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# VOLTAMETER AND ELECTROLYSIS APPARATUS

CAT NO. PH0941



## Experiment Guide

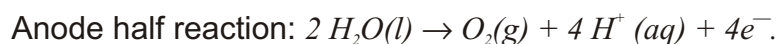


## BACKGROUND

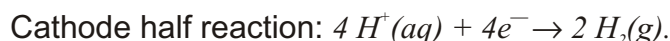
The Voltmeter and Electrolysis apparatus can be used to demonstrate a wide variety of important principles of Chemistry, including stoichiometry, charge measurement, electrolysis, electroplating and electro refining. For these applications, the apparatus requires an electrolyte, a direct current (DC) power supply, and two electrodes. In most cases, a current-limiting resistor is also used, and a multimeter is used for the charge measurement demonstration. An electrolyte is a substance (typically a liquid) which can transfer free ions from one electrode to the other electrode. The transferred ions undergo chemical reactions at the electrodes. These chemical reactions depend strongly on the chemical composition of the electrodes and the electrolyte. In this guide, we'll be considering solid electrodes and liquid electrolytes.

The chemical reaction for the total system can be split up into two half reactions, one for each electrode. In many cases, the constituents of the liquid electrolyte are fully dissociated. The dissociated components carry charge and migrate toward the corresponding electrode. In an electrolytic cell, the electrode with the higher electric potential is called the anode and the electrode with the lower potential is called the cathode. Electrolyte components with positive charge migrate to the cathode, and those with negative charge migrate to the anode. Upon reaching the electrode, each component can participate in the half reaction associated with that electrode.

We'll discuss the simplest possible scenario where the electrolyte is just water and the electrodes are platinum coated (so that the electrodes don't participate in the chemical reactions). It turns out that water is a very poor electrolyte, but the simplicity of the system makes it a good starting point for discussing the pedagogical content. Water consists of water molecules  $H_2O$ , which, in the vicinity of the anode, are oxidized to create oxygen gas and aqueous hydrogen ions,



The symbols  $(l)$ ,  $(g)$ , and  $(aq)$  refer to the state of the molecule, either liquid, gas, or aqueous. The created hydrogen cations  $H^+(aq)$  migrate to the cathode where they combine with 4 electrons to form two Hydrogen gas molecules,

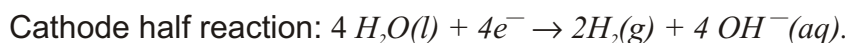


The total reaction is therefore given as

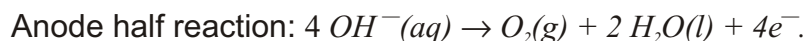


so that two hydrogen molecules are created at the cathode and one oxygen molecule is created at the anode at the cost of 4 electrons and 2 water molecules. The gas which is created at the anode and cathode can be captured using the test tubes which are placed upside down over each electrode. The amount of gas can be measured and then used to determine how much charge has flowed between the anode and cathode. For example, if the total number of oxygen molecules are determined to be X, then a total charge of 4X e was used in the reaction.

Another process in the apparatus also leads to the same total reaction. In this case hydroxide  $OH^-(aq)$  and hydrogen gas  $H_2(g)$  are created at the cathode,



The hydroxide then migrates to the anode and creates oxygen gas,



Since water is such a poor electrolyte, the electrolysis will proceed at a very slow rate when the electrodes are held at typical (single digit) laboratory voltages. By adding an additional water-soluble electrolyte the process can be sped up tremendously, but extreme care must be taken. Some electrolytes produce toxic gas (Chlorine gas, in the case of table salt *NaCl*), and the current flow through the system can increase to the point where it is dangerous if a current-limiting resistor is not placed in series with the power supply (see required equipment below). Under no conditions should an AC power source be used as it will mix the created gases by switching the role of anode and cathode. In the case of hydrogen and oxygen, the mixture is highly explosive. Finally, care must be taken in choosing the electrode composition – stainless steel electrodes, for example, can produce toxic chemicals in the electrolyte.

Precise quantities of electrolyte components which should be used for each type of process and with which electrodes are outside the scope of this guide and the user should consult other sources such as B. Z. Shakhshiri, *Chemical Demonstrations, A Handbook for Teachers of Chemistry*, (University of Wisconsin Press, WI, 1983-1992).

## REQUIRED EQUIPMENT

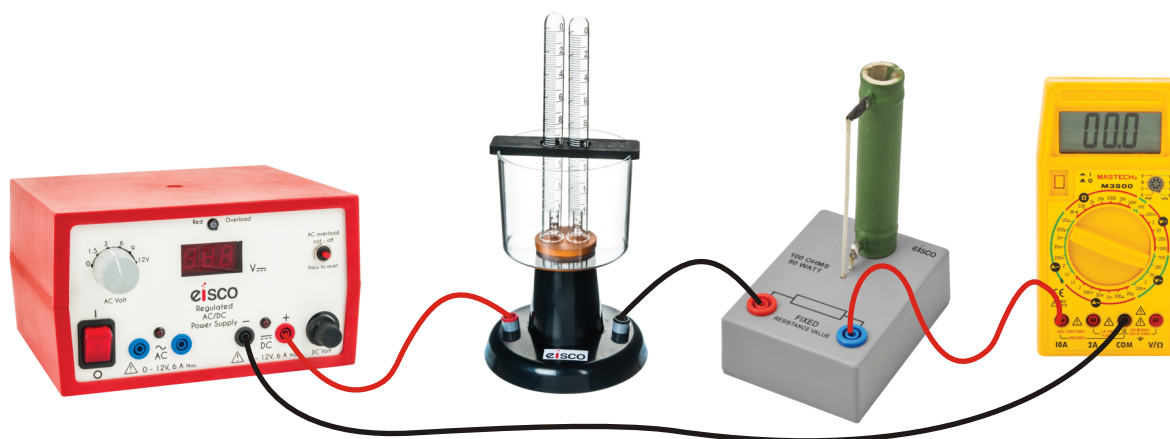
- Electrolytic cell with appropriate electrodes. The electrolytic cells are Eisco models PH0941 (includes platinum electrodes), PH0941ED (carbon electrodes), PH0941EDL (carbon electrodes), or PH0941SPL(copper electrodes).Additional electrodes are Eisco models PH0941ED1-5 with carbon, iron, copper, nickel, and platinum electrodes, respectively. Though only model PH0941ED electrolysis cell is shown in this guide, the descriptions given apply to all model electrolytic cells. All models can be viewed at the following link: [http://www.eiscolabs.com/search?type=product&q=\\*PH0941\\*](http://www.eiscolabs.com/search?type=product&q=*PH0941*).
- 12V/6A variable AC/DC power supply (Eisco model EPR1330 - [www.eiscolabs.com/Store/Product/EPR1330](http://www.eiscolabs.com/Store/Product/EPR1330)).
- 5Ω 50W resistor (Eisco model PH1029M3 - [www.eiscolabs.com/Store/Product/PH1029M3](http://www.eiscolabs.com/Store/Product/PH1029M3)).
- Digital multimeter (Eisco model PH1121C - [www.eiscolabs.com/Store/Product/PH1121C](http://www.eiscolabs.com/Store/Product/PH1121C)).
- Banana connectorized wires 4 mm diameter, quantity 4 (Eisco model PH1055A-H – [www.eiscolabs.com/Store/Product/PH1055A](http://www.eiscolabs.com/Store/Product/PH1055A), for example).



## ASSEMBLY AND USE

**WARNING: RISK OF INJURY BY ELECTRIC SHOCK**  
FOLLOW INSTRUCTIONS CAREFULLY

- 1) Insert the correct electrode for your desired reaction into the electrolytic cell. Connect the electrode leads to the colored banana plug jacks of the same color using a small crescent wrench. In an electroplating demonstration, the object to be plated should be properly cleaned and pre treated using appropriate solvents and abrasives. Then it should be attached to the cathode.
- 2) Fill the electrolysis cell with the appropriate electrolyte. If the products of the electrochemical reaction are gases, place the graduated test tubes (included in each electrolytic cell kit) over the electrodes and slide the test tube stabilizer over the tubes as shown the image below. In some cases, the products of the reaction are either solid or liquid so that no test tubes are needed.
- 3) Plug in the power supply and turn it on. Turn the AC knob to zero, and the DC knob all the way counter-clockwise (to zero). The voltage indicator should read 0V. Turn the power supply off.
- 4) Turn the multimeter to the current measurement setting 'A'. Insert wires into the 'A' and 'COM' ports. The multimeter is used to measure the current flowing through the electrolytic cell. This quantity, along with the elapsed reaction time can be used to check voltameter calculations.
- 5) Insert wires into the electrical ports of the Electrolysis apparatus. The positive output of the power supply should go to the electrode intended as the anode (important for electroplating).



- 6) Use the wires to connect the power supply, resistor, electrolytic cell, and multimeter in series (see diagram below which uses model PH0941EDL electrolyser). Be sure to use the DC (not AC) ports of the power supply. The current reading on the multimeter should be 0A.
- 7) Turn on the power supply and slowly turn up the direct-current voltage. When the voltage exceeds the oxidation and/or reduction potentials the electrochemical reaction will begin to take place. If reaction products are gas, bubbles will begin to form. The duration of the reaction should be recorded if voltameter-based charge measurements are being taken.
- 8) Upon completion of the experiment, all chemicals should be properly disposed of according to local laws and regulations. If plating has accumulated on one of the electrodes it can either be removed using a light abrasive, or it can be removed later in an electro refining demonstration.

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