Determination of the molecular mass of gases

Aims of the experiment

- To show that gases also have a weight
- To determine the molecular mass of gases
- To learn about the molar volume

Principles

Gases always react with each other in simple integer volume ratios, a fact that does not apply to solids and liquids.

As early as 1811, the Italian scientist Avogadro formulated a hypothesis which finally led to clarification of these volume ratios. Due to the universal validity of this hypothesis, this is referred to today as Avogadro's Law.

At the same volume, pressure and temperature, gaseous substances contain an equal number of particles. Resulting from Avogadro's Law, two litres of hydrogen contain exactly twice as many particles as a litre of oxygen.

Chemists recognised the fact that the volume ratio corresponds to the numerical ratio of atoms in the product. Water is the product of hydrogen and oxygen in the ratio 2:1, the empirical formula is H_2O.

According to Avogadro's Law, the amount N = 1 mol of a substance has the same volume for all gases at the same temperature and the same pressure. The molar volume V_m of all gases is therefore constant under the same conditions. The molar volume is the quotient of the volume and the mass in moles of a substance:

$$V_m = \frac{V}{n}, \text{ unit: } \frac{l}{mol}$$

At 20 °C and 1013 hPa the molar volume of all gases is $V_m = 22.4 \frac{l}{mol}$. Gases expand with increasing temperature. Therefore, the molar volume increases with increasing temperature.

In this experiment, the molar mass of oxygen and nitrogen will be determined.

Risk assessment

No hazardous chemicals will be used in this experiment. The gases used are contained in pressurised containers which may explode if heated.

Be careful when using the glass taps on the gas weighing bulb. Breakage hazard! Lubricate the taps 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 stop-cocks, glass	379 07
1	Electronic precision balance	OHSPU123
1	Support ring for 250 mL round-bottom flask	667 072
1	Hand 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 4342
2	Connector, straight 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 pressurised gas can, oxygen	660 998
1	Minican pressurised gas can, nitrogen	661 000
2	Fine regulating valve for Minican cans	660 980
1	Stopcock grease	661 082

Set-up and preparation of the experiment

Note regarding the apparatus

A water-jet pump (375 56) can also be used instead of the manual vacuum pump.

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 regulator valve onto the Minican canister. Caution: Close the main gas valve before connecting the regulator!

4. Cut the silicone tubings to the appropriate lengths. Three pieces of tubing are needed.

5. The tubing connection from the Minican pressurised 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 pressurised gas can to the tubing connector. From there the wider tubing is connected to the gas syringe. The tubing 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 pressurised gas can via the tubing piece.

6. Open the stopcock of the gas syringe and allow gas from the Minican pressurised gas can to flow in (c. 100 mL). Close the valve of the Minican pressurised 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 using 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. 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 gas from the gas syringe into the sphere using the piston).

8. Close the stopcock of the sphere and remove the connecting tubing. Lay the sphere onto the balance and weigh it; note the value.

9. Repeat the experiment three to four times.

Conduct the experiment using oxygen and/or nitrogen gas.

Result of the experiment

Molar mass of the gas oxygen

The molar mass of the gas is determined by the weight difference of the sphere. The empty sphere (e) is compared with the full sphere (f). 100 mL of gas are present in the full sphere (here: oxygen).

	Mass *m* [g]
Sphere (e)	257.41
Sphere (f)	257.55
Difference	0.14

100 mL (= 0.1 L) of gas were weighed at room temperature and under normal pressure. Thus, the litre mass is easily calculated. For obtaining the value for the molar mass, the litre mass is multiplied by 22.4 L/mol.

The following applies to the example oxygen:

Litre mass: (0.14 x 0.1 L) x 1 L = 1.40 g/L

Molar mass: 1.40 g/L x 22.4 L/mol = 31.36 g/mol

Molar mass of the gas nitrogen

	Mass *m* [g]
Sphere (e)	257.38
Sphere (f)	257.50
Difference	0.12

The following applies to the example nitrogen:

Litre mass: (0.12 g/0.1 L) x 1 L = 1.20 g/L

Molar mass: 1.32 g/L x 22.4 L/mol = 27.33 g/mol

The molar mass of oxygen is 32 g/mol, and of nitrogen 28 g/mol.

Gases which are lighter than air are not suitable for this experiment as the display of the balance would have to be laboriously corrected for uplift. This is shown with the gases used, as the values here are always somewhat lower than the expected values. Hydrogen is not suitable for this experiment for these reasons.

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.