Physical Chemistry

Reaction kinetics

Influencing the reaction rate

LD Chemistry Leaflets

C4.1.3.3

Reaction of magnesium in strong and weak acids

Measurement and recording of the gas volume using CASSY

Aims of the experiment

- To observe material conversions.
- To learn about reaction rates.
- To measure and record a gas volume during the reaction.
- To know strong and weak acids and their differences.
- To learn about influences on the reaction rate.

Principles

Every chemical reaction proceeds at a certain rate. It is defined as the change in concentration per time unit. In a reaction, two (or more) particles must collide. In the collision, a reaction can occur or not. In the process, the successful collision of two particles requires a minimum of energy and the correct orientation of the particles relative to one another.

At the beginning of a reaction, only reactant particles are present which, because of their frequency, often collide and form products. The rate of reaction is high. During a reaction, the rate decreases since the concentration of the initial substance decreases and thus the probability that the reactants will collide.

The higher the concentration of reactants, the faster the reaction rate since more particles are available for the reaction. In the reaction of magnesium with an acid, hydrogen is formed.

$$Mg + 2\,H^+ \rightarrow Mg^{2+} + H_2$$

The rate of reaction increases when one or both reactants are present at higher concentrations.

For industry it is important to know the reaction rate of a reaction and to know how it can be influenced in order to design processes more effectively. In order to determine the reaction rate of a chemical reaction, measurement parameters that change during the reaction, such as the mass, the volume or the concentration of the substances involved, can be applied.

In this experiment, the reaction of magnesium with two different acids will be observed with regard to their reaction rates. In the reaction, hydrogen is generated. This can be collected in a gas syringe. The gas volume in the gas syringe is recorded using a displacement sensor as a function of time.

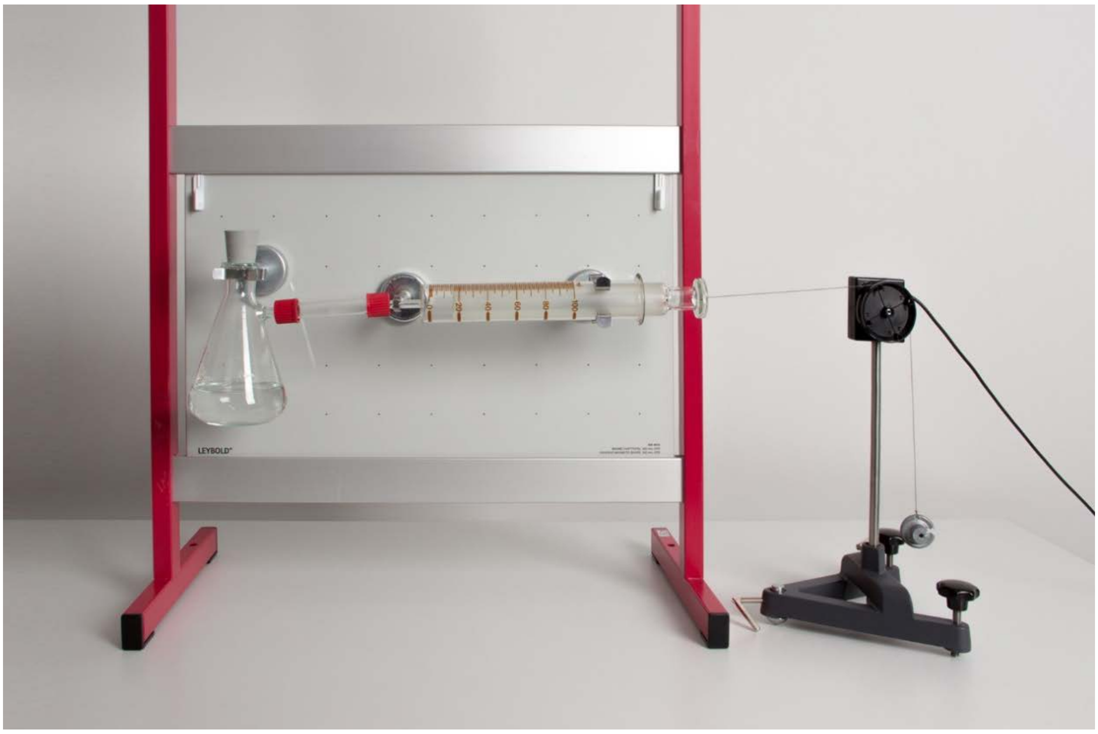

Fig. 1: Experimental set-up.

MS-2018-07

Risk assessment

In working with acids and acetic acid, skin and eye contact must be avoided.

Magnesium is highly flammable. Therefore, do not work near sources of fire.

Acetic acid in the concentration of 1 mol/l is not classified as a hazardous material.

Hydrochloric acid 1 mol/l	
Signal word: Caution	**Hazard warnings** H290 May be corrosive to metals. **Safety information** P234 Keep only in original container. P390 Absorb spillage to prevent material damage. P406 Keep in corrosion-resistant containers with corrosion-resistant linings
Magnesium, ribbon	
Signal word: Caution	**Hazard warnings** H228 Flammable solid. **Safety information** P370+P378 In case of fire: Use metal fire extinguisher / sand for extinguishing

Equipment and chemicals

1 Pocket-CASSY 524 006
1 CASSY Lab 2 .... 524 220
1 Displacement sensor 529 031
1 Stand base, V-shaped, small 300 02
1 Adhesive magnetic board, 500 mm 666 4659
1 Panel frame C50, two-level, for CPS 666 425
1 Holder, magnetic, size 1, 9...11 mm 666 4661
1 Holder, magnetic, size 4, 27...29 mm 666 4664
1 Holder, magnetic, size 5, 30...32 mm 666 4665
1 Gas syringe, 100 ml 665 912
1 Erlenmeyer flask with side tap, 300 ml 602 111
1 Glass connector 667 312
1 Rubber stopper, solid 667 260
1 Fishing line, set of 2 .... 309 48ET2
1 Weights 50 g, set of 6 .... 340 85
1 Measuring cylinder, 100 ml 665 754
1 Acetic acid, 1 mol/l, 1l 671 9590
1 Hydrochloric acid, 1 mol/l, 500 ml 674 6900
1 Magnesium, ribbon, 25 g 673 1000

Set-up and preparation of the experiment

Set-up of the apparatus

1. The apparatus is set up as can be seen in Fig. 1.

2. To do so, clamp the displacement sensor vertically into the stand base.

3. Insert the adhesive magnetic board into the panel frame.

4. Fasten the Erlenmeyer flask to the board using a magnetic holder size 4 and seal the flask with a stopper.

5. Fasten the gas syringe on the board using a magnetic holder size 5 in the back and size 1 in the front.

6. Connect the gas syringe and the Erlenmeyer flask via the side tap using the glass connector. To do so, loosen the GL threaded connector so that the gasket ring widens. Push the tip of the gas syringe through the gasket ring and re-tighten the cap.

7. Fasten a fishing line to the piston of the gas syringe and place across the cylinder of the displacement sensor. A weight is fastened to the other side of the line.

Note: Make sure that the entire set-up is level.

8. Load settings into CASSY Lab 2.

CASSY Lab settings:
Path *s* is active
Range: 15 cm
Zero point: centred
Recording: automatic, add new measurement series

Performing the experiment

Volume measurement

1. Push the piston of the gas syringe all the way in. Then, set the measurement for the path (in cm) in CASSY Lab to zero using the >0< button.

2. Then, pull the gas syringe out to the 100-ml mark and record the displayed path in cm.

3. Between the distance in cm and the volume in ml, there is a linear relationship.

Linear relationship in this experimental example:

100 ml = 12.88 cm

1 ml = 0.1288 cm

1 cm = 7.76 ml

Note: This value is a little different for each gas syringe and hence must be recalibrated for every test.

4. In the menu **Computer**, enter a new formula.

5. Enter “Volume” as the name and “V” as the symbol and “ml” as units.

6. The formula is sA1 * (*value in ml that corresponds to one cm*). In the example, this is therefore sA1 * 7.76.

Performing the experiment

1. Cut two pieces of magnesium ribbon of about 4 cm in length; they should have about the same mass.

2. Place 100 ml of the 1 mol/l hydrochloric acid into the Erlenmeyer flask.

3. Place one magnesium piece into the flask. Seal the flask quickly with the stopper and start the measurement.

4. When there is no further volume change, the measurement can be stopped and the experiment repeated with the 1 mol/l acetic acid.

Observation

Both acids generated gas when the magnesium ribbon was added. The hydrochloric acid caused a more rapid gas generation than the acetic acid. The total volume generated is about the same, however.

Results

Both measurements can be seen in Fig. 2.

It can be seen that in the reaction of hydrochloric acid and magnesium as well as the reaction of acetic acid and magnesium, about the same amount of gas is generated. The two reactions differ only in their rates of reaction.

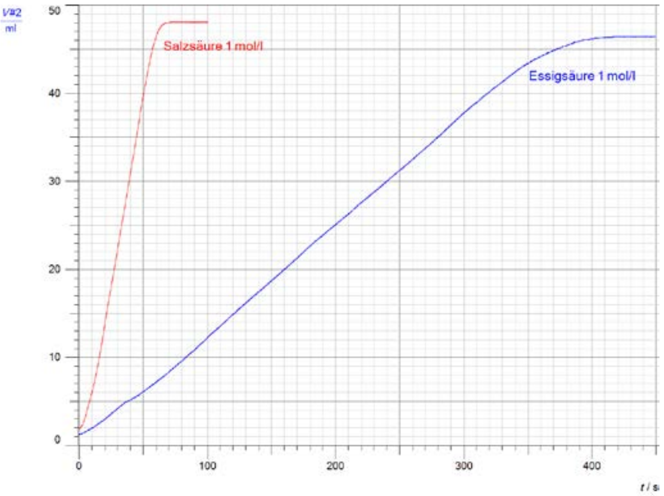

Fig. 2: Measured result. Red: measurement with hydrochloric acid. Blue: measurement with acetic acid.

Although both acids exist in the same concentration and the magnesium used has the same mass, the reaction proceeds at different rates. The reason for this is that hydrochloric acid is a strong acid and acetic acid is a weak acid. This means that hydrochloric acid dissociates completely in water and its protons are completely available for the reaction.

$$Mg + 2\,H^{+} + 2\,Cl^{-} \rightarrow Mg^{2+} + 2\,Cl^{-} + H_2$$

Acetic acid on the other hand is not completely dissociated in water. Thus, there are fewer protons available for the reaction. The reaction proceeds slower.

$$Mg + 2\,CH_3COOH \rightarrow Mg(CH_3COO)_2 + H_2$$

Cleaning and disposal

Both acids can be disposed of in the laboratory sink with plenty of water.

Remarks

The test set-up is suitable for investigating any reaction in which a gas is generated, for example even with marble or zinc as a solid.

By varying the ingredients, other phenomena can be investigated with regard to reaction ranges, such as concentration of an acid, degree of decomposition or temperature dependency.

These experimental instructions were issued at the behest of Martin Schwab, specialist for Chemistry in Franken.