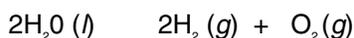


# ***ELECTROLYSIS OF WATER***

## ***STUDY GUIDE***

### **INTRODUCTION**

**Electrolysis** involves the use of an electric current to bring about a chemical reaction that would not occur spontaneously. The electrolysis of water results in a decomposition reaction in which individual water molecules break down into separate hydrogen and oxygen molecules. The water is in a liquid state and the hydrogen and oxygen produced are in the gaseous state. This reaction can be written as a formula as follows:



Looking at the balanced equation above, we see that for every one oxygen molecule produced, there are two hydrogen molecules produced by this reaction. The volumes of oxygen and hydrogen gas produced follow this ratio as well (1:2).

Water does not conduct an electric current in its pure form. An ionic substance called an **electrolyte** must be dissolved into the water for electrolysis to occur. The electrolyte is made up of positively and negatively charged ions that disassociate in the water and allow an electric current to be conducted through the water. In the procedure given below for the electrolysis of water, sodium sulfate ( $\text{Na}_2\text{SO}_4$ ) is used as the electrolyte. It will disassociate in water to its component ions, sodium ( $\text{Na}^+$ ) and sulfate ( $\text{SO}_4^{2-}$ ).

Electrolysis is an **oxidation-reduction (redox)** reaction, in which there is a transfer of electrons. In redox reactions, one substance is **oxidized** (loses one or more electrons) and one substance is **reduced** (gains one or more electrons).

In this experiment, the positive sodium ions move toward one of the electrodes called the **cathode** where the **reduction** of hydrogen occurs. Hydrogen goes from an oxidation number of +1 to 0 and each hydrogen atom gains one electron ( $e^-$ ):



The negative sulfate ions move toward the other electrode called the **anode** where the **oxidation** of oxygen occurs. Oxygen goes from an oxidation number of -2 to 0 with each oxygen atom losing 2 electrons:



Early chemists used a procedure similar to the one you will use to test for the presence of oxygen and hydrogen gas. Oxygen causes a burning splint to glow brightly (burn more vigorously) and hydrogen will cause a burning splint to "pop" (a mini-explosion).

### **MATERIALS**

1. Your electrolysis kit includes the following items:

2 large test tubes	1 pair alligator clip leads
1 bottle (30 g) sodium sulfate ( $\text{Na}_2\text{SO}_4$ )	10 wooden splints
1 250 ml beaker	1 pair stainless steel electrodes
2. You will also need a 6 volt battery (HTT item EL-BATT6) and a watch or clock.

### **ELECTROLYSIS OF WATER**

#### **Experiment 1**

1. **Read the information on the label of the chemical bottle and wear appropriate safety equipment.**
2. Prepare a 1 Molar (M) sodium sulfate solution by dissolving 13 grams (g) of solid sodium sulfate (approximately half the bottle) in 100 milliliters (ml) (about a third of a cup) of water. Stir until completely mixed.
3. Fill the beaker approximately 1/2 full of water.
4. Fill each test tube with the sodium sulfate solution and invert it in the beaker while placing your finger or thumb over the top. Both test tubes need to be upside down in the beaker, completely full of water, with no air at the top. This is a bit tricky, so it's a good idea to do a few practice runs with test tubes full of plain water before trying it with the solution.
5. Add the rest of the sodium sulfate solution to the beaker and stir, being careful not to upset the test tubes. The more the sodium sulfate is mixed through the water, the faster the reaction will occur.
6. Carefully slide the U-shaped end of one of the stainless steel electrodes into the opening in one test tube while keeping the test tube full of water. Repeat with the other electrode and test tube. Make sure the electrodes do not touch.
7. Connect the top part of each electrode to different terminals on a 6-volt battery using the alligator clip leads. Begin timing the reaction.
8. Hydrogen and oxygen gas bubbles will be produced from each electrode.
9. Collect the gases until one test tube is almost full. (This may take up to an hour.) Disconnect the electrodes from the battery and stop timing (record the total time). Mark the water level in each test tube with a black crayon or wax pencil.

10. Carefully remove the test tubes while keeping them upside down to avoid losing the gas.
11. Test the gas in each test tube by inserting a burning splint (see Introduction above). **Which gas is hydrogen? Which is oxygen?**
12. Measure the volume of gases produced by filling each test tube with water to the wax pencil mark and then measuring the volume of water with a graduated cylinder or other liquid measure.
13. Estimate the **ratio** of the volumes of water in the test tubes. Based on this ratio, **what is the ratio of hydrogen produced to oxygen produced?**

You should have seen that that the ratio of the volume of hydrogen produced to that of oxygen was about 2 to 1, as described above in the introduction.

You can repeat this experiment keeping the same sodium sulfate solution and adding the rest of the bottle of the sodium sulfate. Your concentration of sodium sulfate will be approximately double. **How does this affect the rate that electrolysis occurs and therefore the rate at which the gases are produced?** Rinse the electrodes and beaker well in clean water when you are done.

## ELECTROLYSIS OF WATER USING OTHER ELECTROLYTES

### Experiment 2

1. Repeat the above procedure using sodium chloride (table salt) instead of sodium sulfate as the electrolyte. Add the salt to the water as you did the sodium sulfate, stirring until it dissolves.
2. Repeat the procedure and determine if the electrolysis occurs as rapidly as it did with sodium sulfate.
3. Try the procedure again, using baking soda and water. How does the reaction rate compare with that of table salt and sodium sulfate?

**Note:** This reaction may produce small amounts of chlorine gas, similar to the amount present when using bleach.

## TEACHING TIPS FOR YOUNG CHILDREN

Younger children can be taught basic principles about gases and molecules. Begin by explaining that the air around us is made up of gases. We

can't see them or smell them (usually) but we can see their effects. Have your child blow up a balloon and ask what is filling the inside of the balloon. Let the child release the opening of the balloon and feel the air rush across his cheek. Explain that this air is not just made up of one material or gas but several. Hydrogen, oxygen, and nitrogen are the names of some of these gases.

All matter including liquids, gases and solids is made up of tiny atoms. You cannot see atoms, even with a very powerful light microscope. Water is made up of hydrogen and oxygen atoms. There are two hydrogen atoms for every oxygen atom that all together form a water molecule. The hydrogen atoms are smaller than the oxygen atoms and weigh 1/16 as much; the molecule resembles a Mickey Mouse head with two ears.

When we "jostle" the water molecule with electricity, it splits apart. The hydrogen atoms join two at a time and form hydrogen gas and the oxygen atoms do the same. Plants perform this same reaction in their leaves. However, they use sunlight instead of electricity to "jostle" the water molecules (provide the energy to drive the reaction). The leaf then uses the hydrogen to make food for itself and releases the oxygen into the air. This is why we need plants to make our air oxygen-rich so that we can breathe it.

## FURTHER STUDY

Advanced work for this experiment would include balancing redox reactions using the half-reactions. Have your older children balance the redox reaction of the electrolysis of water. They may need a chemistry textbook to use for a reference.

Electrolysis drives a reaction that is not spontaneous and therefore requires the input of energy to occur. Have your older children research other electrolysis reactions and electroplating (a similar type of reaction) and their uses in industry.

Other topics for further study would include research and written reports of scientists whose work pertained to the topics studied in the above experiments. For example, Joseph Priestly was an eighteenth century French scientist who worked extensively with gases and isolated oxygen. Michael Faraday (1791-1867), an English physicist, made the first exact quantitative statements about electrolysis. Other scientists to research include J.J. Berzelius and Sir Humphry Davy.