General and inorganic chemistry

Chemical reactions and stoichiometry
Law of definite proportions

LD Chemistry Leaflets

C1.2.2.1

Synthesis of magnesium oxide

Aims of the experiment

- Carrying out a reaction with the two elements magnesium and oxygen.
- Recognising that substances always react at the same ratio.
- Understanding the law of definite proportions and expansions.
- Becoming familiar with the terms mass ratio, molar mass and stoichiometry.
- Learning how to formulate a chemical equation.

Principles

At the beginning of the 19th century, it hadn't yet been proven that matter is made up of atoms and molecules. However, the first elements such as oxygen, carbon, sulfur and phosphor were defined by Lavoisier as pure elements at the time. A little later, the law of definite proportions was developed, primarily through the oxidation of metals. This law indicates that the elements in a particular compound always exist at the same mass ratio.

In this experiment, this law shall be confirmed by the synthesis of magnesium oxide. For this, the product magnesium oxide is synthesised in a luminous reaction from the elements magnesium and oxygen. Both reactants and the product are weighed out and the consumed oxygen volume is determined. The mass of the integrated oxygen can be determined from this in two different ways. Then the mass ratio of the elements magnesium and oxygen can be determined in magnesium oxide. No matter how much magnesium is used or how much oxygen there is, oxygen is always integrated at a ratio of 1:1.52. However, the law of definite proportions does not only apply to the synthesis of magnesium oxide, but to all reactions, and is thus universally valid.

This is trivial from today's perspective. With these experiments, however, chemistry took the step from alchemy to exact science. The molar concept and stoichiometry were developed based on this law. The actual proportions and the resulting reaction equations could now be established from the quantitative knowledge of reactants and products. The following reaction equation can thus be formulated for the synthesis of magnesium oxide:

$$2\ Mg + O_2 \rightarrow 2\ MgO$$

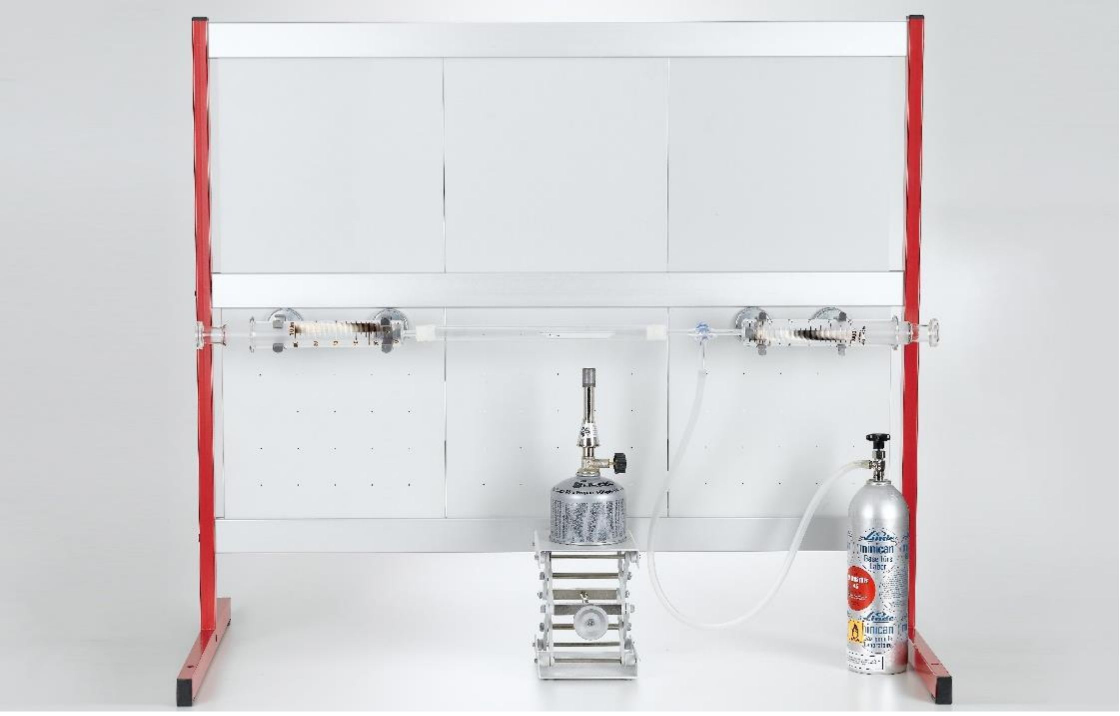

Fig. 1: Experiment apparatus for the synthesis of magnesium oxide.

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Risk assessment

The magnesium burns under a very bright flame. Blinding must be prevented here so that the acceptable levels of exposure, particularly for UV radiation, are not exceeded. The experiment is therefore carried out behind an impermeable screen. For the person conducting the experiment, a pair of stage 5 welding safety goggles is suitable. If you look directly into the flame, your vision may be impaired for several minutes or even hours. As a result, driving can pose a particular risk.

Prepare a bucket of sand in case of fire to extinguish the magnesium if necessary.

Keep the oxygen cylinder away from the ignition source after rinsing the apparatus.

Magnesium, ribbon	
Signal word: Warning	**Hazard statements** H228: Flammable solid. **Precautionary statements** P370+P378: In case of fire: Use metal fire extinguisher / sand for extinguishing.

Oxygen	
Signal word: Danger	**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. P370+P376: In case of fire: Stop leak, if possible to do so safely. P403: Store in a well ventilated area.

Equipment and chemicals

1 Combustion boat, glazed 666 9881
1 Reaction tube, quartz, 300 x 20 mm diam. 664 077
2 Silicone stopper, one 7-mm hole, 16 x 21mm. 667 286
2 Gas syringe, 100 ml with 3-way stopcock 665 914
1 Cartridge burner, DIN type............................. 666 714
1 Cartridge 666 715
2 Laboratory stand 16 cm x 13 cm.................... 300 76
1 Gas igniter, mechanical 666 731
1 Analytical balance ABS 220-4N 667 7990
1 Silicone tubing, 7 mm diam., 1 m 667 194
1 Silicone tubing, 4 mm diam............................ 667 197
1 Tubing connector, PP, straight, 4/15 mm diam. . 604 510
6 Adhesive magnetic board, 300 mm 666 4660
2 Holder, magnetic, size 1, 9...11 mm 666 4661
2 Holder, magnetic, size 5, 30...32 mm.............. 666 4665
1 Panel frame C100, two-level, for CPS 666 428
1 Fine regulating valve for minican gas cans 660 980
1 screen 441 531
1 stand base, V-shaped, small.......................... 300 02
1 Magnesium, ribbon, 25 g 673 1000
1 Hydrochloric acid, 0.5 mol/l, 500 ml 674 6970
1 Minican pressurised gas canister, oxygen 660 998

Set-up and preparation of the experiment

Preparations for the synthesis

Cleaning the magnesium ribbon: 50 – 130 mg of magnesium ribbon (4 – 5 cm) is immersed in hydrochloric acid (0.5 mol/l) for ten seconds for cleaning. Then the piece of magnesium is rinsed with distilled water and carefully dried. Finally, it is sanded down slightly, leaving a bare metal surface.

Note: By cleaning with hydrochloric acid, the oxide layer (black) present on the magnesium ribbon is dissolved.

Set-up of equipment

For the synthesis of magnesium oxide, two gas syringes with 3-way stopcocks are first fixed to the magnetic board with one large and one small clamp each. Then the quartz tube is fixed between the gas syringes using two stoppers. The combustion boat is later placed in the quartz tube with the magnesium for the synthesis. The Bunsen burner with laboratory stand is placed under the quartz tube. The oxygen cylinder is connected to one of the 3-way stopcocks using a hose (see Fig. 1).

Note: When assembling, ensure that the three-way stopcocks are pointing downwards, as this will make it easier to attach the oxygen hose.

Note: Make sure you use a quartz tube, since other glass cannot withstand the temperatures it is exposed to.

As protection against the very bright magnesium flame, a small screen is placed in front of the apparatus. The brightness of the reaction is still highly visible from the scattered light, particularly in a dark room. The screen is fixed to the stand base and brought to the correct height with the second laboratory stand.

Performing the experiment

1. To start with, weigh the combustion boat and the magnesium individually.

2. The combustion boat is then placed in the quartz tube with the magnesium ribbon.

3. The apparatus must now be purged with oxygen. For this, approx. 50 ml of oxygen is fed into the apparatus and pushed through the apparatus 2 to 3 times using the gas syringe. Then the gas is led back out. This process is repeated up to three times.

4. For the synthesis, exactly 100 ml of oxygen is fed into a gas syringe. Then remove the oxygen cylinder.

5. Then ignite the Bunsen burner and heat the magnesium. Position the screen on the laboratory stand in front of the apparatus.

Warning! Do not heat the magnesium too quickly! Otherwise the magnesium will react so strongly that the resulting magnesium oxide does not remain in the combustion boat.

6. When the magnesium has ignited and is burning under a very bright flame, ensure complete combustion through a light gas flow. For this, the oxygen is pushed from one flask into the other.

Warning! Do not look directly at the magnesium flame! Otherwise your vision could be impaired for several minutes or even hours!

Note: The reaction lasts less than a minute. Ensure that there is only a light gas flow for this, otherwise the magnesium oxide will be blown off of the boat.

7. After it cools down, first read off the volume of consumed oxygen. Then the combustion boat is removed from the quartz tube with the resulting magnesium oxide and weighed.

8. Repeat the experiment two more times with different magnesium masses.

Observation

The magnesium burns under a very bright, white flame. In the process, a white porous solid is produced in the combustion boat, the magnesium oxide.

The oxygen volume decreases abruptly in the gas syringes during combustion.

Evaluation

Determination of the oxygen mass

The recorded volume of oxygen can be determined in this experiment in two ways: via the weight increase in the end product or through the volume decrease of the oxygen in the apparatus.

Weight increase of the end product: The mass of the oxygen *m(O)* can be determined via the weight increase of the product using the following formula:

$$m\,(O) = m\,(MgO) - m(Mg)$$

Volume decrease of the oxygen in the apparatus: The mass of the oxygen *m(O)* can also be determined by the volume of consumed oxygen by multiplying this by the density of the oxygen.

$$m(O_2) = \rho(O_2) * V$$

The density of atomic oxygen $\rho(O_2)$ is 0.00143 $\frac{\text{g}}{\text{ml}}$.

Determination of the mass ratio

Then the mass ratio *Mg:O* can be calculated via the quotient of the masses as follows:

$$\text{Mg :O} \rightarrow \frac{m(Mg)}{m\,(O)}$$

Weight increase of the end product: Here, the following mass ratios *Mg:O* were able to be determined experimentally via the weight increase of the end product (see Tab. 1):

Tab. 1: Illustration of the determined masses and the calculated mass ratios from the weight increase of the end product.

No.	*m(MgO)*	*m(Mg)*	*m(O in MgO)*	*Mg:O*
1	136 mg	84 mg	52 mg	1.62
2	156 mg	97 mg	59 mg	1.64
3	146 mg	89 mg	57 mg	1.56

Volume decrease of the oxygen in the apparatus: Via the volume decrease of the oxygen in the apparatus, the following values were able to be determined experimentally for the mass ratio *Mg:O* (see Tab. 2):

Tab. 2: Illustration of the determined masses and the calculated mass ratios from the volume decrease of oxygen.

No.	*$V(O_2)$*	*m(Mg)*	*$m(O_2)$*	*Mg:O*
1	38.0 ml	84 mg	54 mg	1.55
2	42.0 ml	97 mg	60 mg	1.62
3	39.5 ml	89 mg	56 mg	1.58

The value for the mass ratio *Mg:O* cited in literature is 1.52:1. The deviations from this value are very small and can thus be ignored.

Result

The mass of the oxygen in the magnesium oxide was able to be determined in two different ways without using the molar masses. Then the mass ratio of magnesium and oxygen could be calculated.

Magnesium and oxygen always react together to make magnesium oxide at a ratio of 1.52:1, i.e. in definite proportions. The law of definite proportions was thus able to be confirmed. This applies not only to the synthesis of magnesium oxide, but to all reactions and is thus universally valid.

Cleaning and disposal

Dispose of the magnesium oxide in a solids container for organic/inorganic solids (no toxins).