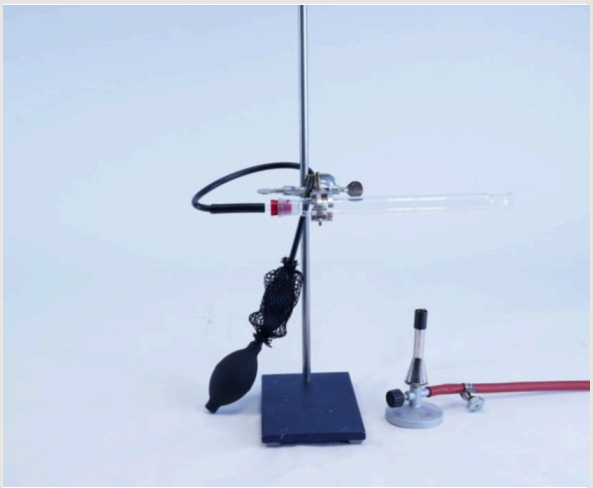

Test setup

In this experiment, the reactivity of nitrogen with various metals is to be investigated. Nitrogen as a typical non-metal should react with (base) metals to form the corresponding salt in the form of an exothermic reaction.

Nevertheless, metals hardly react with nitrogen. At room temperature, for example, nitrogen reacts only with very base metals (alkali metals such as lithium) to form the corresponding nitrides.



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## Other information (1/2)

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**Prior**

Students should have already covered electron pair bonds and polar or nonpolar atomic bonds in class.

**Principle**

It is possible for nitrogen to react with base metals (e.g. calcium or magnesium). However, a corresponding activation energy is required for this.

## Other information (2/2)

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**Learning**

In this experiment, students realize that nitrogen can react not only with very base metals (alkali metals), but also with base metals such as magnesium or calcium.

**Tasks**

The students react the metals magnesium and calcium with nitrogen (from air). To do this, the corresponding metal is heated in a quartz tube and air is pumped through.



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## Safety instructions

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- Wear gloves and protective goggles!
- Concentrated acids (such as hydrochloric acid) are highly corrosive. They destroy skin and textiles. Therefore, protective goggles, protective gowns and gloves must also be worn when experimenting with concentrated acids. When diluting, first prepare the water, then add the acid.
- Do not store calcium and magnesium near open flames.
- 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.

## Theory

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Nitrogen compounds (nitrides, nitrites and nitrates) are of particular importance to man and nature; nitrates are used as fertilizers, for example. However, nitrogen compounds are also needed for the production of important, everyday products such as plastics and dyes.

Pure nitrogen as a starting material for the preparation of nitrogen bonds is unsuitable due to the inertness of the nitrogen molecule. Industrially, ammonia is usually used as a starting material.

However, pure nitrogen can be reacted (under suitable experimental conditions) with very base metals (alkali metals). If a sufficiently high activation energy is available, metals such as magnesium or calcium can also be made to react with nitrogen. This will be investigated in this experiment.



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## Equipment

| Position | Equipment | Item no. | Quantity |
|---|---|---|---|
| 1 | Bunsen stand, 210 x 130 mm, h = 750 mm | 37694-00 | 1 |
| 2 | Double socket, cross clamp | 37697-00 | 1 |
| 3 | Tripod clamp, span 80 mm with set screw | 37715-01 | 1 |
| 4 | Test tube, d = 16 mm, l = 160 mm, 100 pieces | 37656-10 | 1 |
| 5 | Test tube rack, 12 holes, d = 22 mm, wood, 6 draining rods | 37686-10 | 1 |
| 6 | Combustion tube, quartz glass, l = 300 mm, NS 19 | 33948-01 | 1 |
| 7 | Rubber plug 17/22, bore 7 mm | 39255-01 | 1 |
| 8 | Glass tubes, d = 8 mm, l = 80 mm, 10 pieces | 36701-65 | 1 |
| 9 | Rubber blower - double blower- | 39287-00 | 1 |
| 10 | Hos cla b = mm | | |



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# Structure and implementation

## Set-up

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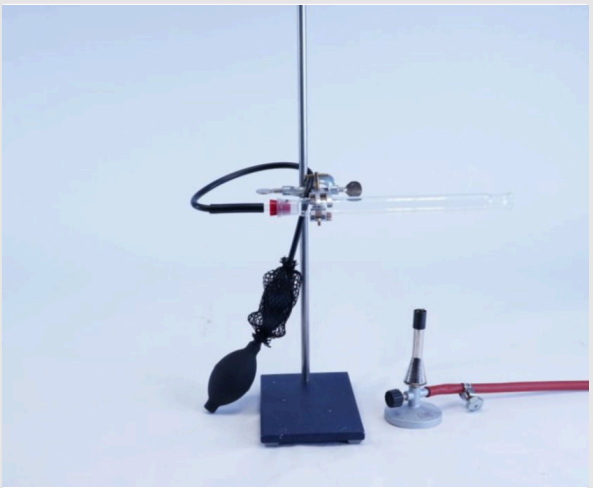
- The apparatus needed to perform the experiment is assembled according to the illustration on the right. By clicking the blue button in the lower right corner you will get a schematic drawing of the experimental setup.
- A porcelain boat filled with magnesium powder or calcium (about one spoonful each) is inserted between two quartz wool balls in the quartz glass combustion tube.



Test setup



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# Procedure (1/3)

**Experiment 1: Reaction of magnesium with air (1/2)**

- After the experimental apparatus is set up and filled with magnesium powder (in a porcelain boat), the quartz tube is heated strongly with a gas burner and at the same time air is pumped through the combustion tube.
- For this purpose, the blower hose is constricted with a hose clamp to such an extent that a uniform air flow, which is not too strong, flows through the apparatus.
- After the reaction has started, the burner is removed and the air is allowed to flow through the quartz tube until the end of the reaction.
- As soon as the quartz tube has cooled down, the porcelain boat is removed from the quartz tube. In addition to a predominantly white mass, areas can also be seen in the reaction product which have a gray (in some cases also greenish-yellow) coloration.

# Procedure (2/3)

**Experiment 1: Reaction of magnesium with air (2/2)**

- Of this reaction product (with the gray or greenish-yellow coloration), place a portion in a test tube and add a few milliliters of water.
- Now fill a second test tube with a quarter of concentrated hydrochloric acid and hold the opening of the test tube diagonally over the opening of the test tube with the colored substance (goal: reaction product (ammonia) is to be mixed with hydrochloric acid vapors).
- Then hold a moistened piece of universal indicator paper over the opening of the test tube (do not touch the test tube walls).



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## Procedure (3/3)

**Experiment 2: Reaction of calcium with air**

- After the experimental apparatus from test part 1 has cooled down, a porcelain boat is filled with calcium and pushed into the experimental apparatus or quartz tube.
- Now quartz tube is strongly heated with a gas burner and at the same time air is pumped through the combustion tube. For this purpose, the hose of the blower is constricted with a hose clamp to such an extent that a uniform air flow, which is not too strong, flows through the apparatus.
- Analogous to experiment part 1, the reaction product is also examined further here. The reaction product in this experiment is also a predominantly white mass, which also has dark (partly brown-yellowish) areas. Part of the dark-colored substance is transferred to a test tube and, as in the first part of the experiment, water is added and then the resulting gaseous reaction product is reacted with hydrochloric acid vapors. The gaseous reaction product is tested with a moistened indicator paper.


# Evaluation



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# Evaluation (1/7)

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**Observation**

Magnesium and calcium do not react (to the naked eye) in air. But after the activation energy is supplied (by heating), both magnesium and calcium ignite in the air stream. The two elements thereby burn with a bright, glistening flame.

Several substances can be distinguished in the product mixture. The main component of the mixture is a white solid (the oxide), and colored substances (the nitride) can also be detected in the reaction mixture.

If the dark-colored substances of the reaction products are dissolved in water, a reaction starts, some of which is violent, in which a gas is formed that forms a white mist with the hydrochloric acid vapors. The indicator paper shows an alkaline reaction on contact with the mist.

# Evaluation (2/7)

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**Evaluation**

Both magnesium and calcium react with air (main components of air: nitrogen and oxygen) in an exothermic reaction after overcoming the activation energy.

The possible reaction products from this are shown in the equations on the right:

$ {Mg}+{2O}_2 \ \longrightarrow \ {2MgO}$ ${\Delta} H=-602.1 kJ/mol$

$ {3Mg}+{2N}_2 \longrightarrow \Mg}_3{N}_2$ ${\Delta} H=-461.6 kJ/mol$

${\Delta} H=-635.6 kJ/mol$

$ {2Ca}+{2O}_2 \longrightarrow {2CaO}$ ${\Delta} H=-632.1 kJ/mol$

$ {3Ca}+{2N}_2 \longrightarrow \Ca}_3{N}_2$



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# Evaluation (3/7)

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**Evaluation**

From the energy balances of the individual reactions it can be seen that both metals react primarily with oxygen (from the air) to form the corresponding oxides.

If oxygen is not supplied quickly enough for the reaction process, a reaction of the metal with nitrogen can also take place. The inert nitrogen molecule is excited by the released heat of reaction (caused by the formation of the oxide) to such an extent that the reaction or formation of the nitride is made possible.

The nitrides formed react with water to form the corresponding hydroxides and ammonia, which forms a mist of ammonium chloride with hydrochloric acid vapors. Ammonia vapors show a basic reaction with the moistened universal indicator paper.

# Evaluation (4/7)

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**Evaluation**

These reactions proceed according to the following equations:

$ {Ca}_3{N}_2+{6H}_2{O} \ {Ca(OH)}_2+{2NH}_3$

$ {Mg}_3{N}_2+{H}_2{O} $ {Mg(OH)}_2+{2NH}_3$

$ {NH}_3+{HCL} \ {NH}_4{Cl}$



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## Evaluation (5/7)

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Can you tell with the naked eye if multiple products have formed in the reaction?

- ○ No, only with the microscope different products can be identified.
- ○ Yes. The main component of the mixture is a red solid (iron oxide). In addition, colored substances (the magnesium) can also be seen in the reaction mixture.
- ○ Yes. The main component of the mixture is a white solid (oxide). In addition, colored substances (the nitride) can also be seen in the reaction mixture.

Check

## Evaluation (6/7)

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Drag the words into the correct boxes!

Magnesium and calcium do _____ react (to the naked eye) in air. But after the _____ is supplied (by heating), both magnesium and calcium ignite in the air stream. The two elements thereby burn with a _____, glistening flame. If the dark-colored substances of the reaction products are dissolved in water, a sometimes violent _____ starts, forming a gas that forms a white mist with the hydrochloric acid vapors.

reaction | activation energy | bright | not

Check



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# Evaluation (7/7)

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Can we conclude from the energy balances of the individual reactions why primarily the metal reacts with oxygen to form the corresponding oxide?

- ○ Yes, because the energy balances from the reactions with oxygen are significantly higher than those that reacted with nitrogen.
- ○ No, because the energy balances are the same for the reaction with oxygen and nitrogen.
- ○ Yes, because the energy balances from the reactions with oxygen are significantly lower than those that reacted with nitrogen.

Check

| Slide | Score / Total |
|---|---|
| Slide 18: Reaction products | 0/1 |
| Slide 19: Observation | 0/4 |
| Slide 20: Energy balances | 0/1 |

**Total** 0/6

Solutions Repeat



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