B1 BATTERIES

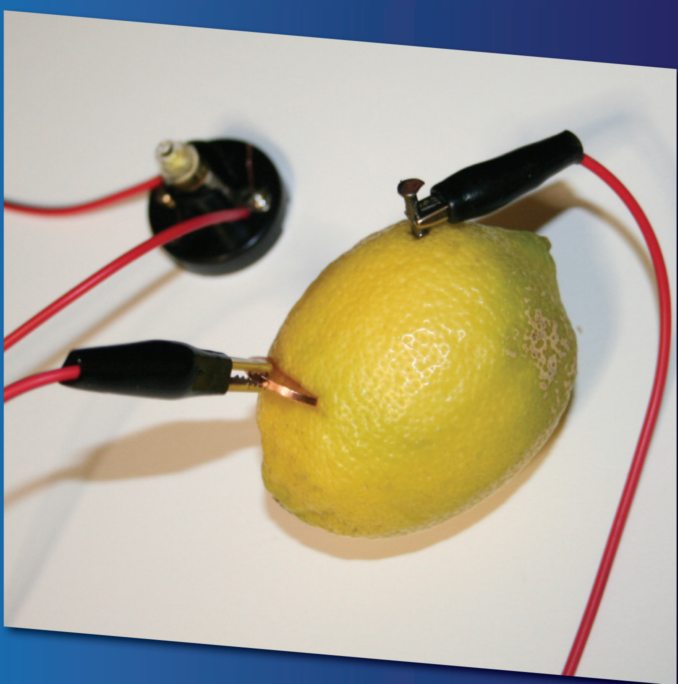
THE ELECTROCHEMICAL CELL

CHEMICAL INDUSTRIES RESOURCE PACK

Making your own battery

You can use lemon juice as an electrolyte! Use a lemon (whole) and copper coin and galvanised nail, making sure they do not touch inside the lemon, and set up a circuit as in the picture. When a low-voltage light bulb, or LED, is connected to this circuit, it will light up. A voltmeter can be connected to measure the potential difference between the electrodes. The potential difference is determined by the choice of electrodes and not the type of fruit. The fruit juice, lemon juice in this case, merely acts as the electrolyte.

The lemon battery



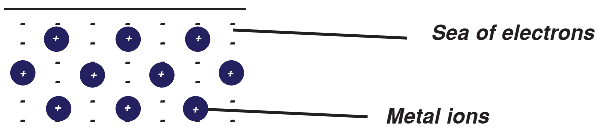
This battery can be made with almost any fruit. The metal electrodes can be varied but must be different metals.

Let's start at the very beginning...

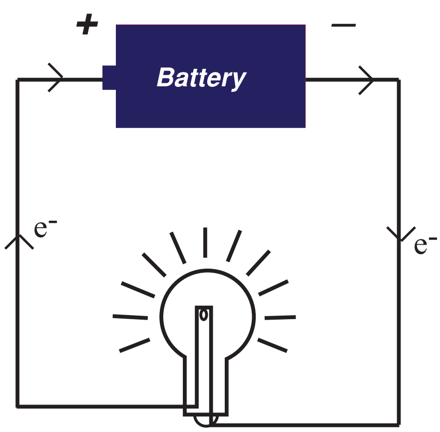
Reduction is when an atom, ion or molecule gains electrons. For example chlorine is reduced to chloride ions in the following reaction: $Cl_2 + 2e^- \rightarrow 2Cl^-$ or magnesium ions are reduced to magnesium metal as follows: $Mg^{2+} + 2e^- \rightarrow Mg(s)$.

Oxidation is when an atom, ion or molecule loses electrons. For example sodium loses an electron to form a sodium ion: $Na(s) \rightarrow Na^+ + e^-$, or sulfide ions lose electrons to form sulfur: $S^{2-} \rightarrow S(s) + 2e^-$.

A **reduction-oxidation reaction (redox reaction)** is a reaction that involves electron transfer. One species is oxidised while another is reduced. In a redox reaction electrons therefore move from one species to the other. Metals are good conductors of electricity and are therefore used in electrochemical cells to connect the anode to the cathode. Charges are able to move in the metal wires because delocalised electrons are present:

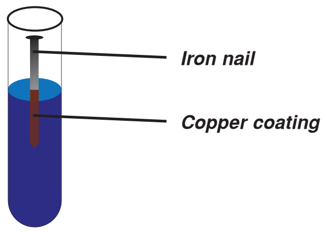


Part of a layer of metal



When the battery is connected in an electric circuit the potential difference in the battery will result in a flow of electrons

An **electrolyte** is a liquid that can conduct electricity. Electrons do not move freely through these liquids, rather it is charged ions present within the liquid that move. The effect is still the movement of charge. Many liquids with ions present are used as electrolytes. Some are pure liquid compounds and some are in solution. Some substances are more readily reduced or oxidised than others. For example, if you place a galvanised (zinc coated) nail into a solution of copper sulfate you can see a red-brown layer forming on the nail. Eventually the blue colour of the solution starts to fade.



Zinc atoms are oxidised to form zinc ions. Copper ions are reduced to form copper atoms.

In this reaction, zinc metal is oxidised to zinc ions by the copper ions in the solution. Two electrons are given off for each zinc atom that is oxidised. $Zn(s) \rightarrow Zn^{2+} + 2e^-$ The copper ions in the solution accept these electrons and become copper atoms. $Cu^{2+} + 2e^- \rightarrow Cu(s)$

These copper atoms then coat the zinc layer. This is the red-brown layer that is observed. The copper ions that are dissolved in water give the solution a blue colour. Since there are less and less of these present in the solution, the blue colour fades during the reaction. The concentration of zinc ions in the solution increases. The overall ionic reaction is:

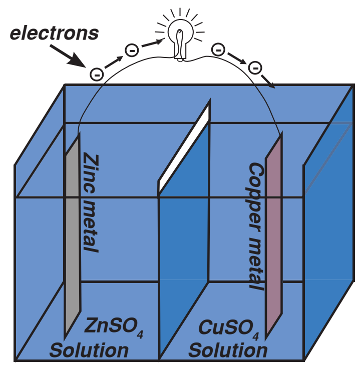
$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

The sulfate ions (SO_4^{2-}) remain unchanged in the solution and are called 'spectator' ions. The full balanced reaction, including these, can be written as:

$$CuSO_4(aq) + Zn(s) \rightarrow ZnSO_4(aq) + Cu(s)$$

The reduction and oxidation process can be physically separated by letting them take place in different compartments. An electrochemical cell, also known as a galvanic or voltaic cell, takes advantage of this situation. With a bit of engineering we have found a way to place a circuit in the middle of this reaction so that instead of electrons moving directly from the zinc to the copper, they move through an external circuit. In doing this we also separate the reduction and oxidation reactions. Both still occur simultaneously, but in different places.

The terminal at which oxidation occurs is called the "anode". For a voltaic cell or battery, this is the negative terminal.



In this picture the two half cells are separated by a membrane that allows SO_4^{2-} ions through, but not Zn^{2+} or Cu^{2+} ions.

The terminal at which reduction occurs is called the "cathode". For a voltaic cell or battery, this is the positive terminal. Since copper ions are constantly being removed from the solution containing the cathode the concentration of Cu^{2+} ions decreases, which causes the blue colour to fade. The mass of the copper electrode increases as copper atoms are formed on its surface. Zinc ions are constantly being added to the solution containing the anode, increasing the Zn^{2+} concentration. The zinc electrode loses mass as zinc atoms are removed from its surface. Once an electrode is completely eroded, or the electrolyte can no longer supply the necessary ions, the battery is said to be 'flat'.

This principle works for many combinations of metals and electrolytes, and is what batteries are based upon. Different anode-cathode combinations give different voltages to the external circuit. If you place in the external circuit a power supply that forces the electrons in the opposite direction, you can force the reactions to reverse, restoring the original state of the electrodes and electrolyte. This is what happens when you recharge a battery.

Concentrations of the electrolytes and surface area of the electrodes influence what kind of battery is produced, but all are based on the same principle: oxidation at the anode, electrons move through the external circuit, reduction at the cathode. The salt bridge/ion-selective membrane/common electrolyte all allow charges to move in the internal circuit, completing the internal (inside the cell) circuit.

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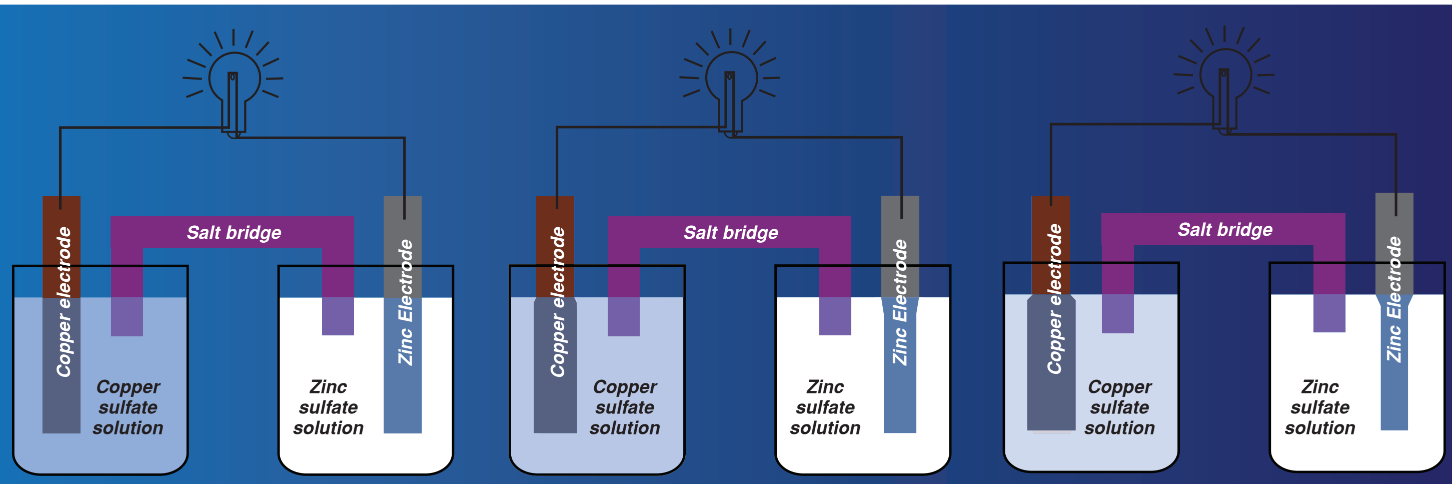


B2 BATTERIES

HISTORY OF BATTERIES

Born: 18 February 1745
Birthplace: Como, Italy (then Lombardy)
Died: 5 March 1827
Best known as: The Italian who built the first battery

Source: Wikimedia Commons

Picture of a painting by Giuseppe Bertini of Alessandro Volta demonstrating his battery to Napoleon in 1801

Source: Wikimedia Commons

Alessandro Volta

Count Alessandro Giuseppe Antonio Anastasio Volta was the Italian physicist who built the first electrochemical battery. He first gained fame across Europe in 1775 with his electrophorus, a charge-generating machine he built while teaching physics in his hometown of Como. He was appointed to the University of Pavia in 1779, where he continued his work with static electricity and built a number of gadgets. Volta's debate with anatomist Luigi Galvani about the nature of electricity in organic tissue (what Galvani called "animal electricity") caused him to experiment with metal plates, and in 1800 he succeeded in creating a sustained flow of electricity with his "voltaic pile," a stack of metal plates in a salt solution. The invention made Volta even more famous and he was called to France by Napoleon in 1801 to receive the first of many honours and decorations. The unit of measurement of electromotive force is called the volt in his honour and was adopted internationally in 1881.

This material was obtained from www.answers.com Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Answers.com. 2010. Alessandro Volta. [Online]. Available: http://www.answers.com/topic/alessandro-volta. [27 July 2010].

Volta called his battery the Voltaic Pile. He stacked alternating layers of zinc, cardboard soaked in salt water, and silver. If you attach a wire to the top and bottom of the pile, you create an electric current because of the flow of electrons. Adding another unit will increase the voltage produced by the pile.

Source: Wikimedia Commons

The Leclanché cell

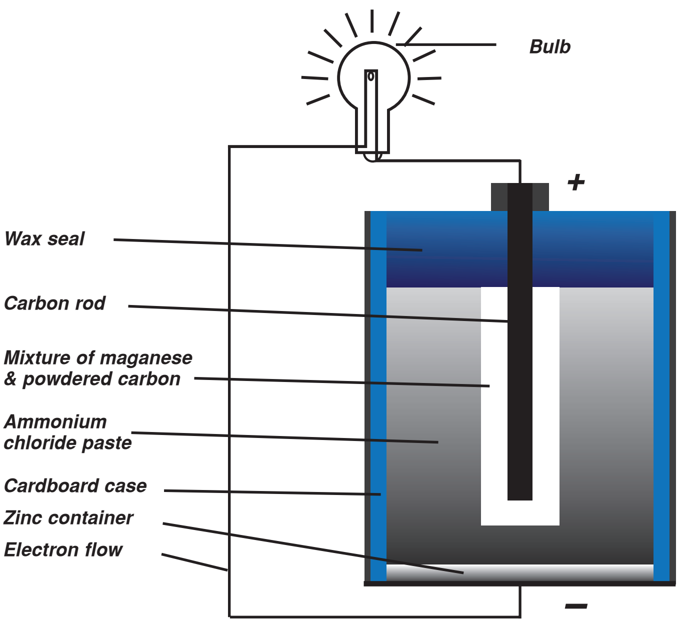
Batteries are items we use day in and day out. They make the seemingly impossible possible; they make appliances run without being connected to a power socket. It is like carrying electricity around in your pocket. The only catch here is that the device you want to use needs to be adaptable for battery usage. A battery is basically an electric cell that converts chemical energy into electricity. Some of the types of battery that we can't do without today include laptop batteries, cell phone batteries and automotive batteries.

The earliest documentation regarding electrochemical batteries dates back to 1800. Telegraph systems were using batteries in the 1830s and by the 1870s batteries had found widespread usage. The 1900s saw the usage of flashlights. The use of domestic radio receivers caught on in the 1920s.

The most common form of primary cell used is the Leclanché cell. The French chemist Georges Leclanché invented this type of cell in the 1860s. The popular name for this type of cell is a dry cell. The Leclanché cell used nowadays is surprisingly similar to its original version. The electrolyte in this cell is a mixture of ammonium chloride and zinc chloride in a paste-like form.

The negative electrode and the outside shell of the cell are made of zinc. The positive electrode is in the form of a carbon rod and is surrounded by a mixture of carbon and manganese dioxide. The voltage produced by a Leclanché cell is about 1,5 V.

The Leclanché cell



Source: Wisedude.com

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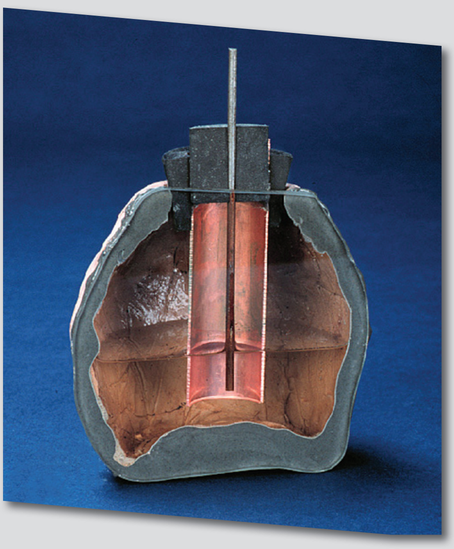
The inside of a Leclanché cell.

Photograph: René Toerien

The Baghdad Battery

The Baghdad Battery is believed to be about 2000 years old (from the Parthian period, roughly 250 BCE to CE 250). The jar was found in Khujut Rabu just outside Baghdad and is composed of a clay jar with a stopper made of asphalt. Sticking through the asphalt is an iron rod surrounded by a copper cylinder. When filled with vinegar – or any other electrolytic solution - the jar produces about 1,1 volts.

There is no written record as to the exact function of the jar, but the best guess is that it was a type of battery. Scientists believe the batteries (if that is their correct function) were used to electroplate items such as putting a layer of one metal (gold) onto the surface of another (silver), a method still practised in Iraq today.



This material was obtained from the Smith College Programme in the History of the Sciences. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Downs, D. & Meyerhoff, A. 2000. Baghdad battery. [Online]. Available: http://www.smith.edu/hsc/museum/ancient _ inventions/battery2.html. [27 July 2010].

B3 BATTERIES

TYPES OF BATTERY

CHEMICAL INDUSTRIES
RESOURCE PACK

Introduction

Electrical energy plays an important role in our daily life. It can be universally applied and easily converted into light, heat or mechanical energy. A general problem, however, is that electrical energy can hardly be stored. Capacitors allow its direct storage, but the quantities are small compared to the demand of most applications. In general, the storage of electrical energy requires its conversion into another form of energy. In batteries the energy of chemical compounds acts as storage medium and during discharge a chemical process occurs that generates energy which can be drawn from the battery in the form of an electric current at a certain voltage. For a number of battery systems this process can be reversed and the battery recharged. In other words, the intake of electric energy can restore the chemical composition that contains higher energy and can closely re-establish the original structures within the battery.

As a consequence, two different battery systems exist: Primary batteries that are designed to convert their chemical energy into electrical energy only once, and secondary batteries are reversible energy converters and designed for repeated discharges and charges. They are genuine electrochemical storage systems.

There is no clear border between them, and some primary battery systems permit charging under certain conditions. Usually, however, the extent to which primary batteries can be recharged is limited. Batteries of larger capacities are employed as standby batteries in stationary applications, and provide energy in vehicles like forklift trucks, or stabilise an electrical network like the starter battery in motor cars. Rechargeable batteries usually are the choice in such applications, since primary batteries would be too expensive for the required rather high capacity. Batteries in portable applications have smaller capacities. In this field primary as well as secondary batteries are used.

This material was obtained from the Battery Technology Handbook. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Kiehne, H. A. (Ed.) 2003. Battery Technology Handbook - Second Edition. Marcel Dekker Inc. New York.

New technology - rechargeable Batteries

22 February 2010

Until recently, rechargeable batteries would lose their charge quicker than non-rechargeable batteries. If a rechargeable was used in low-power appliances, such as a kitchen wall-clock, it would discharge quicker than a non-rechargeable battery. This gave little incentive to purchase rechargeable batteries for low power consumption appliances, because they would lose their power in weeks rather than months. Now, based on a new bio-degradable chemical technology, the Uniross Hybrio range of rechargeable batteries will lose only 20% of their charge in a year. This makes the Hybrio suitable for all types of appliances, while still ideally suited to high-power consumption devices such as digital and video cameras.

Source: This article was published online by Creamer Media's Engineering News. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Engineering News. 2010. New technology - rechargeable batteries. [Online]. Available: www.EngineeringNews.co.za [27 July 2010].

DID YOU KNOW?

The basic element of each battery is the cell. The term 'battery' generally refers to several cells being connected in series or in parallel, but in everyday language single cells are also called 'batteries'; for example the 'battery' used in a torch light.

WHAT IS ENERGY DENSITY?

Energy density is the ratio of a battery's energy-delivery capability to its mass. It is measured in watt-hours per kilogram ($Wh \cdot kg^{-1}$).

Will secondary batteries replace primaries?

Consumer market aside, the largest users of primary (non-rechargeable) batteries are the military, specialty emergency services and forest fire fighters. High energy density, long storage and operational readiness are among their strong attributes. No charging and priming is required before use. Logistics are simple and battery power can be made available at remote locations that are unmanned and have no electrical power. Disposal is easy because most primary cells contain little toxic materials.

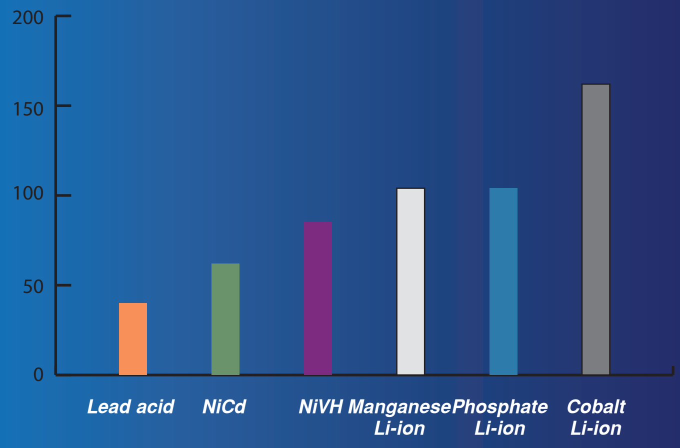
Primary batteries have the highest energy density. Although the secondary (rechargeable) batteries have improved, a regular household alkaline provides 50% more power than lithium-ion, one of the highest energy-dense secondary batteries. The primary lithium battery used in cameras holds more than three times the energy of a lithium-ion battery of the same size. A disadvantage of primary batteries is their relative high internal resistance, which inhibits current flow. High internal resistance has little effect when powering low-current devices such as a television remote control or a kitchen clock. The problem arises with digital cameras and other power-hungry devices. A power drain on an alkaline battery would be unthinkable. The voltage would cause collapse. We now take the same batteries and run them under a load. The purple bars in the bottom graph on the right represent the usable energy if the batteries were used in a device such as a digital camera.

The advantage of secondary batteries therefore is low internal resistance. This allows high current on demand, a property that is essential for digital devices and instruments needing high inrush currents. Power tools, for example, could not be run effectively on alkaline batteries. However, rechargeable batteries have their limitations. Beside marginal energy density, secondary batteries have a defined shelf life and lose the ability to hold charge as they age. Secondary batteries have a limited cycle count. The number of cycles achieved is based on the depth of discharge, environmental conditions, charge methods and maintenance procedures. Each type of battery behaves differently in terms of aging and wear.

A comparison between different types of battery

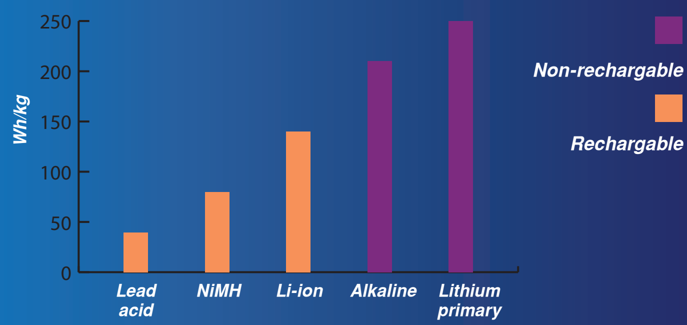
Type	Voltage	Rechargeable?
Dry cell	1,5	No
Alkaline	1,54	No
Mercury	1,3	No
Lithium-iodine	2,8	No
Lead storage	2,0	Yes
Nickel-cadmium	1,46	Yes

This material was obtained from BatteryUniversity.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Buchmann, I. 2005. Batteryuniversity.com - What's the best battery for wheeled and stationary applications? [Online]. Available: www.batteryuniversity.com/parttwo-40.htm. [27 July 2010].



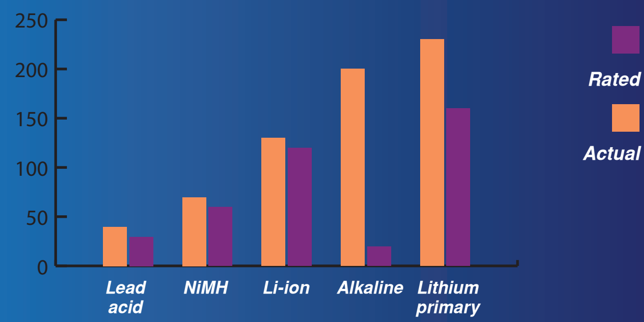
Energy densities of common battery chemistries: Lithium-cobalt enjoys the highest energy density. Manganese and phosphate systems are thermally more stable and deliver higher load currents than cobalt.

Source: BatteryUniversity.com



Energy comparison of rechargeable and non-rechargeable batteries

Source: BatteryUniversity.com



Energy comparison under load. The alkaline works well for a kitchen clock but fails on a digital camera.

Source: BatteryUniversity.com

DID YOU KNOW?

An ampere-hour or amp-hour (symbol Ah or A·h) is a unit of electric charge. One ampere-hour is equal to 3 600 coulombs (ampere-seconds), the electric charge transferred by a steady current of one ampere for one hour. The unit of milliampere-hour (mAh or mA·h) is often used. This refers to one-thousandth of an ampere-hour, or 3,6 coulombs.

B4 BATTERIES

CAR BATTERIES

CHEMICAL INDUSTRIES RESOURCE PACK

Lead-acid batteries

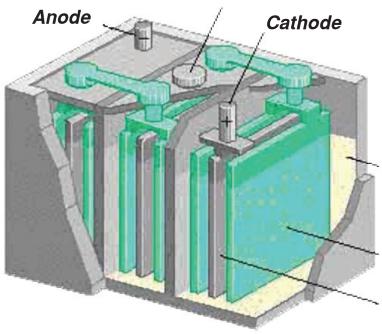
The modern lead-acid battery is by far the most familiar rechargeable storage cell technology. The lead-acid cell was invented in 1859 by a French physicist, Gaston Plante. It uses dilute sulfuric acid for an electrolyte, lead for the anode, and lead oxide for the cathode. The sulfuric acid dissociates into two hydrogen ions (protons) and a sulfate group. The sulfate group reacts with the lead anode to form lead sulfate and releases two electrons through the external circuit. Pb^0 is oxidised to Pb^{2+} and 2 electrons are released:

$$Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$$

At the cathode, the two electrons are taken up by the lead dioxide to form lead sulfate and water. Four H^+ ions also take part in this reaction. Pb^{4+} is reduced to Pb^{2+}:

$$PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$$

As the reaction proceeds, lead sulfate deposits on the electrodes, and the current drops because the contact between the electrolyte and electrodes is reduced. Feeding a current of more or less 2A will reverse the reaction to break down the lead sulfate to form lead dioxide and produce sulfuric acid from the water, therefore recharging the cell.



The basic structure of a lead-acid battery

Source: Colorado College

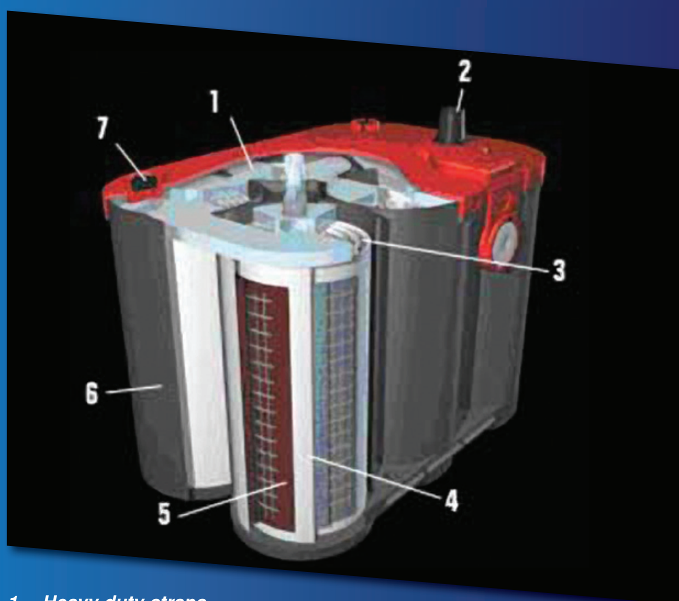
A standard automotive battery consists of a box-shaped casing with internal divider walls to separate its series-connected cells. The electrodes in each cell are built as sets of interleaved plates to provide the maximum surface area for the electrochemical reaction. Each cell in a lead-acid battery provides about two volts. They usually consist of six cells in series to provide a total of 12 V. Lead-acid batteries usually have large capacities, though they tend to run down quickly.

They can be recharged hundreds of times until their electrodes are too eroded to allow the battery to hold a charge. They have indefinite shelf lives if stored without electrolyte. Lead-acid batteries are cheap and effective, and at present the battery of choice where high power capacities are required at sensible cost.

A new type of lead-acid battery was introduced in the late 1990s and operates on the same chemical principles, but has a radically different construction. The electrodes are formed as thin plates, with the electrolyte stored in a separator sheet between the plates, and stored in a sealed can in a "wound" or "jelly-roll" configuration. The improved battery configuration provides higher energy density, though the environmental issues remain much the same. This is about the only significant innovation in lead-acid battery design in over a century of the technology's existence.

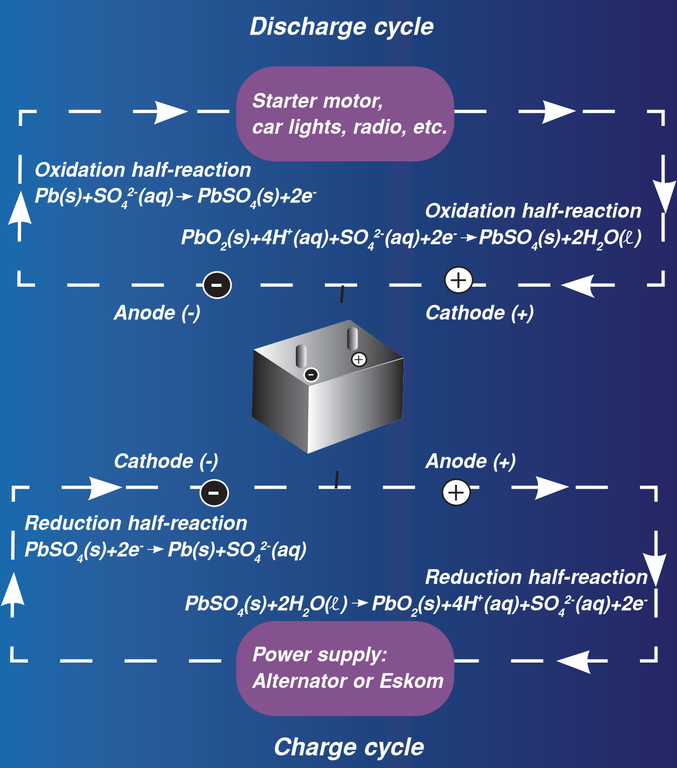
This material was obtained online from www.vectorsite.net. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Goebel, G. 2008. Batteries and Fuel Cells. [Online]. Available: http://www.vectorsite.net/tpchem _ 12.html. [27 July 2010].

Latest design for lead-acid batteries using the Optima patented Spiralcell Technology



1. *Heavy duty straps*
2. *Corrosion resistant terminals*
3. *SpiralCell construction*
4. *Absorbent glass mat separator holds electrolyte like a sponge*
5. *High purity lead grids for long life*
6. *Impact resistant polypropylene case*
7. *Resealable pressure relief valve with flame trap*

Source: Optima Battery



The reactions that occur during discharge can be reversed. The discharge reaction is spontaneous and when charging, an external power supply is used to drive a non-spontaneous reaction.

What's the best battery for the electric vehicle?

The electric vehicle will gain public acceptance as soon as a battery emerges that is inexpensive and provides 10 years of reliable service. The high cost and limited cycle life of the batteries used in hybrid vehicles negate the savings achieved in burning less fuel. The current benefits are environmental in nature rather than in cost savings. Higher fuel prices could force a shift towards battery powered vehicles.

Nickel and lithium-based batteries have been tried but both chemical reactions have problems with durability and stability. Lithium-ion has an advantage in weight but this gain is offset by a high price. Similarly, nickel-metal-hydride used for the hybrid vehicle is expensive and requires forced air-cooling. No battery manufacturer is willing to commit to a 10-year warranty. After excursions into new battery chemistries, design engineers always come back to the old but proven lead-acid battery.

The fuel cell may still be two decades away before offering a viable alternative for cars. An executive from Ford stated recently that it may never be feasible to replace the internal combustion engine with fuel cells. Cost and longevity remain major drawbacks.

This material was obtained from Batteryuniversity.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Buchmann, I. 2005. Batteryuniversity.com - What's the best battery for wheeled and stationary applications? [Online]. Available: www.batteryuniversity.com/parttwo-40.htm. [27 July 2010].

Sodium-sulfur battery

In contrast to the traditional battery, which houses solid electrodes and liquid (or slurried) electrolyte, this design incorporates liquid electrodes separated by a solid electrolyte. Molten sodium (Na) (melting point 98°C) is the anode, and molten sulfur (S) (melting point 113°C) is the cathode (mixed with powdered graphite to improve conductivity). The sodium loses electrons, which pass through the external circuit (wire and stainless-steel electrode housing) and reduce the sulfur (S) to polysulfide ions (S_n^{2-}). The electrolyte is β-alumina, a mixture of metal (Na, Mg, Al) oxides that allows sodium ions to pass through and reach the sulfur ions.

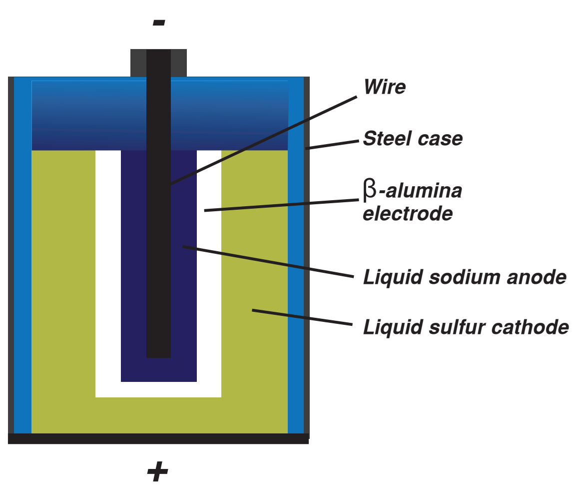
Advantages: Na-S batteries can provide four to five times the energy per unit mass and undergo about three times as many discharge-recharge cycles as lead-acid batteries.

Disadvantages: Moderate speed and short discharge time: a BMW powered by a 265-kg Na-S battery had a top speed of 96 km·h^{-1} and a cruising range of 160 km; earlier versions had long recharge times (16 h). A temperature of 350°C must be maintained to keep reactants and products molten and a high sodium conductivity in the β-alumina.

$2Na(\ell) \rightarrow 2Na^{+}(\ell) + 2e^{-}$

$S(\ell) + 2e^{-} \rightarrow S_n^{2-}(\ell)$

$2Na + 4S \rightarrow Na_2S_4 \quad E_{cell} = 2\ V$



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DID YOU KNOW?

A lead-acid battery self-discharges at only ~5% per month or ~50% per year.

B5 BATTERIES

BUTTON CELLS

CHEMICAL INDUSTRIES
RESOURCE PACK

Mercury button cells

Calculators, hearing aids, and other small electronics devices use tiny non-rechargeable "button" cells. The original technology for button cells was the mercury cell, which had a mercuric oxide (HgO) cathode, an anode made of an amalgam of mercury and zinc, and an electrolyte consisting of potassium hydroxide mixed with zinc hydroxide (or $Zn(OH)_2$).

The **anode** reaction is:

$$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$$

The **cathode** reaction is:

$$HgO + H_2O + 2e^- \rightarrow Hg + 2OH^-$$

Mercury cells had a highly constant cell voltage of 1,35 volts. A similar cell could be made with cadmium instead of zinc, providing a cell voltage of 0,91 volts. Since mercury is toxic, mercury cells are now banned in the US and some other countries; they are now only a historical curiosity.

Zinc-air button cells

Modern zinc-air button cells are similar to alkaline cells. The anode is powdered zinc mixed in a gel, the electrolyte is a layer of potassium hydroxide, and the cathode is a carbon disk, designed to support cathode reactions through the oxygen in the air. A porous teflon membrane allows air into the cell while preventing the electrolyte from leaking out.

The **anode** reaction is:

$$Zn + 2OH^- \rightarrow Zn(OH)_2 + 2e^-$$

The **cathode** reaction is:

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

Zinc-air batteries have a cell voltage of about 1,65 volts. They have a very high energy density, but also have a high internal resistance and are not well suited to high-current applications. They have a long shelf-life provided that they are kept sealed.

Large zinc-air cells have been used in consumer equipment, at least on a limited basis, and very large zinc-air batteries have been experimentally used in vehicles.

Silver-oxide button cells

The silver oxide cell is similar in construction to the zinc-air type, with an anode of powdered zinc in gel with a potassium hydroxide electrolyte, except that instead of having a cathode made of carbon and exposed to the air, it is a silver screen pasted with silver oxide (Ag_2O). They have a cell voltage of 1,55 volts, a flat discharge curve, and long shelf life. They are not generally recharged, but can be recharged a limited number of times.

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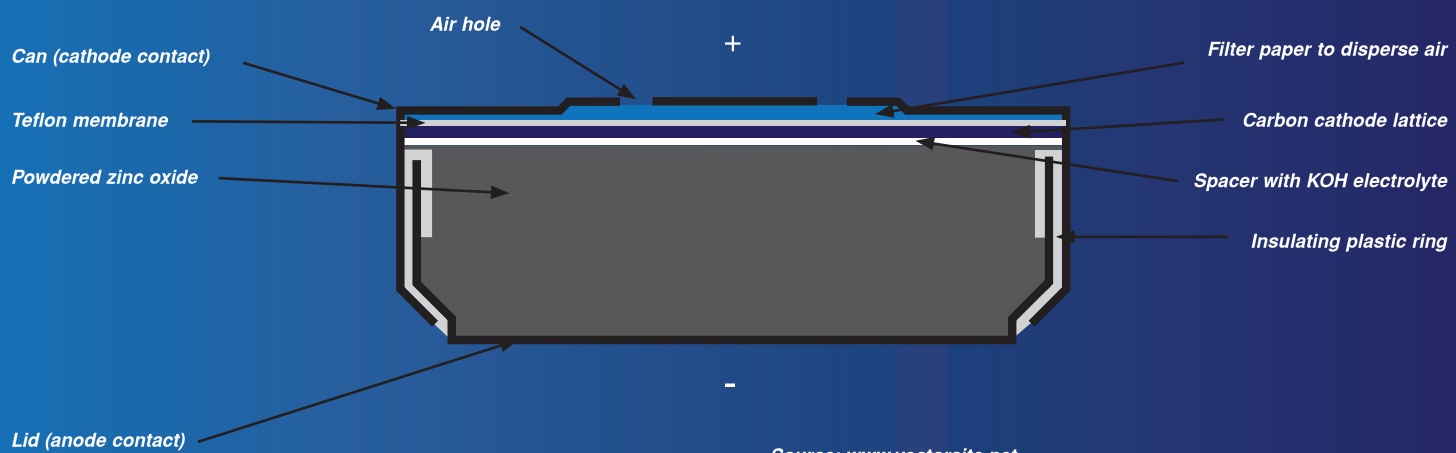
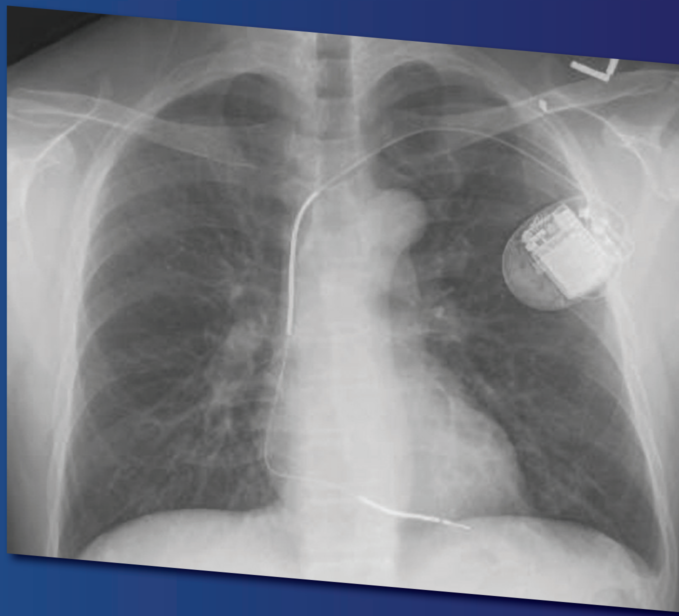
Zinc-air button cell



Source: www.vectorsite.net

An implantable cardioverter-defibrillator (ICD)

Source: Wikipedia



A normal chest X-ray after placement of an ICD

Source: Wikipedia

Comparing button cells

The mercury cell and the silver cell are quite similar. Both use a zinc anode in a basic medium as the reducing agent. The one employs HgO as the oxidising agent, the other Ag_2O, and both use a steel cathode. The solid reactants are compacted separately with KOH, with moist paper for a salt bridge. These cells are most commonly used in watches and calculators, with the silver cells used in cameras, heart pacemakers, and hearing aids. Both are very small, with relatively large voltage. The silver cell has a very steady output and is non-toxic. Discarded mercury cells could release the toxic metal in the environment. Silver cells are expensive.

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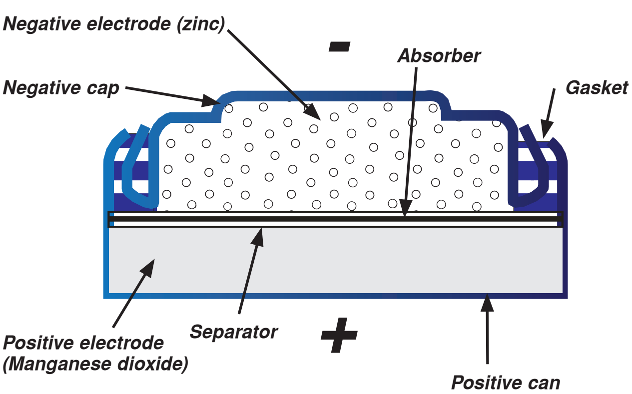
Section through a mercury button cell



Source: Battery Handbook

Batteries in pacemakers

The earliest practical implantable cardiac pacemakers appeared in the late 1950s, powered by Zn/HgO batteries. Throughout the 1960s most implanted pacemakers continued to use Zn/HgO batteries. However, following the introduction of lithium/iodine batteries for cardiac pacemakers in 1972, the usage swung rapidly toward electrochemical power sources based on lithium.

Several lithium-based battery chemistries were introduced. The lithium/iodine system has provided small, simple, highly reliable power sources with power characteristics almost ideally suited to the requirements of cardiac pacing for more than three decades.

The hybrid cathode battery system has since been introduced in other implantable devices including cardiac pacemakers, hemodynamic monitors and drug-delivery devices. The total number of implants powered by hybrid cathode batteries stood at more than 100 000 in January 2005.

In the future this chemistry is expected to find application in the full range of implantable device applications requiring primary batteries, including devices that constantly monitor the rate and rhythm of the heart and can deliver therapies, by way of an electrical shock.

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Zinc-carbon cells

Zinc-carbon cells are used in all regular AA, C and D dry-cell batteries which are used for general appliances such as remote controls, flashlights and toys.

The structure

The zinc-carbon cell (also known as the dry Leclanché cell) is a primary cell. It consists of an outer zinc container, which acts as the anode, and a carbon (graphite) rod surrounded by a mixture of carbon powder and manganese dioxide, which forms the cathode. The manganese dioxide converts the protons that are formed to water. The carbon powder increases the surface area of the electrode and lowers the internal resistance of the cell. The electrolyte used is a paste of zinc chloride and ammonium chloride dissolved in water. The old Leclanché cell was a wet cell consisting of an electrolyte of a strong solution of ammonium chloride. The anode and cathode of the zinc-carbon cell are separated by a sheet of porous material such as paper or cardboard which is soaked in the electrolyte and is called the separator. If the electrode materials were to react together, it would result in the zinc anode being worn away which would decrease the life of the battery. The zinc-carbon cell has an emf of 1,5 volts.

The reactions

The **oxidation reaction** takes place at the anode:
$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

The **reduction reaction** takes place at the cathode:
$2MnO_2(s) + 2H^+(aq) + 2e^- \rightarrow Mn_2O_3(s) + H_2O(\ell)$

The H^+ comes from the $NH_4^+(aq)$ when the electrolyte is dissolved in water: $NH_4^+(aq) \rightarrow H^+(aq) + NH_3(aq)$

The overall reaction is:
$Zn(s) + 2MnO_2(s) + 2NH_4Cl(aq) \rightarrow Mn_2O_3(s) + H_2O(\ell) + Zn(NH_3)_2Cl_2(aq)$

Advantages and Disadvantages:

- The zinc casing of the zinc-carbon cell begins to thin because the ammonium found in the electrolyte is acidic; it therefore reacts with zinc which causes the zinc to be eaten away. This causes the electrolyte to leak out of the battery.

- The zinc-chloride cell is an improvement on the zinc-carbon cell as it has a longer shelf-life and gives a steadier voltage output as it is used. The electrolyte mixture of the zinc-chloride cell is a zinc chloride paste rather than an ammonium chloride paste.

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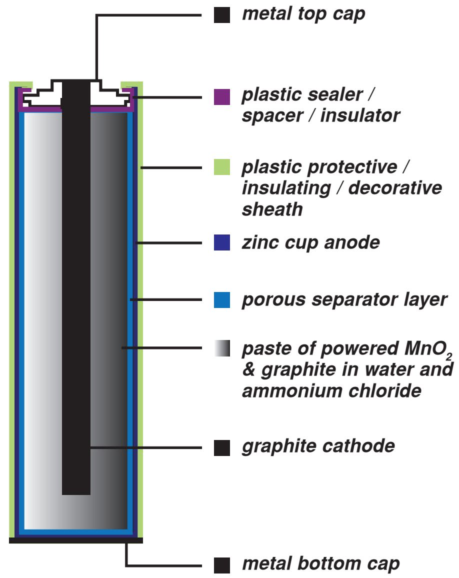
Zinc-carbon cell



Source: www.vectorsite.net

Household items that use batteries

Alkaline cells

Alkaline primary cells resemble zinc-carbon cells very closely because they have the same materials for the electrodes, which both undergo similar reactions. However, there are a number of differences between these two types of cells - primarily that an alkaline paste (hence the name) such as potassium hydroxide is used as the electrolyte. Alkaline cells have the ability to deliver more current. They also last from five to eight times as long as zinc-carbon cells, and produce an emf of 1,5V. Essentially, the energy is derived from a reaction of a metal to form the metal oxide.

The structure

The structure and functioning of this cell is similar to the dry Leclanché cell. However, the anode is made of zinc powder, which allows for an increased rate of reaction and therefore an increased current and a decreased internal resistance. The cathode is a mixture of high purity electrolytic manganese dioxide and carbon, like the carbon-zinc cell. A highly reactive paste of potassium hydroxide (which is an alkali solution) is the electrolyte. Alkaline cells are your general torch, clock and toy batteries. The negative terminal of the cell is the flat end and the positive terminal is the end with the raised button. There is a separator electrically separating the anode and the cathode, and graphite is added to the cathode to increase conductivity.

The reactions

The **anode reaction** is:

$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(\ell) + 2e^-$

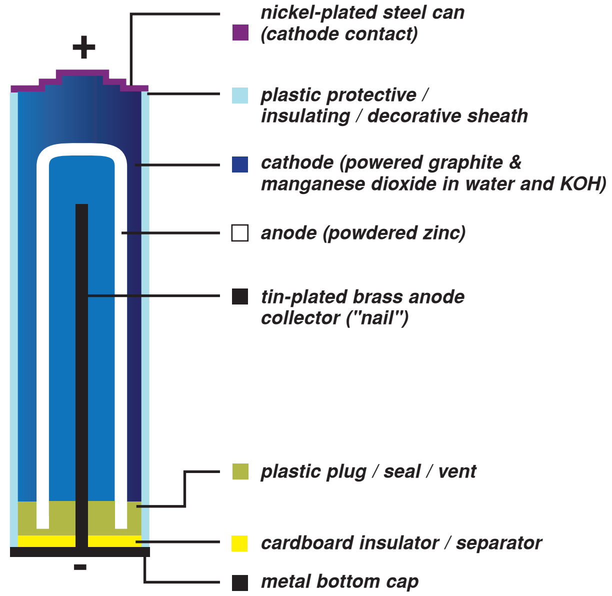
The **cathode reaction** is:

$2MnO_2(s) + H_2O(\ell) + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-(aq)$

Some properties of the alkaline cell

- The faster the alkaline cell is drained, the higher percentage of the load it gives out as heat energy. Therefore the capacity of such a battery is determined by the load. An AA-sized battery might have a high capacity when used in an alarm clock, for example, but when used in a digital camera, the capacity decreases greatly.
- The zinc anode oxidises more readily than that of a zinc-carbon cell. The electrolyte of this cell conducts electricity inside the cell better than the electrolyte in the zinc-carbon cell. Therefore, an alkaline cell can deliver a higher current for a longer period of time.
- No gases are formed during the reaction.
- It has a good shelf-life.
- Better low temperature performance than the equivalent zinc-carbon cell.
- 25% heavier than the zinc-carbon cell.
- More expensive than the Leclanché cell.
- Less leakage than the Leclanché cell.

Alkaline cell



All cells are covered with a plastic sheath to provide protection, insulation, and labelling. Alkaline cells have about twice the power density of carbon-zinc cells, but are several times more costly. Both carbon-zinc and alkaline cells have a cell voltage of about 1,5 volts, and are both regarded as environmentally friendly, at least by the standards of storage cells. Carbon-zinc and alkaline storage cells are not in general rechargeable, though rechargeable alkaline cells have been produced.

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Alkaline cells are used in toys

B7 BATTERIES

NICKEL TECHNOLOGIES

CHEMICAL INDUSTRIES RESOURCE PACK

Nickel-cadmium cells

Nickel-cadmium cells were invented in 1899 by a Swede by the name of Waldmar Jungner, however they were only mass produced in the early 1960s because they were so expensive. Today they are most commonly used in motorised equipment, power tools, two way radios, electric razors, commercial and industrial portable products, medical instrumentation, emergency lighting and toys.

The structure

Nickel-cadmium cells fall under the category of secondary cells which means they are rechargeable. They produce an emf of 1,2 volts. The nickel-cadmium cell (NiCD) is covered in a metal case and contains a cadmium electrode and a nickel hydroxide electrode which are separated from each other by a separator which prevents the electrode materials mixing together and reacting with each other while the cell is not in use. The electrolyte used in the nickel-cadmium cell is an alkaline electrolyte, which is often potassium hydroxide, and is not consumed in the reaction.

The reactions

The reaction at the cadmium electrode (**anode**) is:

$$Cd + 2OH^- \rightarrow Cd(OH)_2 + 2e^-$$

The reaction at the nickel hydroxide electrode (**cathode**) is:

$$2NiO(OH) + 2H_2O + 2e^- \rightarrow 2Ni(OH)_2 + 2OH^-$$

Therefore the overall reaction is:

$$2NiO(OH) + Cd + 2H_2O \rightarrow 2Ni(OH)_2 + Cd(OH)_2$$

During the recharge cycle the reaction goes in the reverse direction.

Over-charging

Overcharging a NiCD cell can damage the cell. Overcharging at the anode produces hydrogen gas and overcharging at the cathode produces oxygen gas. Because of this the anode always has a higher capacity than the cathode because the release of hydrogen gas could cause an explosion. NiCD cells therefore need to have vents to allow the release of oxygen that is formed inside the cell but once the oxygen is released the cell needs to be resealed. This complex sealing mechanism needed in the NiCD cells increases their manufacturing cost.

Advantages and disadvantages

- Compared to an alkaline cell the NiCD cell has a longer shelf-life.
- Nickel metal hydride (NiMH) cells are very similar to NiCD cells except they have a higher capacity and are less toxic but are slightly more expensive.
- NiCD cells have a low internal resistance.
- NiCD cells have a quarter of the capacity of alkaline cells.
- NiCD cells can recharge at a fast rate and the recharge reaction is endothermic so the cell does not over-heat.
- Lead-acid batteries are the most common alternative to NiCD cells. Although NiCD cells are generally much more costly than lead-acid batteries, they have a higher energy density which means they are smaller and lighter than lead-acid batteries.

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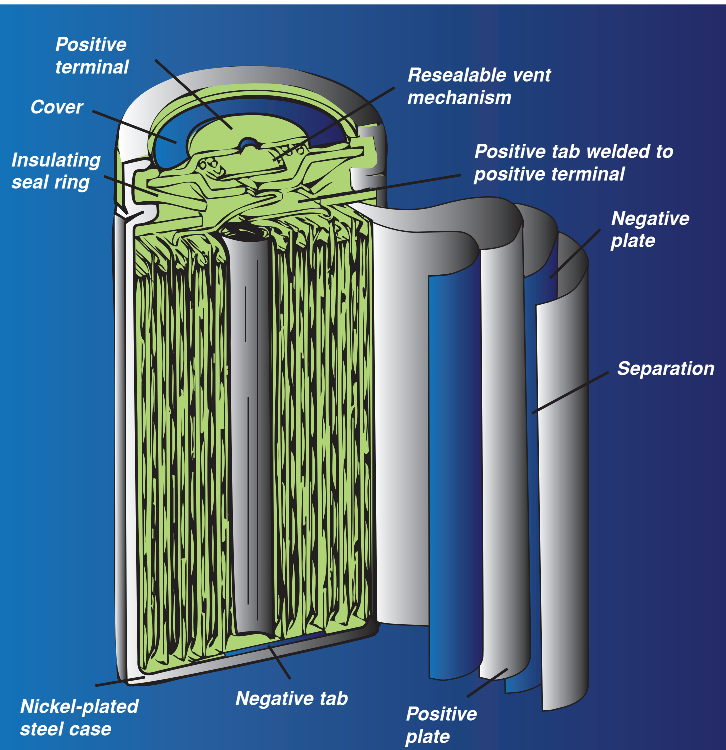

Nickel-based batteries exhibit a relatively high self-discharge. At ambient temperature, a new nickel-cadmium loses about 10% of its capacity in the first 24 hours after charge. The self-discharge settles to about 10% per month afterwards. The self-discharge increases after a nickel-based battery has been cycled for a few hundred times.

Source: BatteryUniversity.com

Memory

It is commonly believed that when rechargeable batteries are not fully discharged between charge cycles that they remember the shortened cycle and are thus reduced in capacity (length of use per charge). This problem was very common with rechargeable batteries up until about 1998. With improvements in batteries and charging technology this 'Memory Effect' is becoming a thing of the past. 'Memory Effect' is the common term used to replace the more accurate term 'Voltage Depression' (VD). VD does not necessarily permanently damage a battery. It can most likely be corrected by fully charging and discharging the battery. VD can be affected by the discharge rate of a battery. Generally speaking, the depth of discharge will be less on discharges at the higher rates. The phenomenon occurs primarily in NiCD batteries. NiMH batteries are almost never affected and Li-ion batteries are never affected.

This material was obtained online from www.zbattery.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Zbattery.com. 2010. Battery Memory Effect. [Online]. Available: http://www.zbattery.com/Battery-Memory-Effect. [27 July 2010].

The effect of crystalline formation

The problem with nickel-cadmium is not so much the cyclic memory but the effects of crystalline formation. The active cadmium material is present in finely divided crystals. In a good cell, these crystals remain small, obtaining maximum surface area. With memory, the crystals grow and conceal the active material from the electrolyte. In advanced stages, the sharp edges of the crystals penetrate the separator, causing high self-discharge or electrical short. When introduced in the early 1990s, nickel-metal-hydride was promoted as being memory-free. Today, we know that this chemistry is also affected but to a lesser degree than nickel-cadmium. The nickel plate, a metal that is shared by both chemistries, is partly to blame. The stages of crystalline formation of a nickel-cadmium cell are illustrated in diagrams below. The enlargements show the cadmium plate in a proper functioning crystal structure, crystalline formation after use (or abuse) and restoration.

This material was obtained online from BatteryUniversity.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Buchmann, I. 2005. BatteryUniversity.com Memory: Myth or fact? [Online]. Available: www.batteryuniversity.com/parttwo-33.htm. [27 July 2010].

Nickel-cadmium rechargeable cells in recharger

The alternative: Nickel Metal Hydride (NiMH) technology

Most NiMH designs are similar to NiCD designs, but replace the cadmium anode with a "metal hydride", based on complex metallic alloys that can store large quantities of hydrogen. The cathode is nickel oxide, the electrolyte is a solution of potassium hydroxide, stored in a polymer separator sheet.

The **anode** reaction, with "(M)" representing the metal hydride, is:

$$(M)H + OH^- \rightarrow (M) + H_2O + e^-$$

The **cathode** reaction is:

$$NiOOH + H_2O + e^- \rightarrow Ni(OH)_2 + OH^-$$

NiMH cells have a typical cell voltage of 1,2 volts, which tends to remain flat through the cell discharge cycle. They tend to have a high self-discharge rate, but are environmentally friendly, at least by the standards of storage cells.

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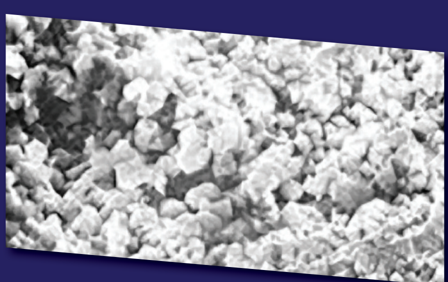
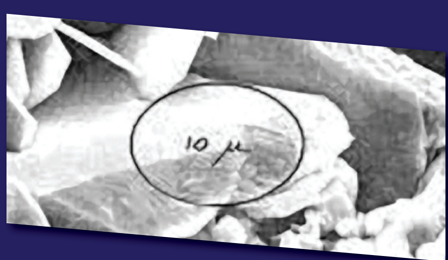
Crystalline formation on nickel-cadmium cell



New nickel-cadmium cell. The anode is in fresh condition. Hexagonal cadmium hydroxide crystals are about 1 micron in cross section, exposing large surface area to the electrolyte for maximum performance.



Cell with crystalline formation. Crystals have grown to 50 to 100 microns in cross section, concealing large portions of the active material from the electrolyte. Jagged edges and sharp corners may pierce the separator, leading to increased self-discharge or electrical short.

Restored cell. After pulsed charge, the crystals reduced to 3 to 5 microns, an almost 100% restoration. Exercise or reconditioning are needed if the pulse charge alone is not effective.

Illustration courtesy of the US Army Electronics Command in Fort Monmouth, NJ, USA.

B8 BATTERIES

LITHIUM TECHNOLOGY

Lithium cells

Lithium is an excellent material for making storage cell anodes, since it gives up electrons very easily and is very light. Lithium cells can provide an order of magnitude better energy density than lead-acid cells. One of the big problems with lithium is that it reacts violently with moisture, and manufacturing lithium cells requires a moisture-free environment.

Lithium cells also require venting and other safety systems to keep them from exploding if moisture does infiltrate the case, or if such cells are heated. The safety issues delayed their use for a long time. There is a large range of lithium cell technologies. They can be basically divided into non-rechargeable lithium cells, and rechargeable "lithium-ion" cells.

The conceptually simplest and most common non-rechargeable lithium cell is the "lithium-manganese" cell. This has a lithium anode, a manganese dioxide cathode, and a carbonate electrolyte.

The **anode** reaction is: $Li \rightarrow Li^{+} + e^{-}$

The **cathode** reaction is: $MnO_2 + Li^{+} + e^{-} \rightarrow MnO_2(Li)$

The cell voltage is about 3 volts. Such cells are constructed in a jelly roll configuration, with a sheet of lithium foil, a separator sheet containing electrolytic salts, and a sheet of manganese dioxide rolled up together. They have an indefinite shelf life.

There are many other non-rechargeable lithium cell configurations, such as "lithium sulfur dioxide", "lithium thionyl chloride", and "lithium polycarbonate monofluoride", with complicated constructions and chemistries that are substantially more capable than lithium-manganese but not as cheap, and so not in as widespread use. The latest generation of non-rechargeable lithium cells uses a polymeric electrolyte. Such "lithium polymer" cells have electrical characteristics similar to those of the predecessors, but they can be more easily built in flat or rectangular configurations that are very useful for lightweight portable equipment.

The latest generation of rechargeable lithium-ion cells feature electrodes made of phosphides of manganese and iron, made of "nano-sized" particles. These new cells are much more robust, have longer lifetimes, and can take a full charge in a matter of minutes.

Lithium-ion technology

Lithium-ion technology has not yet fully matured and is being improved continuously. New metal and chemical combinations are being tried constantly to increase energy density and prolong service life. The improvements in longevity after each change will not be known for a few years.

A lithium-ion battery provides 300-500 discharge/charge cycles. Although lithium-ion is memory-free in terms of performance deterioration, batteries with fuel gauges exhibit what engineers refer to as "digital memory". Here is the reason: short discharges with subsequent recharges do not provide the periodic calibration needed to synchronise the fuel gauge with the battery's state-of-charge. A deliberate full discharge and recharge every 30 charges corrects this problem. Letting the battery run down to the cut-off point in the equipment will do this. If ignored, the fuel gauge will become increasingly less accurate.

All personal computers (and some other electronic devices) contain a battery for memory back up. This battery is commonly a small non-rechargeable lithium cell, which provides a small current when the device is turned off. The PC uses the battery to retain certain information when the power is off.

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Laptop battery

Overcharging can damage batteries

Source: Wikimedia Commons

Counterfeit cell phone batteries (clone batteries)

In the search for low-cost battery replacements, consumers may inadvertently purchase clone cell phone batteries that do not include an approved protection circuit. Lithium-ion packs require a protection circuit to shut off the power source if the charger malfunctions and keeps on charging, or if the pack is put under undue stress (electrical short). Overheating and 'venting with flame' can be the result of such strain.

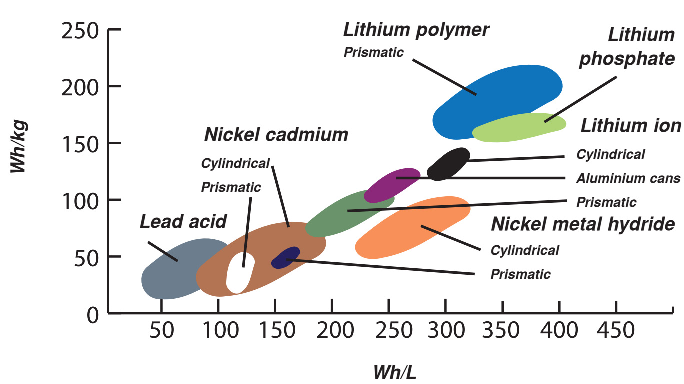
Cell phone manufacturers strongly advise customers to replace the battery with an approved brand. Failing to do so may void the warranty. Counterfeit cell phone batteries have become visible since the beginning of 2003 when the world was being flooded with cheap replacement batteries from Asia.

Heat is the main killer of batteries. A Canadian manufacturer of lithium-polymer batteries is taking advantage of the heat problem. They offer lithium-polymer for standby applications, a battery that needs heat to operate. The high cost remains a drawback and only a few lithium-polymer batteries are used for stationary applications today.

These batteries may be stored and operated within an extremely wide temperature range. Most of the lithium primary batteries may be stored for 10 to 20 years with negligible self-discharge, so that they still deliver most of their nominal capacity. They are continuously active, i.e. at all times ready for service. Typically, only 5% to 10% self-discharge after 10 years at normal temperature storage. Compared to metals used for common batteries such as lead or nickel and cadmium, lithium is not as poisonous as these to biological systems. Disposal of used lithium batteries is therefore a smaller problem.

This material was obtained online from BatteryUniversity.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Buchmann, I. 2005. Part Two: Getting the most from your battery. [Online]. Available: http://www.batteryuniversity.com/parttwo.htm. [27 July 2010].

Secondary cell energy densities



Source: Wikimedia Commons

B9 BATTERIES

RECYCLING

CHEMICAL INDUSTRIES
RESOURCE PACK

Recycling lead-acid batteries

Few people might be aware of one of the most exceptional environmental success stories of our time - the recycling of the lead-acid battery. In the USA, for instance, lead-acid batteries top the list of the most highly recycled consumer products at 93% compared to the 42% of newspapers, 55% of aluminium soft drink and beer cans, and 40% of plastic soft drink bottles.

This success story is due, in part, to the closed loop life cycle of the lead-acid battery which is 98% recyclable. Initially the battery is broken apart in a hammermill. The broken pieces go into a vat or flotation pond where the lead and heavy materials sink to the bottom while the plastic remains afloat. At this stage of the process, the polypropylene pieces are scooped away and the liquids are drawn off leaving the lead and heavy metals behind.

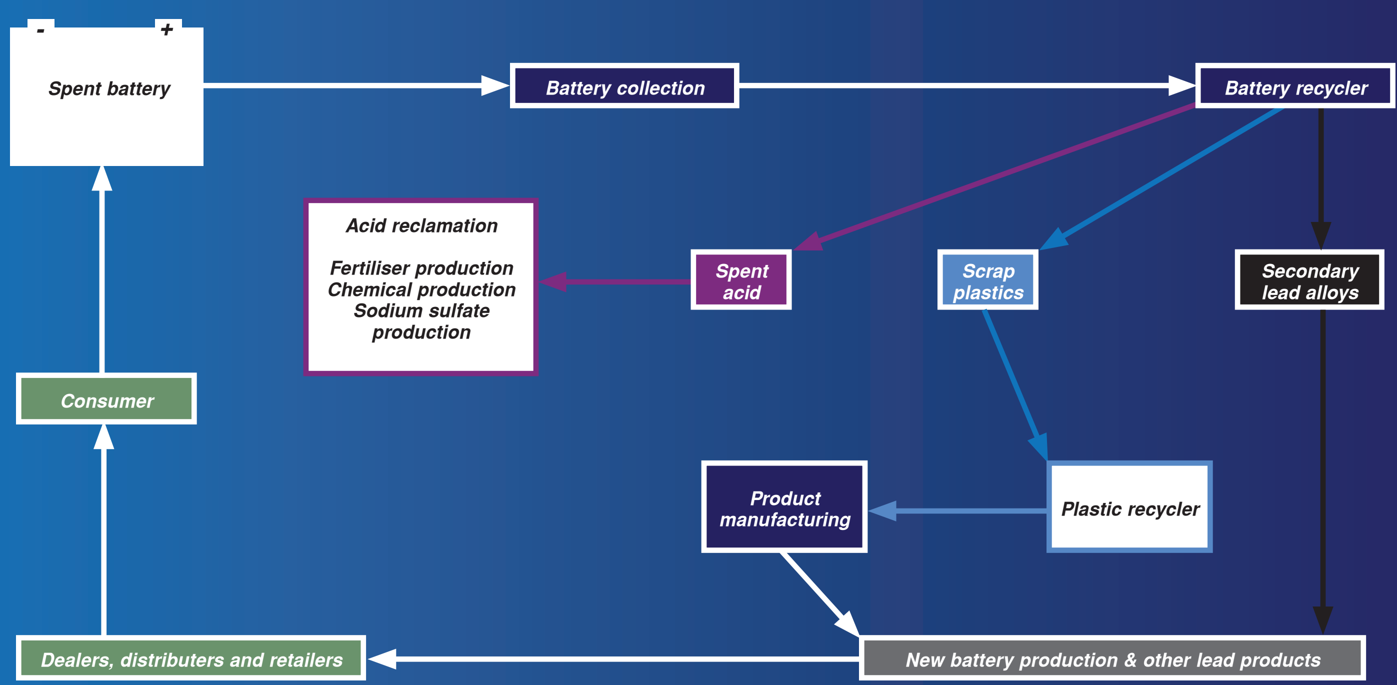
The polypropylene, or plastic pieces are washed, air dried and then melted together into an almost liquid state. The molten plastic is then put through an extruder that produces small uniform plastic pellets. These pellets are then used to manufacture new battery cases.

The lead grids, lead oxide and other lead parts are cleaned and melted together in a smelting furnace along with additives used to help in the removal of impurities. The molten lead is poured into ingot moulds. After a couple of minutes, the impurities, or dross, float to the top of the still molten lead in the moulds and are scraped away. The ingots are then left to cool. Once they have cooled, they are removed and are then ready to be resmelted to produce new lead plates and other parts for new batteries.

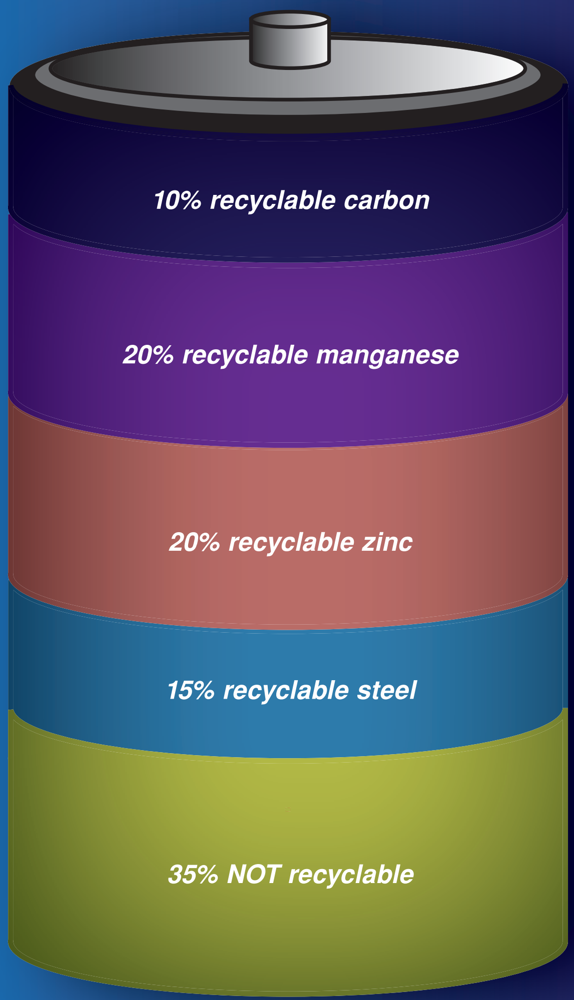
Old battery acid is handled in two ways. The acid is neutralised with an industrial compound similar to household baking soda. The water that is formed is treated, cleaned and tested to ensure that it meets clean water standards. It is then released into the public sewerage system. The sodium sulfate that is formed is used in laundry detergent, glass and textile manufacturing. Thus a potentially noxious substance is transformed into a useful reusable product.

This material was obtained from Willard Batteries. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Willard Batteries. 2010. Bringing Indigenous Trees to Africa. [Online]. Available: http://www.willard.co.za/recycle.html. [27 July 2010].

Flowchart: Lead-acid battery recycling process



Source: Gravita Exim Ltd



Average composition of a primary zinc-carbon battery and how much of it can be recycled

Source: EPBA Battery Handbook

Recycling alkaline batteries

These batteries are recycled during steel making processes, where they are placed in molten mill furnaces as a feedstock. The zinc from the batteries is fumed off into a vacuum baghouse for recovery, while the end metal product is used to make low-grade steel called rebar.

Recycling nickel batteries

These batteries are recycled via a High-Temperature Metal Reclamation (HTMR) process, during which all of the high temperature metals contained within the battery feedstock (nickel, iron, cobalt, manganese, and chromium) report to the molten-metal bath within the furnace, amalgamate, then solidify during the casting operation. The low-melt metals (zinc, lithium, and cadmium) separate during the melting operation and are collected as a metal-oxide.

Recycling lithium batteries

The contents of the batteries are exposed using a shredder or a high-speed hammer depending on battery size. The contents are then submerged in caustic solution. This caustic solution neutralises the electrolytes, and ferrous and non-ferrous metals are recovered. The clean scrap metal is then sold to metal recyclers. The solution is then filtered. The carbon is recovered and pressed into moist sheets of carbon cake. Some of the carbon is recycled with cobalt. The lithium in the solution (lithium hydroxide) is converted to lithium carbonate, a fine white powder. What results is technical grade lithium carbonate, which is used to make lithium ingot metal and foil for batteries. It also provides lithium metal for resale and for the manufacture of sulfur dioxide batteries.

Recycling mercury batteries

The batteries and heavy metals are recovered through a controlled-temperature process. It's important to note that the percentage of mercuric oxide batteries is decreasing since the passage of the Mercury-Containing Rechargeable Battery Management Act (The Battery Act) of 1996. This act prohibits, or otherwise conditions, the sale of certain types of mercury-containing batteries (alkaline-manganese, zinc-carbon, button-cell mercuric oxide and other mercuric oxide batteries) in the United States.

Hearing aid batteries

Various household batteries

B10 BATTERIES

COMPANIES IN SOUTH AFRICA

CHEMICAL INDUSTRIES
RESOURCE PACK

Eveready

Eveready (Pty) Ltd. was established in 1937 and is the only manufacturer of dry cell batteries in South Africa.
Their product range includes:

- a range of battery products including alkaline, lithium and rechargeable batteries.
- alternative energy technology, the Kestrel micro wind turbine, which provides wind energy solutions for customers around the world.
- an alternative battery brand, Ecocell, has been trading in the Middle East for the past 4 years and provides the full range of Eveready products to customers in that region.
- Zinc products like electrodes made by casing and rolling.

Source: www.eveready.co.za

Uniross

Uniross is a Paris-based international company, that started in 1968 in the United Kingdom. It makes and sells rechargeable batteries and battery chargers under the names Encore, UltraLast and Uniross. Uniross has a state-of-the-art battery assembly and testing facility in Midrand.

Source: www.uniross.com

Energizer

Energizer Battery, Schick-Wilkinson Sword and Playtex belong to the same parent company, Energizer Holdings, Inc. (ENR), which was created in April 2000. Combined, Energizer, Schick and Playtex, have commercial and production operations in 49 countries and distribution in another 131 countries. Energizer produces lithium, rechargeable and alkaline batteries. They also produce non harmful, environmentally friendly, zero-mercury hearing aid batteries.

Source: www.energizer.com

The First National Battery

First National Battery started manufacturing batteries in 1931. Batteries produced include automotive starter batteries and batteries for miners' cap-lamps, standby, marine, leisure (boats-caravans) and for solar/rural power storage. Annually more than 2,2 million batteries are produced. Batteries are also exported to more than 30 countries worldwide. Old lead acid batteries are recycled through their own battery breaker and smelter. Their process ensures lead and polypropylene are reused in the manufacture of high quality lead alloys and plastic components.

Source: www.battery.co.za

Willard Batteries

The company started trading as Willard Batteries during January 1954. The manufacturing plant is situated in Port Elizabeth. They produce lead-acid batteries for various vehicles. Willard Batteries have a technological agreement with Moll Batteries in Germany and Johnson Controls in the USA and are currently manufacturing in the order of 1,2 million batteries per annum.

Source: www.willard.co.za

SABAT Batteries

SABAT Batteries is part of Powertech Batteries, one of the largest power electronics and telecommunications groups in Southern Africa. Powertech Batteries is a wholly owned subsidiary of the Altron Group. The manufacturing plant is situated in Port Elizabeth. The core business includes the manufacture and distribution of batteries, DC power systems, cable and cable accessories, transformers, including electrical accessories and lighting technology. SABAT is known for their lead-acid batteries. Batteries are produced for use in cars, bikes, quads, golf-carts, boats, jet-skis and off road vehicles.

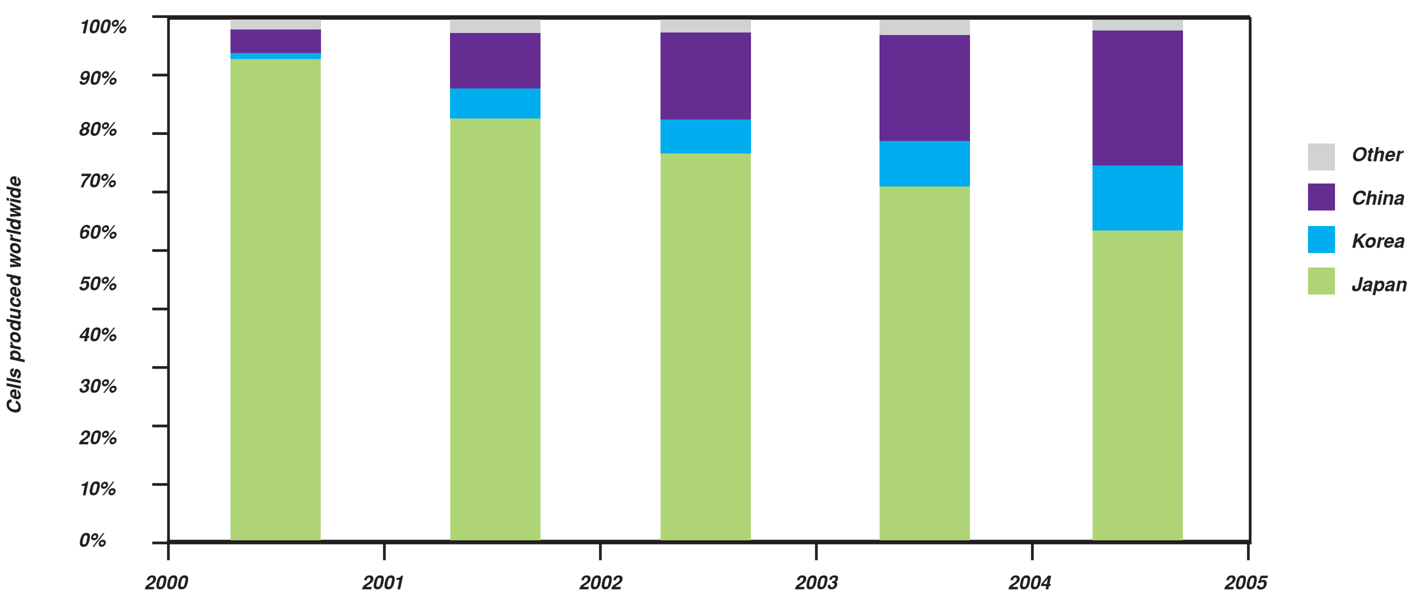
Source: www.sabat.co.za

Dixon Premium Batteries

Dixon started manufacturing batteries in 1955 in Vereeniging. An average motor car battery contains in excess of 85 components and a Dixon Battery contains no less than 90% local component content. Dixon manufacture, supply and distribute over 74 products, ranging from automotive batteries, deepcycle batteries, chargers to testing equipment.

Source: www.dixonbatteries.co.za

Global battery manufacturers



Source: BatteryUniversity.com

B11 BATTERIES

FUEL CELLS & ELECTRIC VEHICLES

CHEMICAL INDUSTRIES
RESOURCE PACK

The fuel cell

A fuel cell is an electrochemical device that combines hydrogen with oxygen to produce electric power, heat and water. In many ways, the fuel cell resembles an electrochemical battery. Rather than applying a periodic recharge, a continuous supply of oxygen and hydrogen is provided from the outside. Oxygen is commonly drawn from the air and hydrogen is carried as fuel in a pressurised container.

As alternatives, methanol, propane, butane, natural gas and diesel can be used. Alternative fuels require a reformer to extract the hydrogen. This allows tapping into existing distribution systems. However, reformers are bulky, expensive and sluggish. Some fuel efficiency is lost and a small amount of pollution is produced, but this is 90% less than from a regular car.

The fuel cell does not generate energy through burning; rather, it is based on an electrochemical process. The energy conversion is twice as efficient as through combustion. There are little or no harmful emissions. The only release is clean water. The fuel cell concept was developed in 1839 by Sir William Grove, a Welsh judge and gentleman scientist. The invention did not take off, partly due to the success of the internal combustion motor. The revival occurred when the first fuel cell was used in the Gemini Space Program during the 1960s. Based on the alkaline system, the fuel cell generated electricity and produced the astronauts' drinking water. Commercial application of this power source was impossible at that time because of high material costs. Improvements in the stack design during the 1990s led to reduced costs and increased power densities.

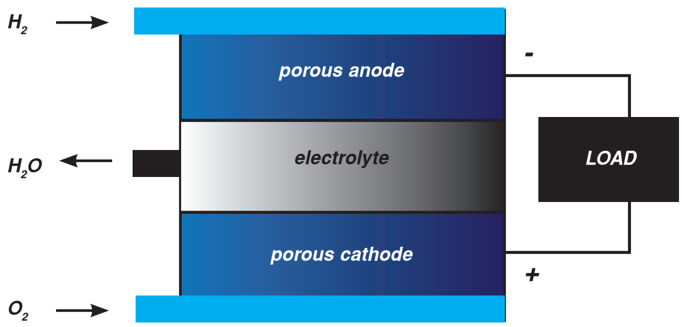
Fuel cell chemistry is simple. The electrolysis of water into hydrogen and oxygen through the application of an electric current ($2H_2O \rightarrow 2H_2 + O_2$) can be reversed to produce water and electricity:

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

Fuel cells are based on reverse electrolysis. They resemble batteries in that their direct current (DC) electrical output is due to an electrochemical process. However, unlike batteries, fuel cells operate off a continuous stream of air as a source of oxygen, and a source of hydrogen fuel.

This material was obtained online from BatteryUniversity.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Buchmann, I. 2005. The Fuel Cell. [Online]. Available: www.batteryuniversity.com/parttwo-52.htm. [27 July 2010].

The general fuel cell construction



Source: BatteryUniversity.com

Mobile hydrogen fuel cell system

A hydrogen fuel cell system powering a television Photograph: Rein Weber

A small scale hydrogen fuel cell system

Picture courtesy UCT Chemical Engineering. Photograph by Rothko

SA's electric car developer outlines its battery-swap thinking

4th June 2010

In today's pricing terms, South Africa's Joule electric vehicle will sell at R235 000 to R285 000, with the battery, the most costly component of the car, leased at an additional R1 500 a month, says Optimal Energy spokesperson Jaco van Loggerenberg. The Joule electrical car will be in showrooms in 2013.

The Joule buyers will not own the lithium-ion battery, but only the vehicle body. It also means that owners may be able to swap a depleted battery for a fully charged one in around a minute, instead of waiting for the battery to charge – if such a system is introduced along with the Joule. Optimal Energy is working towards the large-scale manufacture of fully electric cars for the local and exports markets. The company is headquartered in Cape Town. The first test Joules are being hand-built near Port Elizabeth by Hi-Tech Automotive, which is responsible for building a marketing and test fleet of about 100 vehicles. These will double as research and development units, some of which will be on South African roads by the start of the Soccer World Cup on June 11. Full-scale production of the Joule will begin at the end of 2012. Key design goals for the finished product include a range of 230 km to 300 km before recharging is required, a freeway cruising capability, as well as seating for five.

This news article was published online by Creamer Media's Engineering News. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Venter, I. 4 June 2010. SA's electric car developer outlines its battery-swap thinking. [Online]. Available: http://www.engineeringnews.co.za/article/auto-industry-2010-06-04-1-1 [27 July 2010].

DID YOU KNOW?

The hybrid car is not new - Ferdinand Porsche designed the series-hybrid vehicle in 1898. Called the Lohner-Porsche carriage, the hybrid function served as an electrical transmission rather than power boost. With Mr. Porsche in the driver's seat, the car broke several Austrian speed records, including at the Exelberg Rally in 1901. The hybrid electric vehicle conserves fuel by using an electric motor that assists the internal-combustion engine on acceleration and harnesses kinetic energy during braking.

Source: www.BatteryUniversity.com

The Joule

South Africa's own electric car - The Joule
Picture courtesy Optimal Energy

Sony develops a bio battery powered by sugar

24 August 2007

Sony has developed a biologically friendly battery that generates electricity from sugar in a way that's similar to what's found in living organisms. The battery generates electricity through the use of enzymes that break down carbohydrates, which is essentially sugar. The bio battery could evolve into an ecologically friendly device, because sugar is a naturally occurring energy source produced by plants through photosynthesis and can be found in most areas of the earth, Sony said. In addition, Sony made the battery casing of vegetable-based plastic.

In other recent ecologically friendly battery research, scientists at the Rensselaer Polytechnic Institute reported that creating a paper-sized device that functions as a high-energy battery and a super-capacitor that can use human blood and sweat to recharge. The device is lightweight, thin, flexible, and geared toward future use for medical implants, transportation, and gadgets.

This news article was published on InformationWeek.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Gonsalves, A. 24 August 2007. Sony develops a bio battery powered by sugar. [Online]. Available: http://www.informationweek.com/news/global-cio/show Article.jhtml?articleID=201802311 [27 July 2010].

B12 BATTERIES

FACTORS AFFECTING BATTERY LIFESPAN

CHEMICAL INDUSTRIES
RESOURCE PACK

Temperature effects

The hotter the battery, the faster chemical reactions will occur. High temperatures can thus provide increased performance, but at the same time the rate of the unwanted chemical reactions will increase resulting in a corresponding loss of battery life.

Nickel-metal hydride (NiMH) chemistry in particular is sensitive to high temperatures. Testing has shown that continuous exposure to 45°C will reduce the cycle life of a Ni-MH battery by 60% and as with all batteries, the self-discharge rate doubles with each 10°C increase in temperature.

Loss of electrolyte

Electrolyte may be lost from leakage due to the deterioration over time of the seals closing the cells. Even with good seals the solvents in the electrolyte may eventually permeate through the seal over a prolonged period causing the electrolyte to dry out, particularly if the cells are stored in a dry atmosphere or if the cell contents are under pressure due to high temperatures.

However, the loss of electrolyte is not just due to the physical leakage of the electrolyte from the cell. The electrolyte may be effectively lost to the electrochemical system because it has been transformed or decomposed into another inactive compound which may or may not remain inside the cell casing. Corrosion is an example of this as are other compounds which may have been formed by overheating or abuse. Gassing and evaporation are two other mechanisms by which electrolyte may be lost thus causing an irreversible loss in the capacity of the cell.

Venting

Although most modern cells have a sealed construction to prevent loss of electrolyte, they usually have a vent to relieve pressure if there is a danger of the cell rupturing due to excessive pressure. Whenever a vent operates, it releases or expels some of the active chemicals to the atmosphere and hence reduces the cell's capacity.

This material was obtained from Electropaedia. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Woodbank Communications Ltd. 2005. Electropaedia - Battery and Energy Technologies: Battery life and How to Improve It. [Online]. Available: http://www.mpoweruk.com/life.htm. [27 July 2010].

Plate thickness

Plate thickness (of the positive plate) is important due to a factor called 'positive grid corrosion'. This ranks among the top 3 reasons for battery failure. The positive (+) plate gets eaten away gradually over time, so eventually there is nothing left - it all falls to the bottom as sediment. Thicker plates are directly related to longer life, so other things being equal, the battery with the thickest plates will last the longest. The negative plate in batteries expands somewhat during discharge, which is why nearly all batteries have separators, such as glass mat or paper that can be compressed.

This material was obtained from Northern Arizona Wind and Sun. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Northern Arizona Wind and Sun. 2010. Deep Cycle Battery FAQ. [Online]. Available: http://www.windsun.com/Batteries/Battery _ FAQ.htm. [27 July 2010].

Cell matching

A weak cell holds less capacity and is discharged more quickly than the strong one. This imbalance may cause cell reversal on the weak cell if discharged too low. On charge, the weak cell is ready first and goes into heat-generating overcharge while the stronger cell still accepts charge and remains cool. In both cases, the weak cell is at a disadvantage, making it even weaker and contributing to a more acute cell mismatch.

DID YOU KNOW?

To maximise service life, satellite batteries are kept at a cool temperature and undergo a very shallow discharge of only 10% before recharge. Nickel-based batteries in space also receive a periodic full discharge. This situation allows tens of thousands of cycles.

Closer to Earth, the ideal charge/discharge patterns cannot be scheduled; nor is the temperature always perfect. As a result, a replacement will be required sooner or later.

Interesting battery facts

- Nearly all rechargeable batteries will not reach full capacity until cycled 10-30 times. A brand new battery will have a capacity of about 5-10% less than the rated capacity.
- In situations where multiple batteries are connected in series, parallel or series/parallel, replacement batteries should be the same size, type and manufacturer (if possible). Age and usage level should be the same as the companion batteries. Do not put a new battery in a pack which is more than 6 months old or has more than 75 cycles. Either replace with all new or use a good used battery.
- Inactivity can be extremely harmful to a battery. Instead of buying batteries to "save" them for later rather buy them when you need them, or keep them on a continual trickle charge (a low-level electrical charge applied to a battery that roughly equals its rate of discharge).

New thin, flexible, light battery could bring intelligence to wallpaper, clothing

Andrew Nusca, 30 November 2009

The new biodegradable battery made of cellulose promises to offer thin, flexible, lightweight, inexpensive and environmentally-friendly batteries made without metal parts.

The battery is made from green algae known as Cladophora, found along freshwater beaches around the world.

The new batteries consist of very thin layers of conducting polymer — just 40 to 50 nanometres, or billionths of a metre, wide — that coat algae cellulose fibres just 20 to 30 nanometres wide, collected into paper sheets.

The batteries are said to hold 50 to 200 percent more charge than similar conducting polymer batteries. With more optimisation, the batteries could compete head-to-head with commercial lithium batteries, found in consumer electronics such as mobile phones and laptop computers, according to the researchers.

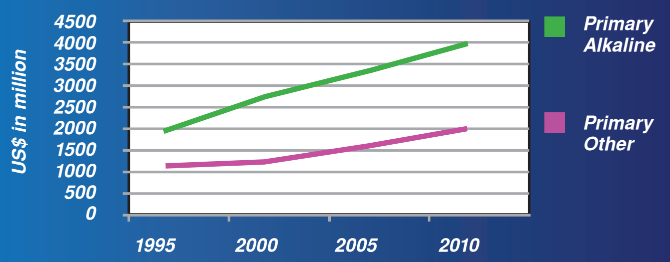
The new batteries could be used in applications such as flexible electronics (e.g. e-book readers), clothing and packaging.

This material was obtained from SmartPlanet.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Nusca, A. 2009. New thin, flexible, light battery could bring intelligence to wallpaper, clothing. [Online]. Available: http://www.smartplanet.com/business/blog/smart-takes/new-thin-flexible-light-battery-could-bring-intelligence-to-wallpaper-clothing/2366/ [27 July 2010].

Definitions

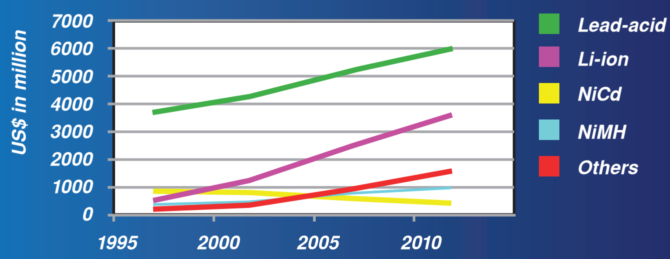
Capacity: The maximum total electrical charge, expressed in ampere-hours, which a battery can deliver to a load under a specific set of conditions.
Self discharge: A phenomenon in batteries in which internal chemical reactions reduce the stored charge of the battery without any connection between the electrodes. Self-discharge decreases the shelf-life of batteries and causes them to have less charge than expected when actually put to use.

Demand for primary batteries



Primary alkaline is leading the market. Other primary chemistries are expected to increase at a slower pace.

Demand for secondary batteries



Lead-acid will be the most commonly used secondary battery. Among portable secondary batteries, lithium-ion shows the most promise.

This material was obtained from BatteryUniversity.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Buchmann, I. 2005. Battery Statistics. [Online]. Available: www.batteryuniversity.com/parttwo-40.htm [27 July 2010].

DID YOU KNOW?

If lead-acid batteries are discharged quickly (at high power), the amount of energy that can be extracted from the battery is much less than if the battery is discharged very slowly. In other words there is an inverse relationship between the power of the battery and the storage capacity.

Source: V-Fuel Pty Ltd