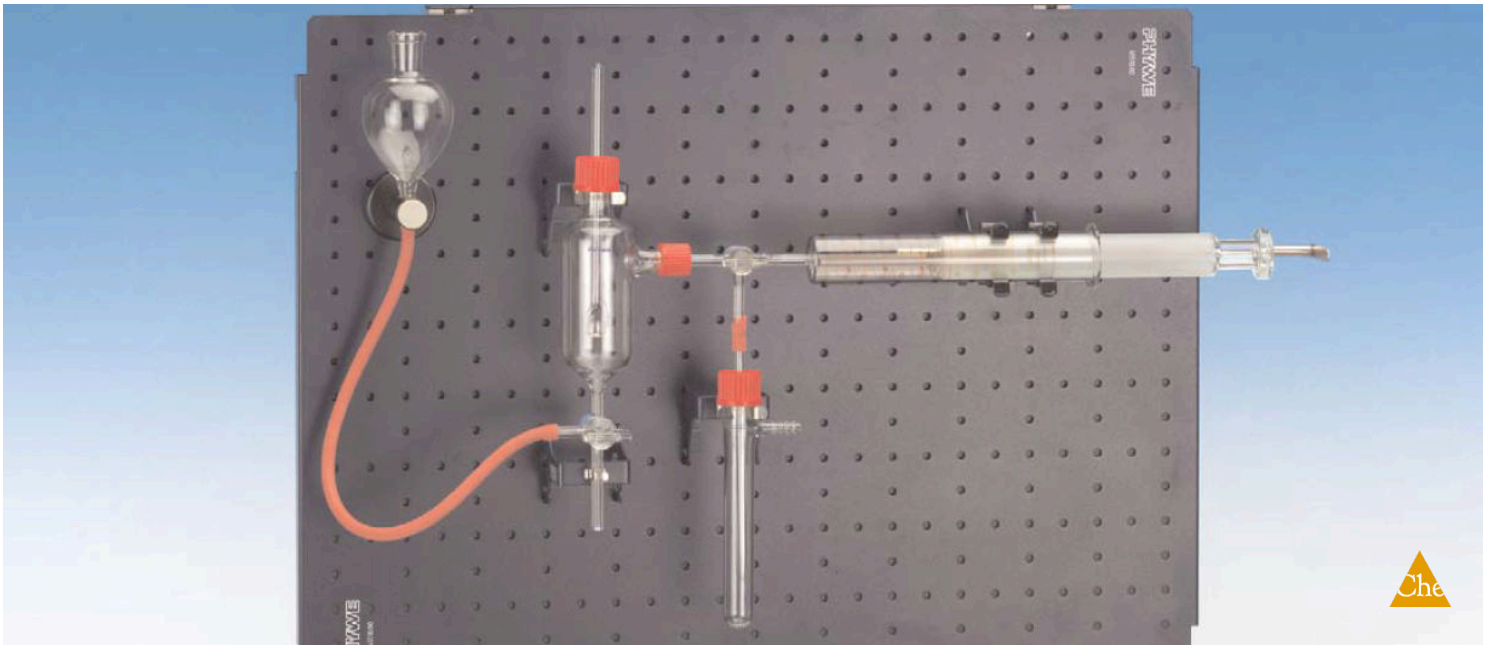
Determination of the molar masses of metals



The students learn the determination of the molar masses of metals by using the ideal gas law, measured values and the relationship M = m/n.

Chemistry > General Chemistry > Chemical reactions > Basics of chemical reaction

Difficulty level	Group size	Preparation time	Execution time
medium	1	20 minutes	10 minutes

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General information

Application

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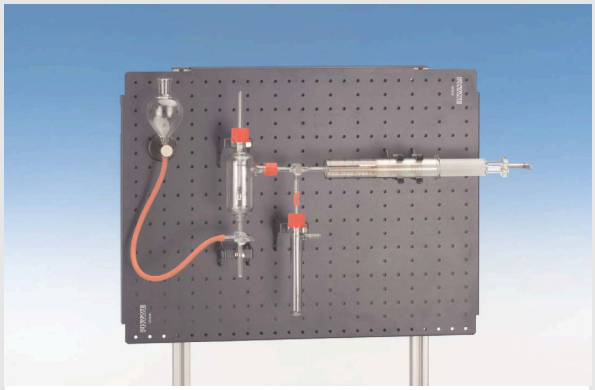

Experimental setup

An important application of the ideal gas law is the determination of the molar mass.

With the Victor Meyer method, the variables m, p and T are given, and the volume V is determined in the experiment.

$$n = \frac{p \cdot V}{R \cdot T}$$

The general gas equation or ideal gas law establishes not only a relationship between the three variables pressure, volume and temperature, but also for the amount of substance (n).

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Other information (1/2)

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Prior knowledge

The students should know the ideal gas law and the theory behind the determination of molar masses of metals. They should also be familiar with the handling of acids.

Scientific principle

The molar mass of zinc can be determined from the measured values, the ideal gas law and the relationship M = m/n (where M = molar mass, m = mass and n = amount of material).

Other information (2/2)

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Learning objective

The students learn the determination of the molar masses of metals by using the ideal gas law, measured values and the relationship M = m/n.

Tasks

The students are to determine the molar mass of zinc.

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Safety instructions

- Use protective glasses!
- Use protective gloves!
- Concentrated hydrochloric acid is a clear, colourless, water-miscible liquid that smokes when exposed to air. It causes corrosion and its vapours irritate the respiratory organs.
- For this experiment the general instructions for safe experimentation in science lessons apply.
- For H- and P-phrases please consult the safety data sheet of the respective chemical.

Theory (1/2)

The general gas equation or ideal gas law establishes not only a relationship between the three variables pressure, volume and temperature, but also for the amount of substance (n).

$$n = \frac{p \cdot V}{R \cdot T}$$

With the Victor Meyer method, the variables m, p and T are given, and the volume V is determined in the experiment.

To determine the molar mass M, it is necessary to measure the four variables p, V, m and T, which can be recorded easily if the experimental conditions are chosen appropriately

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Theory (2/2)

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The following general equation is valid for metals:

$$Me + xH^+ \rightarrow Me^{x+} + \frac{x}{2}H_2$$

For zinc, x = 2, the equation becomes:

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

An equimolar amount of hydrogen molecules is generated by one mole of zinc.

The amount of substance determined from the volume of hydrogen therefore corresponds directly to the zinc used.

For other metals with x = 3, the following equation is given (example for aluminum):

$$Al + 3H^+ \rightarrow Al^{3+} + \frac{3}{2}H_2$$

This means: 1,5 moles of hydrogen molecules are generated from one mole of aluminium.

The amount of substance for aluminium so correspondence to 2/3 of the amount of substance of the hydrogen collected.

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Equipment

Position	Material	Item No.	Quantity
1	Frame for complete experiments	45500-00	1
2	Rear-cover for compl.-exp. panel	45501-00	1
3	Panel for complete experimental setups	45510-00	1
4	Clamping holder, 0-13 mm, fixing magnet	02151-07	1
5	Clamping holder,18-25mm	45520-00	2
6	Clamping holder,turnable,8-10mm	45522-00	1
7	Holder for syringes	45523-00	1
8	Spring plugs, 50 off	45530-00	1
9	Lab thermometer,w.stem,+15..+40C	38057-00	1
10	Reaction cylinder with stopcock, GL25	35852-15	1
11	Gas syringe, 100 ml, with 3-way cock	02617-00	1
12	Levelling bulb,glass	36515-00	1
13	Test tube GL25/8, w.hose connec.	36330-15	1
14	Glass tubes,straight, 150 mm, 10	36701-64	1
15	Laboratory pen, waterproof, black	38711-00	1
16	Rubber tubing, i.d. 6 mm	39282-00	1
17	Beaker, Borosilicate, tall form, 250 ml	46027-00	1
18	Funnel, glass, top dia. 80 mm	34459-00	1
19	Hydrochloric acid 37 %, 1000 ml	30214-70	1
20	Zinc, granul., 99.5%, 500 g	31998-50	1
21	Water, distilled 5 l	31246-81	1
22	Precision barometer, d=100mm	87998-00	1

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Setup and procedure

Setup

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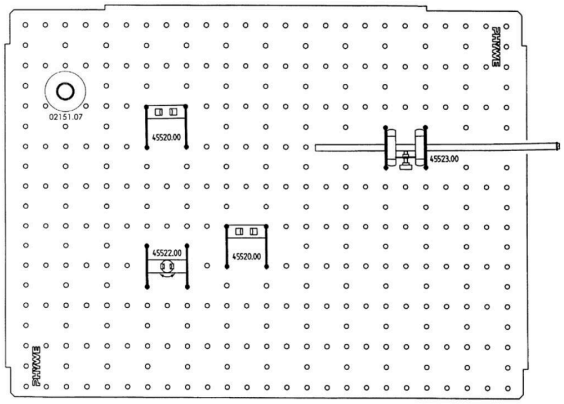
- Position the clamping holders on the panel for complete experiments as shown in Fig. right, and subsequently fix the apparatus to it as shown in the experimental setup.
- Pour 50 ml of distilled water and about 50 ml of concentrated hydrochloric acid into the beaker (work in the fume cupboard).
- Fill this 50% diluted acid into the reaction cylinder via the levelling bulb.
- Fill the test tube up to about 2 cm below the side arm with water. This serves as excess-pressure value.



Position the clamping holders on the panel for complete experiments.

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Procedure (1/2)

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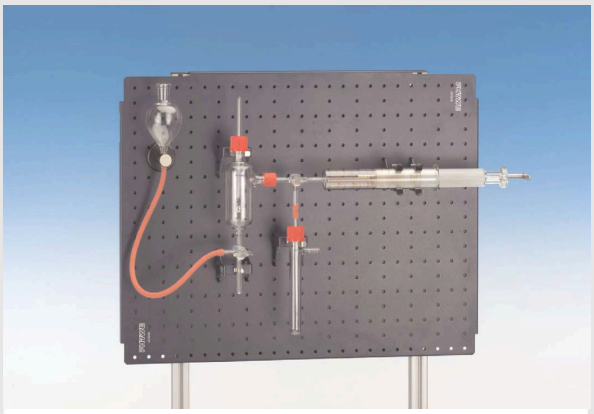
- Accurately weigh a zinc granule and place it in the glass vessel fixed to the slidable rod.
- Position this rod in the reaction cylinder and screw on the connecting cap to make the cylinder airtight.
- Lower the zinc granule down into the acid until it is immersed by about 1 cm.
- After roughly 10 minutes, raise up the granule out of the acid (without opening the apparatus!) and wait until the reaction is finished.
- Equalise pressure by changing the height of the levelling bulb, until the level of the liquid in the cylinder is again at the initial, marked height.



Experimental setup

Procedure (2/2)

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- Balance the pressure in the gas syringe by so adjusting the plunger that the level of the liquid in the glass tube that is inside the test tube is at the same height as the water in the test tube.
- Now read off the volume of gas in the gas syringe.
- Remove the granule from the vessel, dry it with a paper tissue or by using alcohol or acetone, the re-weigh it.
- Note the ambient atmospheric pressure and temperature.
- Repeat the experiment with a small piece of aluminium rolled to form a ball. There are two things that are important here. The aluminium ball should not weigh more than 0,05 g, and the slidable rod should not be immersed too far - only a total of about 1 cm.

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Evaluation

Evaluation (1/6)

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Observations

The zinc granule reacts only a little at first with some gas formation, but more lively as time goes by. During the 15 minutes of immersion, the granule loses between 0,10 g and 0,25 g in mass, and 25 to 80 ml of gas are collected.

The aluminium ball, on the other hand, appears first not to react at all. After about 30 seconds, the first bubbles are formed, and within a short time the reaction takes place very violently until it ends after about 3 minutes - the ball has reacted completely.

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Evaluation (2/6)

The molar mass of zin is determined from by the ideal gas law and the relationship M = m/n (where M = molar mass, m = mass and n = amount of material).

An experiment was made with 4 zinc granules. An average mass loss of 0,148 g zinc was found, and an average gas volume of 56,75 ml was determined. The ambient temperature was 24,8°C and atmospheric pressure 996 hPa.

From these values, and using the ideal gas law, the amount of hydrogen can be calculated:

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

$$n = \frac{p \cdot V}{R \cdot T}$$

where:

p = 99600 Pa	(pressure)
V = 56,75 ml = 0,057 l	(gas volume)
R = 8314,4 $Pa \cdot mol^{-1} \cdot K^{-1}$	(universal gas constant)
T = 24,8°C = 297,8 K	(temperature)
m = 0,148 g	(mass of metal)

Evaluation (3/6)

The measured values give $n = 2,29 \cdot 10^{-3}$ for the amount of hydrogen gas. As for zinc:

$$n_{H_2} = n_{Zn}$$

it follows that:

$$M_{Zn} = \frac{m_{Zn}}{n_{H_2}}$$

and so that

$$M_{Zn} = \frac{0,148g}{2,29 \cdot 10^{-3}mol} = 65,56g \cdot mol^{-1}$$

A value M = 65,56 g\moles has been experimentally found for the molar mass of zinc. The value given in the literature is 65,39 g\moles.

In three determinations with aluminium balls, on taking average, a gas volume of 43,33 ml was generated from 0,031 g of aluminium. The pressure was 995 hPa and the temperature 23,7°C.

These values give a molar mass for aluminium of M = 26,4 g\moles (literature value: 26,982 g\moles).

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Evaluation (4/6)

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Mark the general equation for metals.

- ○ The general eqution for metals is $Me + xH^{+} \rightarrow Me^{x+} + \frac{x}{2}H_2$.
- ○ There is no general equation for metals.
- ○ The general eqution for metals is $Me + xH^{2+} \rightarrow Me^{x+} + \frac{x}{2}H_2$.
- ○ The general eqution for metals is $Me + 3xH^{-} \rightarrow Me^{x+} + \frac{x}{2}H_2$.

Überprüfen

Evaluation (5/6)

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Drag the words into the correct boxes!

The zinc granule reacts only _____ at first with some _____ formation, but more lively as time goes by. During the 15 minutes of immersion, the granule loses between _____ g in mass, and _____ ml of gas are collected.

The aluminium ball, on the other hand, appears first not to react at all. After about 30 seconds, the first bubbles are formed, and within a short time the reaction takes place very violently until it ends after about 3 minutes - the ball has reacted _____.

25 to 80 | gas | completely | 0,10 and 0,25 | a little

Überprüfen

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Evaluation (6/6)

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Choose the correct statements.

- [ ] An equimolecular amount of hydrogen molecules is generated by one mole of zinc.
- [ ] 3 moles of hydrogen molecules are generated from one mole of aluminium.
- [ ] The molar mass of zinc can be determined from the measured values, the ideal gas law and the relationship M = m/n.
- [ ] 1,5 moles of hydrogen molecules are generated from one mole of aluminium.

Überprüfen

Slide	Score / Total
Slide 17: General equation for metals	0/1
Slide 18: Summary of the experiment	0/5
Slide 19: Correct statements	0/3

Total Score 0/9

Show solutions Retry

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