Qualitative water synthesis

Aims of the experiment

- To burn hydrogen.
- To learn about a reaction with a gas.
- To provide evidence that water is the oxide of hydrogen.
- To describe the redox reactions of gases.

Principles

Water is an oxide of hydrogen. It consists of two atoms of hydrogen (H) and one atom of oxygen (O). A gaseous mixture of these two elements can be stored for an indefinite amount of time. However, if energy is introduced from the outside, a strongly exothermic reaction is produced (detonating gas reaction) with the following reaction equation:

$$2\ H_2 + O_2 \rightleftharpoons 2\ H_2O + \text{heat} \qquad \Delta_R H = -572\ \text{kJ/mol}$$

In this case we are dealing with an electron transfer reaction, also called a redox reaction. Here, the hydrogen is oxidised and releases electrons. On the other hand, the oxygen is reduced and accepts the electrons.

$$\text{Oxidation:} \quad \overset{0}{H_2} \rightarrow 2\ \overset{+I}{H^+} + 2\ e^-$$

$$\text{Reduction:} \quad \overset{0}{O_2} + 2\ e^- \rightarrow \overset{-II}{O^{2-}}$$

Accordingly, the redox reaction would be as follows:

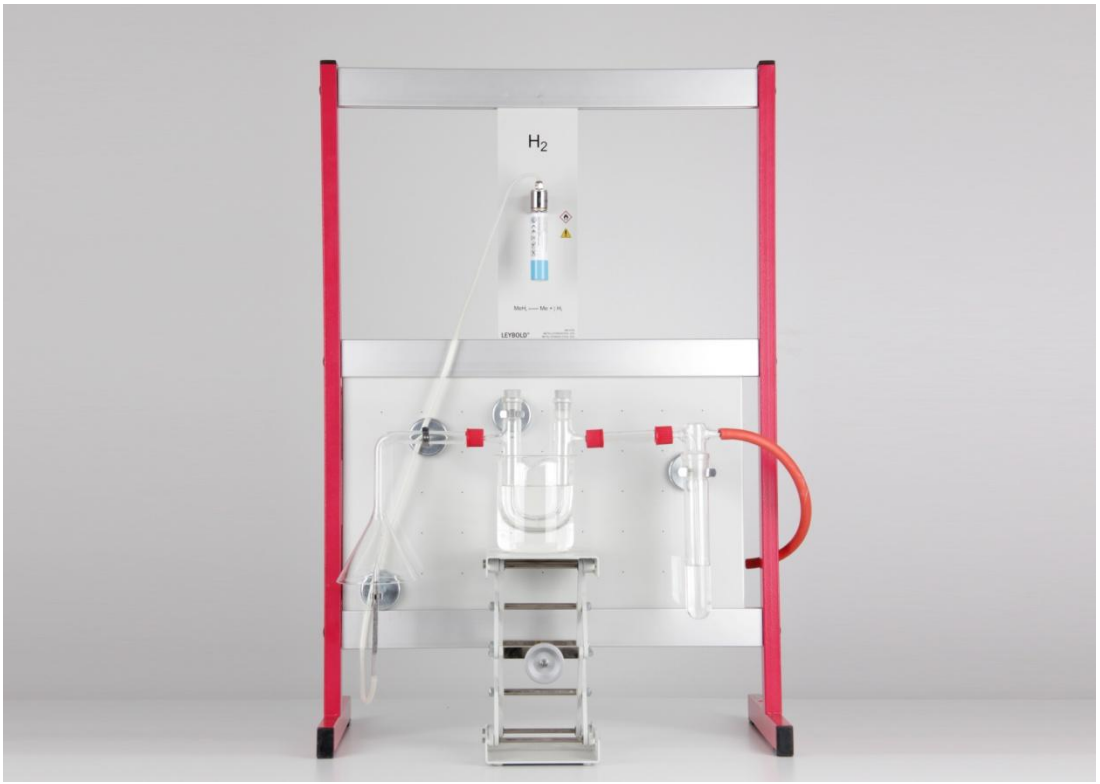
$$H_2 + 0.5\ O_2 \rightarrow H_2O$$

As reaction equations are formulated such that the stoichiometric coefficients occur as whole numbers and not as fractions, each term of the equation is multiplied by two. We therefore obtain the following reaction equation:

$$2\ H_2 + O_2 \rightarrow 2\ H_2O$$

Water is an asymmetric molecule. Both hydrogen atoms are arranged at an angle of about 105° around the central oxygen atom. Additionally, the atoms in the molecule have distinct partial charges. Oxygen is partially negatively charged because of an electronegativity of 3.5, and hydrogen is partially positively charged because of an electronegativity of 2.1. The water molecule is therefore a dipole. Water's special properties result precisely from the formation of this dipole.

The dipole allows the formation of hydrogen bridge bonding. Here, intermolecular bonds are formed between neighbouring O and H atoms. Because of this hydrogen bridge bonding, water is liquid under normal conditions. Also the cohesion (surface tension), the relatively high boiling point and the density anomaly of water can be explained among other things by this dipole.



Through its property as a polar solvent, water plays a decisive role in almost all metabolic processes in organisms. It serves in the transport of substances within organisms and in temperature regulation. It also has a high importance in geological and ecological processes.

In this experiment, water will be produced quantitatively. To achieve this, hydrogen will be burnt and the combustion gases collected. The combustion gas consists of water vapour, which can be tested for using anhydrous copper sulfate.

Risk assessment

When using hydrogen gas, detonating gas mixtures can be produced. However, hydrogen can be used safely as long as it is burnt under controlled conditions and a negative pressure is maintained in the apparatus.

Hydrogen	
 **Signal word:** **Hazard**	**Hazard statements**: H220 Extremely flammable gas. H280 Contains gas under pressure; may explode if heated. **Precautionary statements** P210 Keep away from heat/sparks/open flames/hot surfaces. No smoking. P377 Leaking gas fire – do not extinguish unless leak can be stopped safely. P381 Eliminate all ignition sources if safe to do so. P403 Store in a well ventilated place.

Equipment and chemicals

For setting up in CPS:
1 Panel frame C50, two-level, for CPS 666 425
1 Adhesive magnetic board 500 mm.....666 4659
1 Holder, magnetic, size 1, 9...11 mm.....666 4661
2 Holder, magnetic, size 2, 11...14 mm.....666 4662
1 Holder, magnetic, size 4, 27...29 mm.....666 4664
1 Glass connector, 2 x GL 18 .....667 312
1 HydroStik PRO, CPS 666 4795

For setting up with stand materials:
2 Stand base, V-shaped, small 300 02
2 Stand tube 750 mm x 10 mm diam. 608 051
5 Bosshead S.....301 09
5 Universal clamp 0...80 mm 666 555
1 HydroStik PRO.....666 4796
1 Regulating valve 666 4797

For both versions:
1 Water-jet pump 375 56
1 Beaker, Boro 3.3, 800 mL, squat 602 024
1 Funnel for gas collection 665 001
1 Gas scrubber bottle, lower section.....664 800
1 Gas scrubber bottle insert.....664 805
1 Glass nozzle, straight.....665 237
1 U-tube, 160 x 24 mm, 2 side taps 664 093
2 Rubber stopper, solid, 19...24 mm diam. 6672 57
1 Laboratory stand II (laboratory jack-stand) 300 76
1 Copper(II) sulfate, anhydrous, 50 g.....6729 700
1 Water, pure, 5 l 6753 410
1 Iron wool, 50 g 671 8400

1 HydroFill PRO 666 4798
1 Silicone tubing 4 mm diam., 1 m 667 197
1 Rubber tube 1 m x 8 mm diam., DIN 12865 .. 604 483

Set-up and preparation of the experiment

Setting up the CPS apparatus

Set up the apparatus in accordance with the illustration:

1. The hydrogen source (the HydroStik PRO, CPS) is mounted into the upper section, the adhesive magnetic board into the lower section.
2. The funnel for gas collection and the U-tube are each attached to the adhesive magnetic board with a size 2 magnetic holder.
3. Place a spatula tip of anhydrous (white) copper(II) sulfate in the U-tube and close the tube using the two rubber stoppers.
4. Connect the U-tube to the funnel using a GL connector.
5. Attach the gas scrubber bottle using a size 4 magnetic holder. Connect the long connector of the gas scrubber bottle to the U-tube using a glass connector.
6. Fill the glass nozzle with iron wool to act as flash-back protection. This is placed under the glass funnel using a size 1 magnetic holder and connected to the regulating valve of the HydroStik PRO, CPS using the silicone tubing.

Setting up the apparatus with stand materials

1. Insert a stand tube into each stand base. Clamp the funnel for gas collection onto one of the stand tubes using a bosshead and a universal clamp.
2. Attach the regulating valve to the same stand tube using a bosshead and a universal clamp.
3. Similarly, the U-tube is attached to the other stand tube using a bosshead and a universal clamp. Place a spatula tip of anhydrous (white) copper(II) sulfate in the U-tube and close the tube using the two rubber stoppers.
4. Connect the U-tube to the funnel using a GL connector.
5. Attach a gas scrubber bottle to the other side of the U-tube via the long connector. This is connected to the same stand tube using a bosshead and a universal clamp.
6. Fill the glass nozzle with iron wool to act as flash-back protection. This is located below the glass funnel using a clamp and bosshead and connected to the regulating valve via the silicone tubing.

Common set-up of both versions

7. Connect the short connector of the gas scrubber bottle to a water-jet pump using a piece of rubber tubing. This is necessary in order to produce a negative pressure in the apparatus to ensure that all exhaust gases can actually be collected.
8. Place a beaker filled with water on a laboratory jack-stand beneath the U-tube.

The hydrogen source

The hydrogen is provided from a HydroStik PRO metal hydride storage cartridge. This is filled with hydrogen which has previously been produced by electrolysis. The electrolysis takes place in a HydroFill PRO system, from which the HydroStik PRO is also filled at the same time.

1. Open the cover of the water tank and carefully pour in distilled or deionised water up to the inner ridge. Close the cover.

2. Connect the AC-DC adaptor and plug it into an AC mains socket. The status indicator will now flash green.

3. Screw the HydroStik PRO into the HydroFill PRO. The status indicator will now change from green to red to show that the connection has been made. Firmly screw in the HydroStik PRO.

4. The HydroStik PRO is filled automatically, which is shown by the red status indicator. Charging takes about 4 to 6 hours. An occasional hissing sound indicates that the system is rinsing. The oxygen produced can be seen in the form of bubbles.

5. When the status indicator changes to green, the Hydro-Stik PRO is fully charged and can be removed. A brief hissing sound will occur at this time.

6. A further HydroStik PRO can now be charged. For this, repeat the instructions from step 3.

7. When charging is complete, disconnect the HydroFill PRO from the mains socket and empty the water tank.

Performing the experiment

1. On turning on the water-jet pump, air is aspirated through the apparatus, which can be confirmed through the presence of bubbles in the gas scrubber bottle.

Caution! It must be ensured that a negative pressure exists in the apparatus for the whole duration of the experiment. This can be confirmed through the presence of bubbles in the gas scrubber bottle. Only in this way can all gases be collected.

2. Screw the HydroStik fully onto the regulating valve to allow hydrogen to be released.

3. Ignite the hydrogen at the glass nozzle and place the flame below the glass funnel.

4. Quickly lower the U-tube into the water bath.

5. The U-tube will now mist up on the inside.

6. When a small amount of liquid has collected in the U-tube, the experiment can be terminated by turning off the hydrogen supply and the water-jet pump.

Observation

The hydrogen burns with a barely visible, bluish flame.

A liquid collects in the U-tube through which the anhydrous copper(II) sulfate turns blue.

Result of the experiment

A liquid is formed which is capable of turning the white anhydrous copper(II) sulfate blue. Copper(II) sulfate pentahydrate forms blue crystals. It can therefore be proven by means of the colour change of anhydrous copper(II) sulfate that the liquid formed is water.

$$CuSO_4 + 5\ H_2O \rightleftharpoons CuSO_4 \cdot 5\ H_2O$$

(white) (blue)

When hydrogen is burned, water is created:

$$2\ H_2 + O_2 \rightleftharpoons 2\ H_2O + \text{heat} \qquad \Delta_R H = -572\ \text{kJ/mol}$$

Cleaning and disposal

The copper(II) sulfate pentahydrate can be collected in an appropriately labelled container and used in other experiments. When heated over a Bunsen burner, it releases its water of crystallisation and becomes white anhydrous copper(II) sulfate again.