![Arbor Scientific — Tools That Teach.]

Voltaic Cell

P6-2605

CONTENTS:

1 Plastic Cup Assembly
1 Iron Electrode
1 Aluminum Electrode
1 Brass Electrode
1 Carbon Rod Electrode
1 Zinc Electrode
1 Tin Electrode
1 Nickel Electrode
1 Copper Electrode
1 Porous Cup

Required but not included: <u>one of these</u> electrolyte solutions:

- acetic acid (vinegar)
- dilute sulfuric acid (10% H_2SO_4)
- dilute hydrochloric acid (.1M [0.3%] HCl)

CAUTION: Diluting acid can be hazardous. Use only factory-diluted acids for this experiment, unless you have had specific training in diluting acids.

ACCESSORIES:

Digital Multimeter (P6-8015)

Alligator Leads (P4-3000)

Galvanometer, ± 500 microamps (P4-1207)

INDIVIDUTAL ELECTRODES:

Aluminum (P6-2610)

Copper (P6-2611)

Iron (P56-2612)

Zinc (P6-2613)

Carbon rod (P6-2614)

Class pack (P6-2620): Contains 10 each of aluminum, copper, iron, zinc and carbon.

EXPLANATION:

Student Cell:

The student cell kit is a great demonstration item for studying the conversion of chemical energy into electrical energy. Chemical energy can be used in various ways for this purpose.

The flow of an electric current occurs when two electrical conducting materials with different electrical potential, are connected together via a conducting wire. Electric current travels from the conductor with a higher potential to the conductor with a lower potential and this process of flow of current consumes energy. The electrical current will continue until a potential equilibrium is achieved. Alessandro Volta discovered this around the end of the eighteenth century. He developed a cell that demonstrated how electro motive force (eml) is generated by chemical reactions. He also discovered that if a copper and a zinc electrode are placed in a vessel containing dilute sulphuric acid ($H2SO4$) that an electric current flowed through the wire. This type of electric cell was named after him.

The chemical reaction taking place in a zinc-copper voltaic cell can be summarized as:

At zinc plate (-ve electrode): $\qquad$ $Zn \rightarrow Zn^{2+} + 2e^-$

In the Solution: $\qquad$ $H_2SO_4 \rightarrow 2H+ + SO_4^{2-}$

$\qquad\qquad\qquad\qquad\qquad$ $2H^+ + SO_4^{2-} \rightarrow ZnSO_4$

At Copper plate (+ve electrode): $\qquad$ $2H^+ + 2e^- \rightarrow H_2^{\wedge}$

The result being that the zinc plate acquires a negative charge. As more zinc ions move into the solution, the zinc plate acquires a greater negative charge and thus negative potential. This negative potential attracts zinc ions until an equilibrium is established and the number of ions formed is balanced by the number of zinc ions returning to the electrode. At this point the potential of the zinc plate should be –0.62V. This is the electrode potential of zinc. The positively charged zinc ions repel the positively charged hydrogen ions toward the copper plate. When they reach the copper plate, the hydrogen ions acquire electrons from the plate and form hydrogen gas. The copper plate then loses electrons and becomes positively charged with a positive potential. In time the loss of electrons from copper stops because the positive potential developed repels positively charged hydrogen ions. At this point the potential of the copper plate should be 0.46V. This is the electrode potential of copper. Thus the potential difference between the two plates is 1.08V {0.46V-(0.62V0} and is referred to as the electro motive force (emf) of the cell.

The emf of the cell is equal to the energy drawn from the source and dissipated in the circuit when unit quantity of electricity flows around the circuit and is defined as the potential difference between the two electrodes of the cell in the open circuit.

When the two plates of the cell are connected by electrical conducting material an electric current flows from copper to zinc in the external circuit. Because of the flow of electrons, the negative potential of the zinc falls and more number of zinc ions move into the solution, again rising its negative potential. When electrons reach the copper its positive potential decreases which is then compensated by more hydrogen ions reaching the copper plate. Electric current will continuously flow until the zinc plate dissolves completely or the sulfuric acid is consumed.

The emf of the cell depends upon:

Nature of the two electrodes (as discussed above).
The temperature (since, its affects kinetics of the chemical reactions).
Concentration of the electrolytes and depolarizers.

The emf is independent of the size of the plates (electrodes) and the distance between them, although these two factors do influence the maximum current produced by the cell.

Problems with a conventional Voltaic Cell:

Polarization: As previously discussed the hydrogen ions receive electrons from the copper electrode and produce hydrogen gas. This hydrogen gas collects on surface of the electrode and eventually causes the current in the external circuit to be reduced until it completely stops because hydrogen is a bad conductor of electricity. Hydrogen also is easily oxidisable, another cell between hydrogen and zinc plate is formed with dilute H_2SO_4 as electrolyte. In this cell, hydrogen forms the negative electrode and zinc forms the positive electrode, it sets up an emf in the opposite direction to that of the emf of the zinc-copper cell. It also produces some other effects like decomposing the zinc sulphate in the solution and causing a deposit of zinc on the copper plate.

Local Action: Local Action is the result of the presence of impurities found in most zinc. Impurities such as lead, iron, arsenic and carbon. These impurities are most often electropositive with respect to zinc. When a zinc electrode plate is dipped in H_2SO_4, these impurities together with the zinc form small cells giving small local currents, with the result that the zinc goes on dissolving even when an external current is being drawn. The current produced in these cells decreases the current in the external circuit. This effect is referred to as the local action and can be remedied by amalgamating the zinc plate (coating the zinc plate with mercury). The impurities due not form amalgam with mercury and remain inside and are thus prevented from coming in contact with the acid. When placed in electrolyte, the amalgam reacts with it. When zinc is dissolved, the liberated mercury again forms amalgam with the additional zinc thus preventing local action.

Here are just a few applications for electrochemistry:

The Extraction of Metals from Ores
Purification of metals
Electroplating
Electrolytic capacitor
Noden Value
In many manufacturing processes
For medical use

CONSTRUCTION:

The plastic cup assembly provided consists of is a simple plastic cup with two metal clamps fitted on top of them to facilitate the holding of various electrode plates and also for the proper electrical connection of the electrodes externally. Fill up to two-third level of the cup with the electrolyte like acetic acid or dilute H2SO4 / dilute HCl and fix the electrodes in the clamp in such a way that they are dipping inside the electrolyte. Using connecting wires, connect the terminals of electrode to the voltmeter, so that positive end of the voltmeter is connected to the terminal holding the copper plate. It will be observed that the voltmeter shows a voltage of approximately 1V. On reversing the connections of voltmeter, voltmeter will show a negative reading thus indicating the polarity of both the electrodes.

DRY CELL:

A dry cell is a variation of the web cell in which the electrolyte, amnionium chloride (NH4Cl), is replaced with a paste made of starch, flour and NH4Cl (Aq). A carbon rod acts as the anode and is surrounded by a powdered mixture of manganese dioxide (MnO2) and carbon. This is placed inside a zinc can and the space between is filled with thick NH4Cl paste (as prepared above). The zinc can then act as cathode for the cell.

EXPERIMENTS:

1. Prepare a mixture using powdered MnO2 and NH4Cl solution.

2. Place this mixture in a porous cup that fits easily inside the plastic cup assembly and fix a carbon rod and zinc plate on the two terminals of plastic cup assembly in such a way that the carbon rod is positioned inside the porous cup.

3. Fill the porous cup with paste as prepared in the step (1), in such a way that the carbon rod is embedded in the paste filled in the cup.

4. Fill the plastic cup with NH4Cl solution to a level slightly below the top of the porous cup, and the construction of Dry cell from the kit is complete.

5. Fix the +ve end of voltmeter to carbon rode and the –ve terminal to zinc plate. There will be a +ve deflection on the voltmeter. This shows existence of potential difference between two electrodes.

How a dry cell works:

Ammonium chloride (NH4Cl) solution acts as the electrolyte and MnO2 paste acts as the depolarizer. The two electrodes are carbon (anode) and zinc (cathode).

The reactions taking place can be summarized as below.

Anode - $Zn_{(s)} \longrightarrow Zn^{+2} + 2e^-$

Cathode - $2NH_4^+{}_{(aq)} + 2MnO_2{}_{(s)} + 2e^- \longrightarrow Mn_2O_3{}_{(s)} + 2NH_3{}_{(aq)} + H2O_{(l)}$