Determination of the oxygen content of air

Aims of the experiment

- To determine the oxygen content of air by chemical means
- To allow magnesium to react with oxygen
- To learn about gases as reaction partners
- To identify the main components of air

Principles

Air consists for the most part of oxygen and nitrogen, which can mix with each other in any ratio of volumes. The gases are present as molecules containing two atoms of oxygen and two atoms of nitrogen, respectively. Chemically, the molecules are distinctly different. In the nitrogen molecule, the two atoms are linked via a triple bond. All electrons are present as electron pairs. In contrast, the two oxygen atoms are formally connected via a double bond. Nevertheless, the energetically most favourable state is achieved when it contains two unpaired electrons. Because of these unpaired electrons, oxygen is much more reactive than nitrogen.

Oxygen has an oxidising effect on many substances. The term "oxidation" is also derived from such reactions with oxygen. However, the reaction proceeds very slowly at room temperature. With around 20 % oxygen in the atmosphere, this is also necessary, as otherwise substances would immediately oxidise. But this also implies that substances on the earth, meaning materials and living organisms, are able to deal with this reactive oxygen atmosphere.

Oxygen and nitrogen can therefore be readily distinguished chemically. In this way, therefore, the oxygen content of air can be readily determined. To achieve this, oxygen from a defined volume of air is made to react. This cannot succeed at room temperature, but succeeds quickly in a heated reaction chamber. In most cases, nitrogen will not react at the same time.

Copper is used in this experiment, which reacts with oxygen in an oxidation reaction to form black copper oxide.

$$2\ Cu + O_2 \rightleftharpoons 2\ CuO$$

A roll of copper wire gauze will be used in this experiment, which has a large surface area over which the air can flow. It is carefully heated to a glow, so that the reaction proceeds quickly.

After cooling, the volume of the air has been reduced by the amount of oxygen it contained. The remainder of the air is passed over a candle. This will extinguish (be choked) immediately, as the residual constituents consist for the most part of nitrogen.

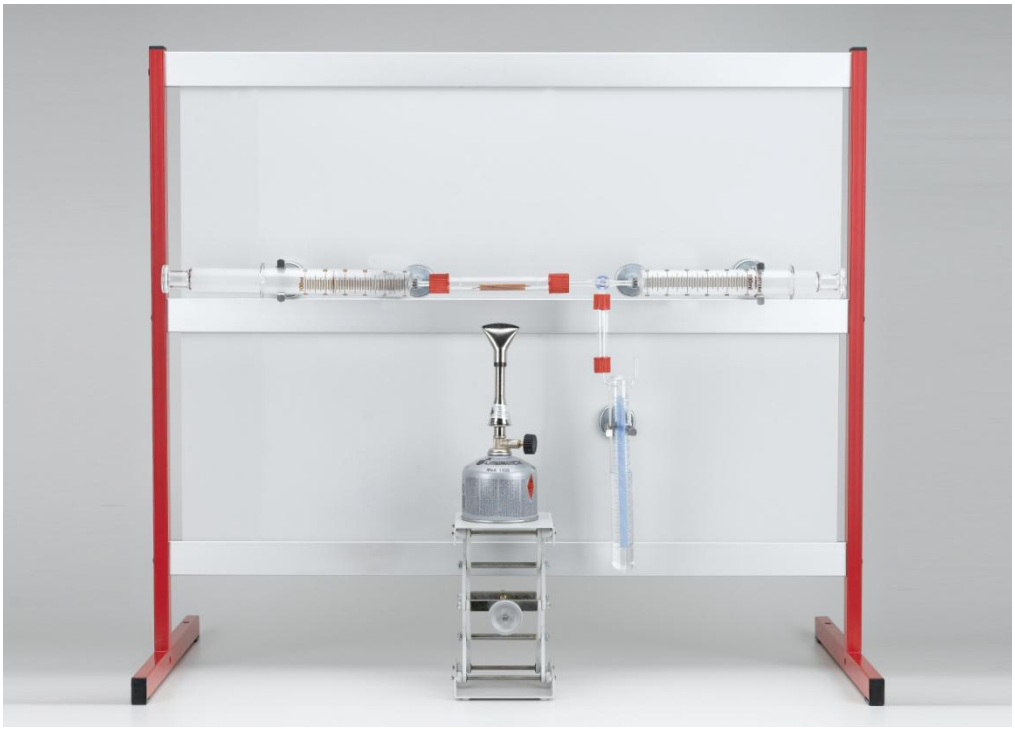

Fig. 1: Set-up of the experiment.

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Risk assessment

Be careful when using the burner! Tie long hair back!

In case of glass breakage: Risk of injury!

The temperature is controlled in the experiment such that the copper wire gauze does not melt.

The air should be passed through slowly without strong pressure. If the pressure is strong, the wall of the reaction tube could blow out.

Equipment and chemicals

1 Reaction tube, quartz, GL 18 .....664 0771
1 Copper wire gauze roll 80 x 7.5 mm diam.....664 079
1 Gas syringe 100 mL.....665 912
1 Gas syringe, 100 mL with three-way stopcock665 914
1 Schiele immersion tube manometer.....665 936
1 Cartridge burner, DIN type.....666 714
1 Wide-flame attachment.....666724
1 Laborboy II (laboratory jack-stand) 300 76
6 Adhesive magnetic board 300 mm.....666 4660
2 Holder, magnetic, size 1, 9...11 mm.....666 4661
3 Holder, magnetic, size 5, 30...32 mm.....666 4665
1 Panel frame C100, two-level, for CPS 666 428
1 Glass connector, 2 x GL 18 .....667 312
Also required:
Candle, lighter

Set-up and preparation of the experiment

Place six adhesive magnetic boards into the panel frame. Fix the gas syringe onto it with a small magnetic holder on the nozzle and a large magnetic holder on the body. Place the copper wire gauze roll into the reaction tube. Place the reaction tube between both gas syringes and fix firmly and airtight with the GL fittings (see Fig. 1). The seals might need to be replaced for this. Fill the immersion tube manometer half way with water and place it so that it can be easily connected with a glass connector to that of the apparatus.

Place the burner onto the laboratory jack-stand and locate it beneath the reaction tube.

Performing the experiment

With the three-way stopcock open, set the right gas syringe to the zero position and via this fill the left one with 100 ml of air. Set the three-way stopcock so that both gas syringes are connected to each other, but the system is closed off to the outside. In order to check whether the system is airtight, first push the entire amount of gas into the right gas syringe and then move it back and forth. The air volume should not change during this.

Note: Gas syringes have the best seal if pistons and bodies which belong together are used. It can therefore be helpful to mark these.

You can now start to heat the copper wire gauze roll. To do this, heat the copper using a luminous flame until it glows red.

Caution! Do not set the burner too high, as the quartz glass can otherwise melt and the apparatus will leak!

Pass air over the glowing copper until the volume is constant again. It increases initially due to the heat, but then decreases quickly.

Turn off the burner and wait until the apparatus has cooled down.

Check using the immersion tube manometer whether the internal pressure is equal to the surrounding pressure. Regulate the level if necessary using the gas syringes. For this, open the three-way stopcock fully in all directions. Read off the new volume.

Check the residual gas in the gas syringe for its chemical properties. To do this, light a candle and slowly blow out the gas from the right gas syringe onto the flame.

Observation

On heating the copper wire gauze roll it initially starts to glow. After a while a black colouration can be seen in addition.

The volume in the apparatus increases at the start, before it falls from 100 mL to around 76 mL.

The residual gas in the apparatus does not burn and extinguishes a burning candle. It therefore cannot support combustion.

Evaluation and result

The black colouration of the copper wire gauze is due to the formation of copper oxide.

$$2\ Cu + O_2 \rightleftharpoons 2\ CuO$$

Oxygen is completely removed from the gas chamber through this reaction. Mainly nitrogen is left over then. The volume reduces by around 24 mL. The oxygen content in air is therefore about 24 %. The complete composition of dry air is shown in Table 1.

Tab. 1: Composition of dry air.

Gas	Percent volume
Nitrogen	78 %
Oxygen	21 %
Inert gases, mainly argon	0. 93 %
Carbon dioxide	0.037 %

The residual gas in the gas syringe does not burn and extinguishes the flame of a candle. The name of the gas, nitrogen, is derived from this "extinguishing" property.

Cleaning and disposal

The blackened copper wire gauze can be reduced again to copper. To do this, remove the wire gauze roll from the combustion tube and hold in the burner flame with crucible tongs. While it is still hot, immerse it in a test tube containing about 1 to 2 mL of 2-propanol.

Caution! Fix the test tube in a test tube rack located at a suitable distance away from the burner. Risk of burning!

2-propanol is then oxidised to acetone in the test tube and the copper oxide reduced to copper. Allow the red copper wire gauze role to dry. It can be used again for this experiment. Dispose of the mixture of 2-propanol and acetone in a container for water-miscible organic solvents.