Determination of the density of gases

Aims of the experiment

- How to handle gases
- How to weigh gases
- How to determine the density of gases

Principles

Gases have no physical form and will entirely fill any vessel they are placed into. They can be easily moved. Without gases we would not be able to hear, balloons and aeroplanes would not be able to fly, we would have no weather and humans and animals would have nothing to breathe. Gases make possible the transport of energy in wind turbines and rocket propulsion, and spray cans would not work without them. They protect food from spoiling, provide safety for welding and prevent the chemical decomposition of base metals. Gases are coolants and are responsible for stormy weather. They play an important role in combustion and in reactions from lighting strikes. Gases can be ionised and in a fog chamber can be used to detect radioactive radiation.

In this experiment, the density of gases is to be determined. Density is a value that is determined by the material of a body and is independent of its shape and size. Density is defined as the quotient of mass and volume.

$$\text{density } \rho = \frac{\text{mass } m}{\text{volume } V}$$

Density in the case of solids and liquids is usually expressed in the units g/cm^3, in the case of gases in g/l.

Density is dependent on temperature. Substances expand with increasing temperature. The volume thus increases and the density becomes smaller. With a constant mass, a higher volume automatically means a lower density. However in the case of gases, the density depends not only on the temperature, but also on the pressure. In tables one usually finds values for 20 °C and normal atmospheric pressure of 1013 hPa. In this experiment, the density of oxygen and nitrogen will be determined under these normal conditions.

Risk assessment

No hazardous chemicals will be used in this experiment. The gases used are contained in pressurised containers which can explode on heating.

Take care when using the glass stopcocks on the sphere. Breakage hazard! Lubricate the stopcocks well!

Oxygen	
Signal word: **Hazard**	**Hazard statements** H270 May cause or intensify fire; oxidizer H280 Contains gas under pressure; may explode if heated. **Precautionary statements** P244 Keep valves and equipment parts free from oil and grease P220 Keep/store away from clothing/…/combustible materials
Nitrogen	
Signal word: **Caution**	**Hazard statements** H280 Contains gas under pressure; may explode if heated. **Precautionary statements** P403 Store in a well ventilated place.

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Equipment and chemicals

1 Sphere with 2 stopcocks (gas weighing bulb) 379 07
1 Electronic precision balance OHSPU123
1 Support ring for 250 ml round flask, cork 667 072
1 Manual vacuum pump...................................375 58
1 Gas syringe...665 913
1 Silicone tubing 4 mm diam., 1 m....................667 197
1 Silicone tubing 8 mm diam., 1 m....................604 434
2 Tube connector, 4 x 15 mm 604 510
1 Vacuum rubber tubing 8 mm diam. 667 186
1 Vacuum rubber tubing 6 mm diam. 604 491
1 Minican gas can, oxygen 660 998
1 Minican gas can, nitrogen 661 000
2 Fine regulating valve for Minican gas cans 660 980
1 Stopcock grease 661 082

Setup and preparation of the experiment

Preparation

1. Lubricate the stopcocks of the sphere and the gas syringe with stopcock grease.

2. Close all doors and windows as far as possible during the experiment, so that there is little air movement in the room.

3. Screw the fine regulating valve onto the Minican can. (Caution: close the main gas valve before connecting the regulating valve!)

4. Cut the silicone tubes to the appropriate lengths. Three pieces of tube are needed.

5. The tube connection from the Minican gas can to the gas syringe should be long enough to allow the gas syringe to be laid comfortably on the worktop. The narrower piece of tubing connects the Minican gas can to the tube connector. The wider tube is connected from there to the gas syringe. The tube from the sphere to the gas syringe should be as short as possible.

Performing the experiment

1. Lay the sphere on the cork ring. Open the stopcocks of the sphere and connect the manual vacuum pump to the second stopcock. Draw air through the sphere to flush it out.

2. Close one stopcock of the sphere and pump some air out using the manual vacuum pump (down to c. 200 mbar).

3. Close the second stopcock and remove the manual vacuum pump with the piece of tubing.

4. Lay the cork ring on the balance and tare the balance. Lay the sphere onto the cork ring on the balance, weigh the sphere and note the weight. Remove the sphere with the cork ring from the balance.

5. Connect the gas syringe to the Minican gas can via the tubing piece.

6. Open the stopcock of the gas syringe and allow gas from the Minican gas can to flow in (c. 100 ml). Close the valve of the Minican gas can and remove the gas syringe. Press out the contents of the gas syringe using the syringe piston. Repeat this flushing of the gas syringe with the gas under investigation.

7. Remove exactly 100 ml of gas for the measurement. Close the stopcock of the gas syringe. Quickly connect the gas syringe to the sphere.

8. Open the stopcock of the sphere, open the stopcock of the gas syringe. The gas from the gas syringe will flow into the sphere (press out any residual amount of gas from the gas syringe into the sphere using the piston).

9. Close the stopcock of the sphere and remove the connection tubing. Lay the sphere onto the balance and weight it, note the value.

10. Repeat the experiment three to four times.

The experiment can be conducted using oxygen and/or nitrogen gas. Repeat the experiment several times to improve the accuracy of measurement.

Result of the experiment

Density of oxygen

Weight difference of the sphere:

Sphere (e) (e = empty): air has been aspirated out of the sphere.

Sphere (f) (f = full): 100 ml of oxygen has been pumped into the sphere

	Mass *m* [g]
Sphere (e)	294.524
Sphere (f)	294.651
Difference	000.127

According to the formula:

$$\rho = \frac{m}{V}$$

The following applies to the example oxygen:

$$\rho = \frac{0.127\,g}{100\,ml}$$

$$\rho = 1.27\,\frac{g}{l}$$

In tables one will find 1.33 g/l for the density of oxygen at 20 °C and an atmospheric pressure of 1013 hPa.

Density of nitrogen

The calculation is made analogously to that for oxygen.

	Mass *m* [g]
Sphere (e)	294.534
Sphere (f)	294.650
Difference	000.116

The following applies to the example nitrogen:

$$\rho = \frac{0.116\,g}{100\,ml}$$

$$\rho = 1.16\,\frac{g}{l}$$

In tables one will find 1.17 g/l for the density of nitrogen at 20 °C and an atmospheric pressure of 1013 hPa.

Density of hydrogen gas

With the following additional equipment, the density of hydrogen can also be measured:

1	HydroStik PRO	666 4795
1	Regulating valve	666 4797
1	HydroFill PRO	666 4798

Density of hydrogen gas:

	Mass *m* [g]
Sphere (e)	287.627
Sphere (f)	287.634
Difference	000.007

The following applies to the example hydrogen:

$$\rho = \frac{0.007\,g}{100\,ml}$$

$$\rho = 0.007\,\frac{g}{l}$$

In tables one will find 0.084 g/l for the density of hydrogen at 20 °C and an atmospheric pressure of 1013 hPa.

As the density of hydrogen is so low, it can only be expressed here as an order of magnitude. The weight difference between the bulb with and without gas is insufficient to improve on this.

Cleaning and disposal

Open the stopcocks of the sphere and allow air to enter. In the case of the gas syringe, draw air through several times.

If the sphere is not to be used again for a long time, degrease the stopcocks with petroleum ether or benzine and replace them with a piece of paper inserted as a separator.

The fine regulating valve is not completely airtight. Therefore unscrew it for storage.