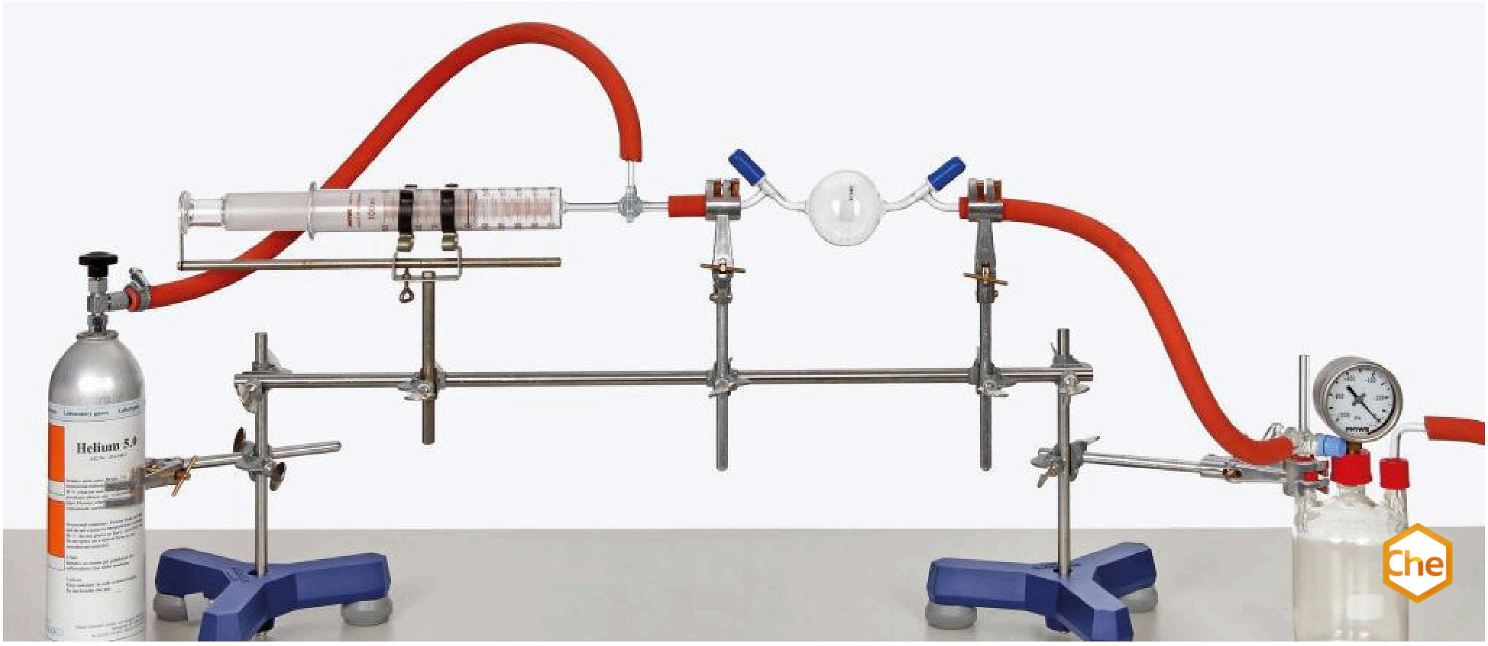
# Determination of molar mass using the ideal gas law




Students will be able to determine the molar mass by using the ideal gas law.

Chemistry > General Chemistry > Stoichiometry

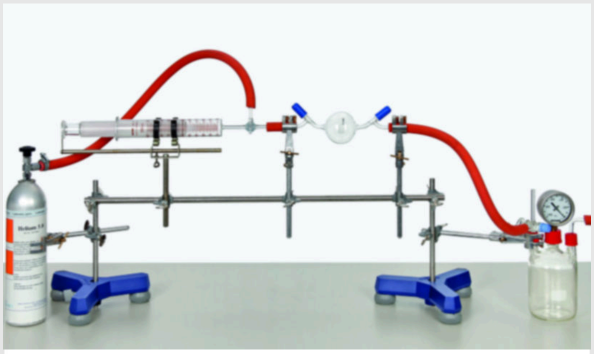
| Difficulty level | Group size | Preparation time | Execution time |
|---|---|---|---|
| medium | 2 | 10 minutes | 20 minutes |

This content can also be found online at:

http://localhost:1337/c/60b2250d6b5a0f00039aff55

# General information

## Application



Experimental set-up

In this experiment, the students will learn the determination of molar mass using the ideal gas law. They will determine the molar masses of the gases helium, nitrogen, carbon dioxide and methane.

The ideal gas law describes the state of the gas in terms of pressure, volume, temperature and amount of substance (or number of particles or mass).



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## Other information (1/2)

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**Prior knowledge**

Students should be familiar with molar and relative molar mass, properties of gases, ideal and ordinary gases and equations of state.

**Scientific principle**

By using the ideal gas law it is possible to determine the molar mass.

$$M = \frac{m \cdot R \cdot T}{p \cdot V}$$

## Other information (2/2)

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**Learning objective**

Students will be able to determine the molar mass by using the ideal gas law.

**Tasks**

The students will determine the molar masses of the gases helium, nitrogen, carbon dioxide and methane.



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## Safety instructions

- When handling chemicals, you should wear suitable protective gloves, safety goggles, and suitable clothing.
- For this experiment the general instructions for safe experimentation in science lessons apply.

## Theory

All gases may be considered, to a first approximation, to obey the ideal gas equation which relates the pressure p, volume V, temperature T and amount of substance n of a gas.

The amount of gas n is expressed as the number of moles and is equal to m/M where m is the mass of gas present and is the mass of one mole of the gas.

The volume occupied by a known mass of gas is to be measured at a given temperature and pressure, so that the ideal gas equation can be used to estimate the molar mass of the gas.



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# Equipment

| Position | Material | Item No. | Quantity |
|---|---|---|---|
| 1 | Tripod base PHYWE | 02002-55 | 2 |
| 2 | Support rod, stainless steel, l = 250 mm, d = 10 mm | 02031-00 | 2 |
| 3 | Support rod, stainless steel, 750 mm | 02033-00 | 1 |
| 4 | Universal clamp | 37715-01 | 4 |
| 5 | Right angle boss-head clamp | 37697-00 | 7 |
| 6 | Gas-syringe holder with stop | 02058-00 | 1 |
| 7 | Gas syringe, 100 ml, with 3-way cock | 02617-00 | 1 |
| 8 | Glass sphere, 2 stopcocks, 100 ml | 36810-00 | 1 |
| 9 | Secure bottle, 500 ml, 2 x Gl 18/8, 1 x 25/12 | 34170-01 | 1 |
| 10 | Spring manometer, 0...-1000 mbar | 34170-02 | 1 |
| 11 | Glass tubes, right-angled, 10 | 36701-57 | 1 |
| 12 | Stopcock,3-way,t-shaped, glass | 36731-00 | 1 |
| 13 | Rotary valve vacuum pump, two stages, 115 V / 230 V | 02741-95 | 1 |
| 14 | Adapter for vacuum pump | 02657-00 | 1 |
| 15 | Rubber tubing,vacuum,i.d.6mm | 39286-00 | 3 |
| 16 | Rubber tubing,vacuum,i.d.8mm | 39288-00 | 1 |
| 17 | Hose clip, diam. 8-16 mm, 1 pc. | 40996-02 | 4 |
| 18 | Hose clip f.12-20 diameter tube | 40995-00 | 2 |
| 19 | Weather monitor, 6 lines LCD | 87997-10 | 1 |
| 20 | Silicon grease Molykote, 50 g | 31863-05 | 1 |
| 21 | Fine control valve | 33499-00 | 1 |
| 22 | Compressed gas, nitrogen, 12 l | 41772-04 | 1 |
| 23 | Compressed gas, CO2, 22 g | 41772-06 | 1 |
| 24 | Compressed gas, methane, 12 l | 41772-08 | 1 |
| 25 | Compressed gas, helium, 12 l | 41772-03 | 1 |



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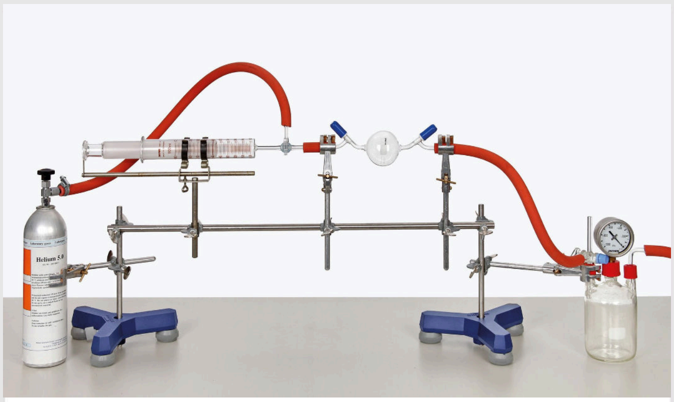
# Setup and procedure

## Setup

- Thoroughly clean and dry the syringe and the glass bulb and lightly grease the three-way stopcock (do not grease the syringe plunger!).
- Assemble the apparatus as shown in Fig. right. Make sure that the plunger stop is positioned to prevent the plunger from being fully removed from the syringe barrel whilst still allowing the syringe to be filled to its maximum volume of 100 ml.
- In the following, S1 is the three-way stopcock on the gas syringe, S2 is the Teflon stopcock between S1 and the glass bulb and S3 is the Teflon stopcock between the glass bulb and the pump.



Experimental set-up



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## Procedure

- To determine the mass of the glass bulb, close S2, open S3 and evacuate the glass bulb by pumping for 10 minutes, close S3, disconnect the bulb from the vacuum line and weigh it.
- Following this, reconnect the bulb to the vacuum line and open S2 and S3.
- Turn S1 to connect both the syringe and the bulb to the gas bottle and evacuate the entire vacuum line for a further 5– 10 minutes.
- Close S2 and S3 and carefully open the needle valve regulator on the gas bottle to fill the syringe with gas.
- Record the volume of gas introduced into the syringe (between 95 ml and 100 ml) to the nearest 0.5 ml. Fill the bulb with gas by turning S1 through 180° and slowly open S2. After closing S2, remove the bulb from the vacuum line and re-weigh it.
- Calculate the mass of the gas in the bulb and record it together with the ambient pressure and temperature. Replace the bulb and repeat the procedure twice before measuring the next gas.

# Evaluation



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## Evaluation (1/6)

### Theory and evaluation

The molecules of a hypothetical perfect gas do not interact (do not attract or repel each other), so the ideal gas equation is obeyed exactly.

$$p \cdot V = n \cdot R \cdot T$$

where $R$ = Gas constant

For ordinary gases (whose particles do interact), equation (1) represents a limiting law. An ordinary gas behaves more and more like an ideal gas as its density is reduced, since at low densities the intermolecular distance is so large that the interactions between the gas molecules become insignificant.

### Theory and evaluation

Even at standard temperature and pressure (T = 298 K, p = 1 bar) many gases obey equation (1) remarkably well and it may be used to determine the molar masses of gases in a simple way. Rearranging equation (1) gives:

$$M = \frac{m \cdot R \cdot T}{p \cdot V}$$

## Evaluation (2/6)

### Data and results

The results of a typical experiment are shown in Table 1 (next slide). Given the simple nature of the determination, the agreement is very satisfactory. However, the student should be aware of possible sources of random and systematic error in this experiment, such as the volume between the end of the syringe barrel and the bulb that is neglected here, the accuracy of the reading of the gas volume in the syringe and fluctuations in the temperature.

The size and relevance of these and other errors should be critically discussed.



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## Evaluation (3/6)

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| Gas | Volume $V$ / ml | Mass $m$ / g | Ambient pressure $p$ / mm Hg | Ambient Temperature $T$ / K | Molar mass $M$ / g · mol$^{-1}$ | |
|---|---|---|---|---|---|---|
| | | | | | Exp. | Lit. |
| He | 98.5 | 0.017 | 746.6 | 294.2 | 4.2 | |
| | 99.0 | 0.018 | 746.6 | 294.2 | 4.5 | |
| | 100.0 | 0.019 | 746.6 | 294.2 | 4.7 | |
| | | | | | mean: 4.5 | 4.00 |
| $N_2$ | 98.5 | 0.115 | 746.6 | 294.2 | 28.7 | |
| | 99.5 | 0.115 | 746.6 | 294.2 | 28.4 | |
| | 99.0 | 0.118 | 746.6 | 294.2 | 29.3 | |
| | | | | | mean: 28.3 | 28.02 |
| $CO_2$ | 99.0 | 0.178 | 746.0 | 294.7 | 44.3 | |
| | 99.0 | 0.175 | 746.0 | 294.7 | 43.5 | |
| | 98.0 | 0.179 | 746.0 | 294.7 | 45.0 | |
| | | | | | mean: 44.3 | 44.01 |
| $CH_4$ | 99.5 | 0.066 | 744.5 | 294.7 | 16.4 | |
| | 100.0 | 0.072 | 744.5 | 294.7 | 17.8 | |
| | 98.0 | 0.069 | 744.5 | 294.7 | 17.7 | |
| | | | | | mean: 17.3 | 16.04 |

## Evaluation (4/6)

PHYWE

What is described by the ideal gas law?

- It is the worldwide law on how a gas must be delivered.
- The packaging unit in which gas is delivered.
- The state of the gas in terms of pressure, volume, temperature and amount of substance (or number of particles or mass).
- None of the answers is correct.

Überprüfen



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## Evaluation (5/6)

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Mark the formula that describes the ideal gas law for a perfect gas.

- ☐ None of the answers is correct.
- ☐ There is no formula that describes the ideal gas law for a perfect gas, because there is no ideal gas law.
- ☐ The formula is $p \cdot V = n \cdot R \cdot T$ .
- ☐ The formula is $M = \frac{m \cdot R \cdot T}{p \cdot V}$ .

Überprüfen

## Evaluation (6/6)

PHYWE

Drag the words into the correct boxes!

All ______ may be considered, to a first approximation, to obey the ideal gas equation which relates the pressure p, volume V, temperature T and amount of substance n of a gas. The amount of gas n is expressed as the ______ and is equal to m/M where m is the mass of gas present and is the mass of one mole of the gas. The ______ occupied by a known mass of gas is to be measured at a given temperature and pressure, so that the ______ can be used to estimate the molar mass of the gas.

- volume
- gases
- number of moles
- ideal gas equation

Überprüfen



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| Slide | Score / Total |
| --- | --- |
| Slide 15: Ideal gas law | 0/1 |
| Slide 16: ideal gas law for a perfect gas | 1/1 |
| Slide 17: Ideal gas equation: Drag Text | 0/4 |

**Total Score** 1 / 6

Show solutions  Retry



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