STUDENT CELL

Parts List: 7-1822
1 Plastic Cup Assembly
1 Copper Electrode
1 Zinc Electrode

Other useful items:
Voltmeter
Ammeter
Analytical Balance
Rheostat
Stop Watch
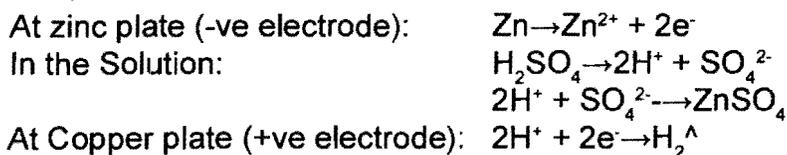Connecting Wires
Electrolytes (as required)
Porous Cup

Parts List: 7-1826
1 Plastic Cup Assembly
1 Iron Electrode
1 Aluminum Electrode
1 Brass Electrode
1 Carbon Rod Electrode
1 Nickel Electrode
1 Copper Electrode
1 Zinc Electrode
1 Tin Electrode
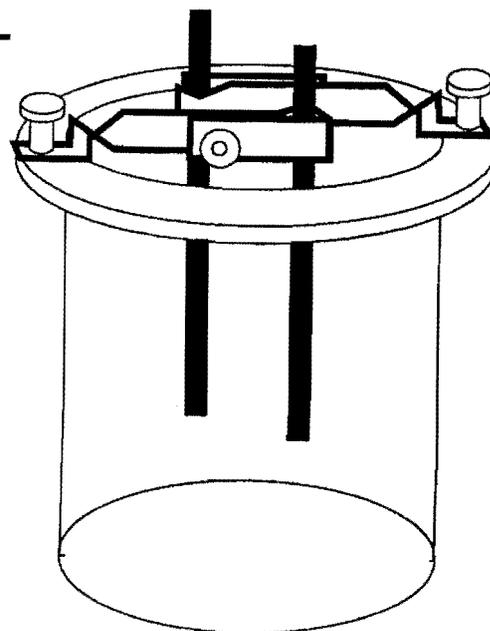
Student Cell:
The student cell kit is a great demonstration item for studying the conversion of chemical energy into electrical energy. Chemical energy can be used in various ways for this purpose.

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 for 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 sulfuric acid (H_2SO_4) 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): $Zn \rightarrow Zn^{2+} + 2e^-$
In the Solution: $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$
                                    $2H^+ + SO_4^{2-} \rightarrow ZnSO_4$
At Copper plate (+ve electrode): $2H^+ + 2e^- \rightarrow H_2 \wedge$

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-(0.62V)} 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 round the circuit through 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 flow form 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 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, it affects kinetics of the chemical reactions).
Concentration of the electrolytes and depolarisers.

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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 oxidizable, 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 the emf of the zinc-copper cell. It also produces some other effects like decomposing the zinc sulfate 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 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 no 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 with mercury). The impurities do not form amalgam with mercury and remain inside and are thus prevented form 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   Noden value
Purification of metals   In many manufacturing processes
Electroplating   For medical uses
Electrolytic capacitor

Amalgamating Zinc Electrode

Minimizing the local effort of a voltaic cell can be accomplished by amalgamating zinc electrodes with a coating of memory (Hg) or zinc the electrodes. To enhance the life of zinc electrodes try applying a coat of mercury on it. To prepare simply dip the zinc electrode in a shallow container filled with dilute hydrochloric acid (HCl). Hydrogen will begin to form which will be apparent by the bubbles that be produced. When the formation of hydrogen gas bubbles occurs on the surface of zinc, pour a drop of mercury into the solution. Spread the mercury evenly all over the surface of zinc electrode, using a stirrer. Carefully remove the zinc plate and wipe it dry being careful not to touch the mercury with your hands. The zinc electrode is now amalgamated and can be used in the cell.

Construction of Simple Voltaic Cell

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 H_2SO_4/ 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 reserving the connections of voltmeter, voltmeter will show a negative reading thus indicating the polarity of both the electrodes.
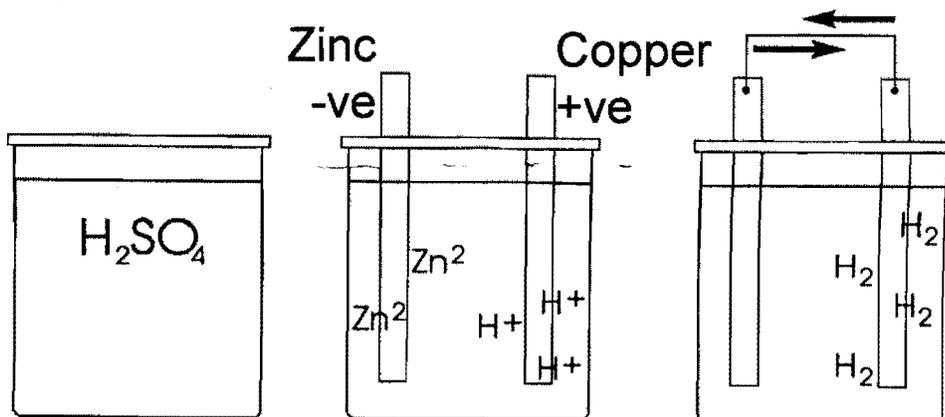
DRY CELL

A dry cell is a variation of the wet cell in which the electrolyte, amnionium chloride (NH_4Cl), is replaced with a paste made of starch, flour and NH_4Cl (Aq.). A carbon rod acts as the anode and is surrounded by a powdered mixture of manganese di oxide (MnO_2) and carbon. This is placed inside a zinc can and the space between is filled with the thick NH_4Cl paste (as prepared above). The zinc can then acts as cathode for the cell.

Experiment
1. Prepare a mixture using powdered MnO_2 and NH_4Cl 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 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 NH_4Cl 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 the voltmeter rod & -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 (NH_4Cl) solution acts as electrolyte and MnO_2 paste acts as depolariser. The two electrodes are carbon (anode) and zinc (cathode).

The reactions taking place can be summarized as below.

1. $NH_4Cl + H_2O \rightarrow NH_4OH + HCl$
$HCl \rightarrow H^+ + Cl^-$
$Zn \rightarrow Zn2^+ + 2e^-$
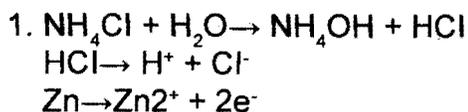
The zinc ions produced repel hydrogen (H+) ions towards the carbon rod and the zinc plate gets negatively charged. Once near carbon rod, the H+ ions take electrons from it, making it positively charged. So, when the electrodes are connected externally by a conducting wire, the excess electrons flow from zinc electrode to carbon electrode in order to complete the deficiency of electrons in carbon rod, which constitutes the electric current. In this way chemical energy in a dry cell is converted into electrical energy. A dry cell keeps on producing emf until the electrolyte is consumed or the paste becomes totally dry.

ELECTROPLATING

In order to demonstrate electroplating you will need an electrolyte solution containing 75g of nickel ammonium sulfate and 20g of nickel sulfate heptahydrate mixed with 1 liter of water.

You will be using a nickel electrode as the anode and a copper electrode as cathode along with the electrolyte solution.

When current is passed through the electrolyte, nickel sulphate ($NiSO_4$) solution decomposes.
$NiSO_4 \rightarrow Ni^{2+}SO_4^{2-}$
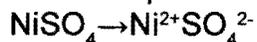
For proper results a current density of about 2.5A per square decimeter of cathode is required at a temperature of about 50°C. The Ni^{2+} ions move toward the copper plate cathode where they gain electrons of form nickel (Ni), which deposits on the surface of copper.
$Ni^{2+} + 2e^- \rightarrow Ni$
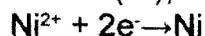
The SO_4^{2-} ions move towards anode where nickel dissolve to form Ni^{2+} ions so that equilibrium between Ni^{2+} & SO_4^{2-} ions is maintained uniformly, throughout the process. Hence, the Ni electrode loses its weight and is equal to the gain of weight of cathode (i.e., the weight of nickel deposited on copper).

Experiment:

Fill the cup two thirds full of the electrolyte solution. Clean both electrodes thoroughly then fasten the nickel electrode to one of the electrode connection and fasten the copper electrode to the other. Make sure that the electrode are well into the solution. Connect the positive terminal of a six to twelve volt DC power supply to the nickel electrode and the negative terminal to the copper electrode.

After a short period of time you should begin to see a nickel layer form on the copper plate. In commercial electroplating processes the copper electrode would be replaced with the item to be electroplated.