

Primary cells and secondary cells

Objectives: At the end of this lesson you shall be able to

- state the chemical effect of electric current
- state the Laws of electrolysis
- state the basic principles of electroplating
- state the principle and construction of primary cells
- state the principle and construction of secondary cells (lead acid, nickel iron and nickel cadmium)
- compare the primary cells and secondary cells .

Chemical effects of electric current

'There are some liquids in which a passage of electric current is accompanied by chemical changes.' This effect is known as chemical effect of electric current.

The applications of chemical effect of electric current may be observed in daily life; e.g., nickel or copper plating on metallic articles, production of E.M.F by a cell, etc. If two leads taken from the positive and negative terminals of a battery are immersed in a salted water, then the production of bubbles can be seen at the lead ends; it is all due to chemical effect of electric current.

Electrolysis

If an electric current is passed through different liquids or solutions in turn, then it is observed that the current passes through some of the solutions only and not through all of them. The liquid or a solution, through which an electric current can pass, is called a conductor-liquid such as ammonium chloride solution, silver nitrate solution etc.; and, through which an electric current can't pass, is called an insulator-liquid such as distilled water, alcohol, oil etc. If some salt or acid is mixed in the distilled water, then it becomes conductive.

Thus, 'the process of chemical changes due to the passage of an electric current through a liquid or a solution is called electrolysis.'

Electrolyte

'The liquid or solution which undergoes a chemical change in it on account of the passage of an electric current, is called an electrolyte'; e.g., salted water, acidic or a basic solution etc.

Electrodes (Anode and cathode)

'Two conductor plates are immersed in the liquid to form a passage of current through it, they are known as electrodes'. The electrode through which the current enters the liquid, is called a positive electrode or anode, while the other through which it leaves the liquid (electrolyte) is called a negative electrode or cathode.

Ions

During electrolysis, the molecules of the electrolyte split into their constituents which are called ions. When a p.d. is applied across the two electrodes, the positively charged ions (cat ions) move towards the cathode and the negatively charged ions (an ions) move towards the anode. On reaching at any electrode, an ion gives up its charge and ceases to be an ion. The process of converting atoms into ions is called **ionization**.

Electrochemical equivalent: The mass of a substance liberated or deposited during electrolysis by one coulomb of electricity is termed as electrochemical equivalent (ECE) of that substance.

The ECE of silver is 1.1182 milligram/coulomb.

Coulomb: The coulomb (C) is the unit of electric charge (Q) or the quantity of electricity.

The coulomb is the product of current in ampere and time in seconds.

Faraday's Law of Electrolysis

1. First law: The mass of the substance liberated or deposited at any electrode during electrolysis is proportional to the quantity of electricity passed through the electrolyte. The mass of the substance liberated at any electrode will be more, if more current is passed or a current for more time is passed through the electrolyte. If the mass liberated is m then

$$m \propto I$$

$$m \propto t \quad \text{-----(i)}$$

$$m \propto I \cdot t \quad \text{-----(ii)}$$

$$m = Z \cdot I \cdot t$$

Where, I = current, amperes

t = time, seconds

m = mass of the substance liberated, grams

Z = constant

Here, the constant Z is known as electro-chemical equivalent (ECE).

2. Second Law - 'When the same quantity of electricity is passed through different electrolytes, then the quantities of elements liberated at the different electrodes are proportional to their electro-chemical equivalents.'

$$\text{Mass} \propto E.C.E$$

$$M \propto Z$$

Where Z = electro-chemical equivalent

According to Faraday's laws of electrolysis

$$m = Z \cdot I \cdot t$$

Where, m = mass of substance liberated in grams

z = Electro chemical equivalent of the substance in gram

I = Current in amperes

t = Time in seconds

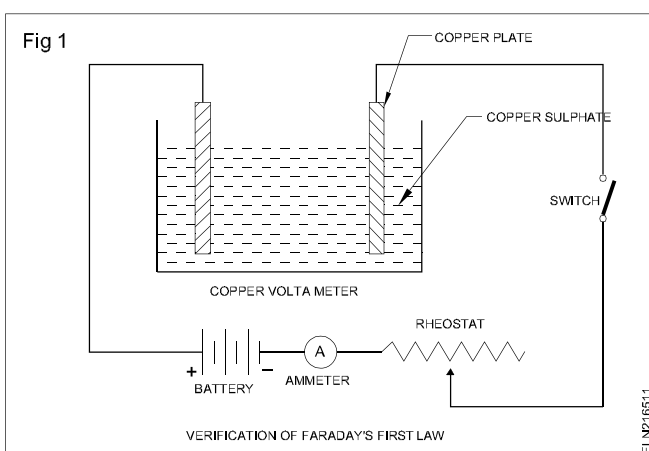
Note. Mass deposited m = Volume $\times$ Density

$$\text{Equivalent weight} = \frac{\text{Atomic weight}}{\text{Valency}}$$

$$\text{E.C.E. of nickel} = \frac{\text{Equivalent wt. of nickel}}{\text{Equivalent wt. of silver}} \times \text{E.C.E. of silver}$$

Verification of Faraday's laws

(1) Verification of first Law - For the verification of Faraday's first law, a copper sulphate solution is taken in a glass container (called a voltameter). Two copper plates are immersed in the solution. A battery, switch, ammeter and a rheostat are connected to the plates (Fig 1).

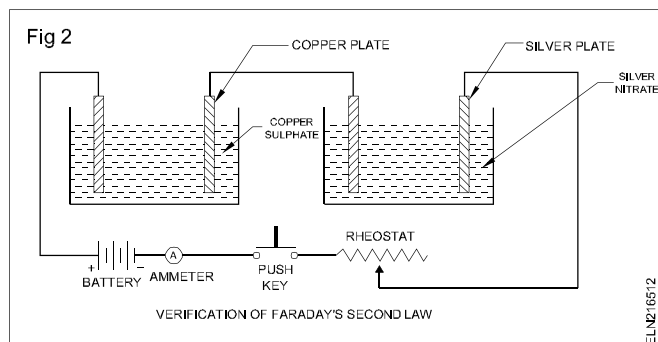


The negative electrode is dried and weighed. After passing a definite amount of current (which can be adjusted by the rheostat) for a definite time, the cathode is weighed again, after being dried once again.

Now, the mass of copper deposited at the cathode is equal to the weight of cathode after passing the current minus the weight of cathode before passing the current.

The above experiment is repeated for twice the time of the first measurement. It is observed that the mass of copper deposited is doubled. Similarly, if the current is doubled instead of the time, then also the mass of copper deposited is doubled. These three above observations verify that the mass of copper deposited at the cathode is proportional to the product of current and time.

(2) Verification of Second Law - For the verification of Faraday's second law, two voltameters are taken, i.e., copper and silver voltameters. The copper voltameter has a solution of copper sulphate and two copper electrodes whereas the silver voltameter has a solution of silver nitrate and two silver electrodes. Both voltameters are connected in series across a battery through a switch, ammeter and a rheostat (Fig 2).



Now a definite current is passed for a definite time through both the voltameters. If the mass of copper deposited at the copper cathode is m_1 and the mass of silver deposited at silver cathode is m_2 and their chemical equivalents are w_1 and w_2 respectively, then it is found that -

$$m_1 : m_2 = w_1 : w_2$$

or

$$\frac{m_1}{w_1} = \frac{m_2}{w_2} \quad \text{or} \quad \frac{m_1}{m_2} = \frac{w_1}{w_2}$$

$$\frac{\text{the mass of copper deposited}}{\text{the mass of silver deposited}} = \frac{31.5}{108}$$

(Since the chemical equivalents of copper and silver are 31.5 and 108 respectively)

The relation $\frac{m_1}{m_2} = \frac{w_1}{w_2}$ verifies the second law.

Table for Electro-Chemical Equivalents of Elements

Name of Element	Atomic Weight	Valency	Electro-Chemical Equivalent mg/c	Chemical equivalent g/c
Hydrogen	1.008	1	0.01045	1.008
Aluminium	27.1	3	0.0936	9.03
Copper	63.57	2	0.3293	31.78
Silver	107.88	1	1.118	107.88
Zinc	65.38	2	0.3387	32.69
Nickel	58.68	2	0.304	29.34
Chromium	52.0	3	0.18	17.33
Iron	55.85	2	0.2894	27.925
Lead	207.21	2	1.0738	103.6
Mercury	200.6	1	2.0791	200.6
Gold	197.0	1	2.0438	197

Note. (mg/c = milli-gram per coulomb)

Application of electrolysis

The principal applications of electrolysis are as follows:

1. Electroplating
2. Electro-refining of metals
3. Electrolytic capacitor
4. Electrotyping
5. Extraction of metals.

Electroplating

The process of depositing a metal on the surface of another metal by electrolysis is known as electroplating. Electroplating is widely used in giving an attractive appearance and finish to all types of products. In this process inferior metals are coated with costly metals (such as silver, nickel, gold, chromium, etc.) to give an attractive shiny appearance and rust-proof surface.

Conditions for electroplating

The following conditions must be fulfilled before electroplating an article.

- (i) The article to be electroplated must have a chemically cleaned surface, i.e. it must not have any sort of dirt, rust and greasy surface.
- (ii) The article to be plated should form a cathode.
- (iii) The anode must be of the metal to be deposited for maintaining the concentration of the solution constantly during electrolysis.
- (iv) The metal to be coated has to be in the solution of an electrolyte.

The electrolyte is contained in a wooden reinforced cement concrete tank which is known as a "vat". The anode as well as the article to be plated are hung through the conducting wires so as to dip in the solution. The value of the current is adjusted according to the metal deposited on the surface area of the article. The time required for electroplating can be calculated if we know the mass of the metal deposited and ECE with the formula

$$M = Zit$$

Therefore, Time $t = \frac{M}{IZ}$

we know $M = Zit$ ----- (1)

$$I = \frac{M}{Zt} \text{ and } Z = \frac{M}{It} \text{ mg / Coulomb}$$

We know Volume = Area x Thickness -----(2)

$$\text{Area} = \frac{\text{Volume}}{\text{Thickness}} \text{ and}$$

$$\text{Thickness} = \frac{\text{Volume}}{\text{Area}}$$

Mass = Volume x Density ----- (3)

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} \text{ cc}$$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \text{ gm / cc}$$

Example1: If 111.83 mg of silver is deposited on the cathode in 3 min 20 s, by a DC current of 0.5A, calculate the ECE of silver.

Solution:

$$t = 3 \text{ min } 20 \text{ s} = 200 \text{ s}$$

$$M = 111.83 \text{ mg}$$

From Faraday's law,

$$M = Zit$$

$$Z = \frac{M}{It} = \frac{111.83}{0.5 \times 200}$$

$$= 1.1183 \text{ mg/ C}$$

Example 2: It is required to be deposited copper on the both surfaces of an iron plate 200 cm² in area. What thickness of copper will be deposited if one ampere of

current is passed through the solution for 1 1/2 hours. The density of copper is equal to 8.9 g/cc and E.C.E. of copper is 0.329 mg/C.

Solution:

$$Z - 0.329 \text{ mg/C} = \frac{0.329}{10^3} = 0.329 \times 10^{-3} \text{ g/C}$$

$$I = 1\text{A}$$

$$t = 90 \times 60 = 5400 \text{ s}$$

From Faraday's law,

$$M = ZIt$$

$$0.329 \times 10^{-3} \times 1 \times 5400 = 1.7766 \text{ g (i)}$$

Suppose the thickness of copper deposited = T cm

$$\text{Area} = 200 \text{ cm}^2$$

$$\text{Density} = 8.9 \text{ g/cc}$$

Volume of copper deposited

$$= 2 \times \text{area} \times \text{thickness}$$

$$= 2 \times 200 \times T \text{ cc}$$

Mass of copper deposited

$$= \text{Volume} \times \text{density}$$

$$= 400 \times T \times 8.9 \quad (\text{ii})$$

Equating (i) and (ii);

$$400 \times 8.9 \times T = 1.7766$$

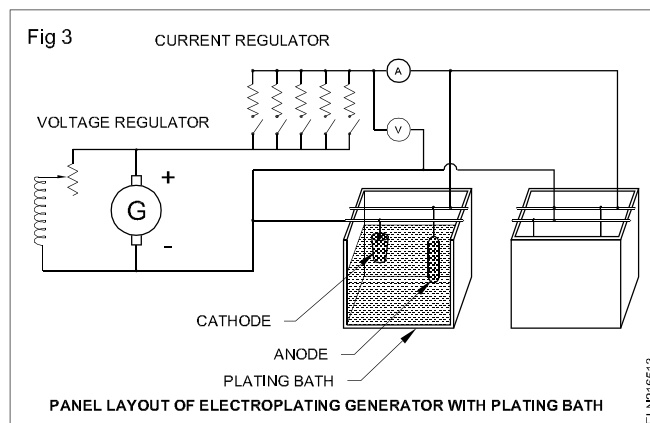
$$\text{or } T = \frac{1.7766}{400 \times 8.9} = 0.000499 \text{ cm} \quad \text{Ans.}$$

Current required for plating

Low pressure direct current (DC) supply is always used for electroplating purposes. The pressure used varies from 1 to 16 V depending upon the rate of plating and the nature of the electrolyte.

Dynamo for electroplating (Fig 3)

The shunt dynamo is generally used for electroplating. It delivers large current at low pressure and this requires a large commutator and brush gear. Such types of dynamos are run by either an AC or a DC motor or the petrol engine, etc and the current required for plating is controlled by the current regulator. The generated voltage of the dynamo is controlled by the voltage regulator (Fig 3).



Cathodic protection in Electroplating

Cathodic protection (CP) is a technique used to control the corrosion of a metal surface by making it as the cathode of an electrochemical cell. A simple method of protection connects the metal to be protected to a more easily corroded sacrificial metal to act as the anode.

The sacrificial metal then corrodes instead of the protected metal. For the structures such as long pipe lines where passive galvanic cathodic protection is not adequate an external DC electrical power source is used to provide sufficient current.

The CP system protects a wide range of metallic structures steel water, fuel pipe line, storage tanks water heaters, steel wire pipes, oil platform, oil well casing, wind farms etc. Another common application is in galvanised steel in which a sacrificial coating of zinc on steel parts protects them from rust. CP protection can in some cases prevent the stress corrosion cracking.

Type of cells

Cell: A cell is an electrochemical device consisting of two electrodes made of different materials and an electrolyte. The chemical reaction between the electrodes and the electrolyte produces a voltage.

Cells are classified as

- dry cells
- wet cells.

A dry cell is one that has a paste or gel electrolyte. With newer designs and manufacturing techniques, it is possible to completely (hermetically) seal a cell. With complete seals and chemical control of gas build-up, it is possible to use liquid electrolytes in dry cells. Today the term 'dry cell' refers to a cell that can be operated in any position without electrolyte leakage.

Wet cells are cells that must be operated in an upright position. These cells have vents to allow the gases generated during charge or discharge to escape. The most common wet cell is the lead-acid cell.

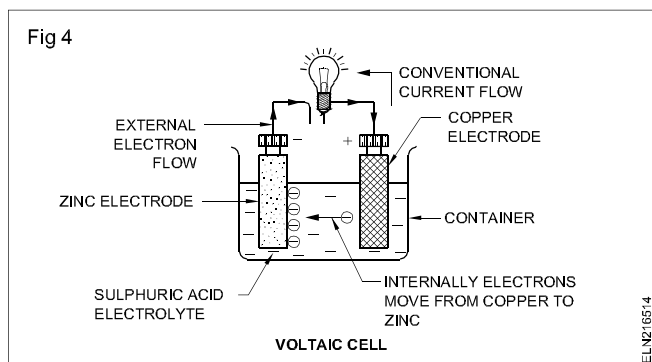
Cells are further classified as primary and secondary cells.

Primary cells: Primary cells are those cells that are not rechargeable. That is, the chemical reaction that occurs during discharge is not reversed. The chemicals used in the reactions are all converted when the cell is fully discharged. It must then be replaced by a new cell.

Types of primary cells:

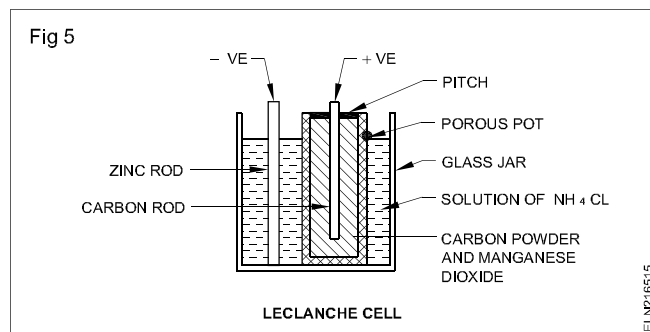
- Voltaic cell
- Carbon-zinc cell (Leclanche cell and Dry cell)
- Alkaline cell
- Mercury cell
- Silver oxide cell
- Lithium cell

Simple voltaic cell: A voltaic cell uses copper and zinc as the two electrodes and sulphuric acid as the electrolyte. When they are placed together a chemical reaction occurs between the electrodes and the sulphuric acid. This reaction produces a negative charge on the zinc (surplus of electrons) and a positive charge on the copper (deficiency of electrons). If an external circuit is connected across the two electrodes, electrons will flow from the negative zinc electrode to the positive copper electrode (Fig 4).



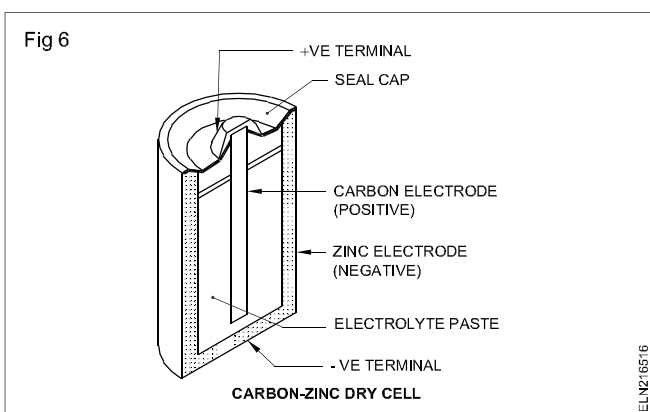
The electric current will flow as long as the chemical action continues. In this type of cell the zinc electrode is eventually consumed as part of the chemical reaction. The voltaic cell is also known as a wet cell because it uses a liquid solution for the electrolyte.

Leclanche cell (Carbon-zinc cells): The container of this cell is a glass jar. The jar contains a strong solution of ammonium chloride (NH_4Cl). This solution is an alkali and acts as the electrolyte. A porous pot is placed at the centre of the glass jar. This porous pot has in it a carbon rod surrounded by a mixture of manganese dioxide (MnO_2) and powdered carbon. The carbon rod forms the positive electrode of the cell and MnO_2 acts as the de-polarizer. A zinc rod is dipped in the solution in the jar and acts as the negative electrode (Fig 5).



Dry cell (Carbon-Zinc cell): The danger of spilling the liquid electrolyte from a Leclanche type of cell led to the invention of another class of cells called dry cells.

The most common and least expensive type of a dry cell is the carbon-zinc type (Fig 6). This cell consists of a zinc container which acts as the negative electrode. In the centre is a carbon rod which is the positive electrode. The electrolyte takes the form of a moist paste made up of a solution containing ammonium chloride.



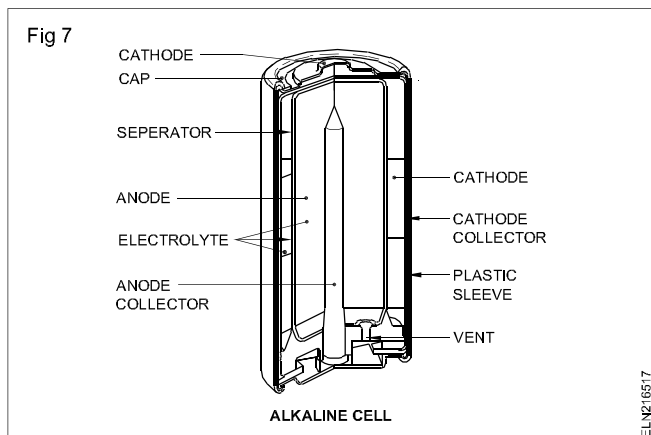
As with all primary cells, one of the electrodes becomes decomposed as part of the chemical reaction. In this cell the negative zinc container electrode is the one that is used up. As a result, cells left in equipment for long periods of time can rupture, spilling the electrolyte and causing damage to the neighbouring parts.

Carbon-zinc cells are produced in a range of common standard sizes. These include 1.5 V AA, C and D cells. (AA Pen type cell, 'C' medium size and 'D' large/economy size).

Alkaline cells: Alkaline cells use a zinc container for the negative electrode and a cylinder of manganese di-oxide for the positive electrode (Fig 7). The electrolyte is made up of a solution of potassium hydroxide or an alkaline solution.

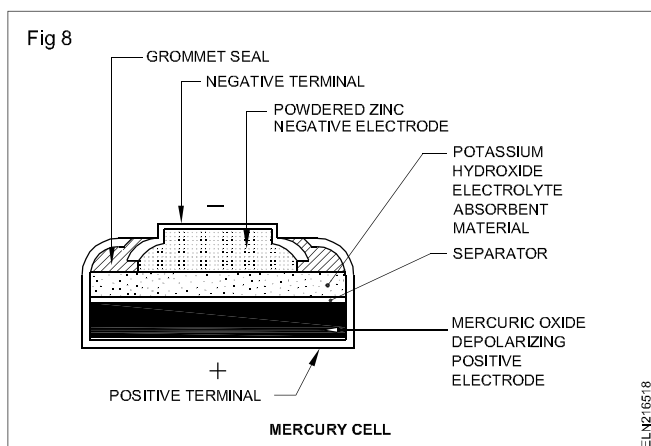
Alkaline cells are produced in the same standard sizes as carbon-zinc cells but are more expensive. They have the advantage of being able to supply large currents for a longer period of time. For example, a standard 'D' type 1.5 V alkaline cell has a capacity of about 3.5 AH compared with about 2 AH for the carbon-zinc type. A second advantage is that the alkaline cell has a shelf life of about

two and a half years as compared to about 6 to 12 months for the carbon-zinc type.



Mercury cells: Mercury cells are most often used in digital watches, calculators, hearing aids and other miniature electronic equipment. They are usually smaller and are shaped differently from the carbon-zinc type (Fig 8).

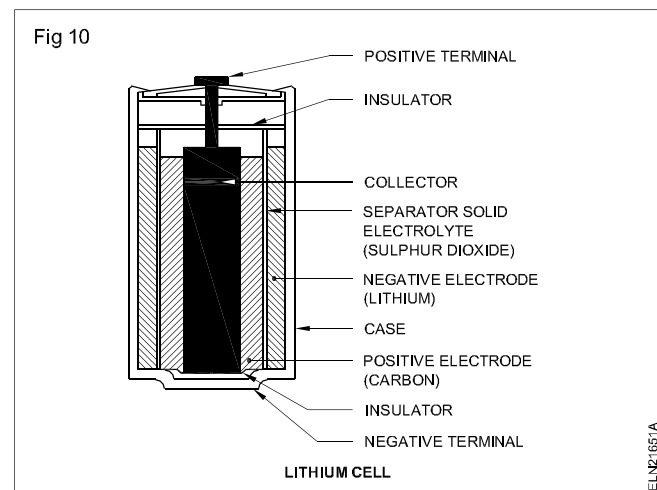
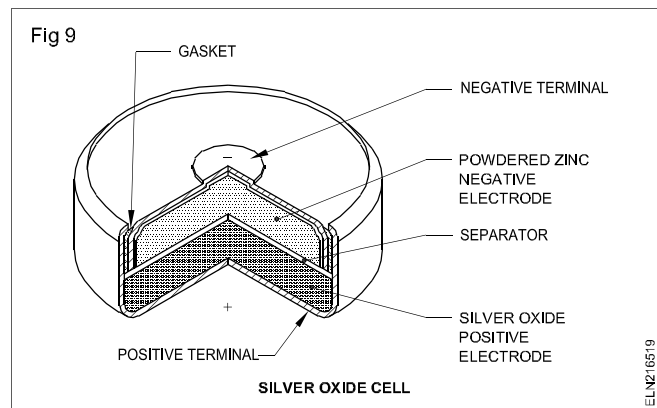
The electrolyte used in this cell is alkaline and the electrodes are of mercuric oxide (cathode) and zinc (anode).



Silver oxide cells: Silver oxide cells are much like mercury cells. However, they provide a higher voltage (1.5 V) and they are made for light loads. The loads can be continuous, such as those encountered in hearing aids and electronic watches. Like the mercury cell, the silver oxide cell has good energy-to-weight and energy-to-volume ratios, poor low-temperature response, and flat output voltage characteristics.

The structures of the mercuric and silver oxide cells are very similar. The main difference is that the positive electrode of the silver cell is silver oxide instead of mercuric oxide. Fig 9 shows the cross-section of a silver oxide cell.

Lithium cells: The lithium cell is another type of primary cell (Fig 10). It is available in a variety of sizes and configurations. Depending on the chemicals used with lithium, the cell voltage is between 2.5 and 3.6 V. Note that this voltage is considerably higher than in other primary cells. Two of the advantages of lithium cells over other primary cells are:



- longer shelf life - up to 10 years
- higher energy-to-weight ratios up to 350 WH/Kg.

Lithium cells operate at temperatures ranging from -50 to $+75^{\circ}\text{C}$. They have a very constant output voltage during discharge.

Uses: Primary cells are used in electronic products ranging from watches, smoke alarms, cardiac pacemakers, torches, hearing aids, transistor radios etc.

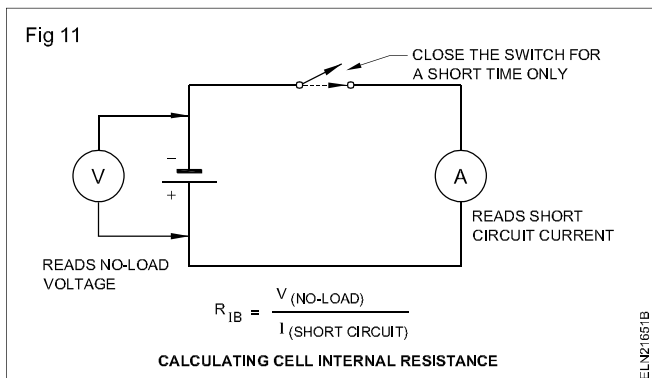
Internal resistance: The output voltage from a cell varies as the load on the cell changes. Load on a cell refers to the amount of current drawn from the cell. As the load increases, the voltage output drops. The change in output voltage is caused by the internal resistance of the cell. Since materials from which the cell is made are not perfect conductors, they have resistance. Current flowing through the external circuit also flows through the internal resistance of the cell.

According to Ohm's law, a current flowing through a resistance (either external or internal) results in a voltage drop ($V = IR$). Any voltage developed across the internal resistance is not available at the terminals of the cell.

The voltage at the terminals is the voltage produced due to the chemical reactions minus the voltage dropped across the internal resistance. The terminal voltage of a cell, therefore, depends on both the internal resistance of the cell and the amount of load current.

In some applications, the changes in cell terminal voltage are so small that they make no practical difference. In other applications, the changes are very noticeable. For example, when an automobile engine is started, the battery output voltage changes from about 12.6 to 8V.

Fig 11 shows the method of calculating the internal resistance of a cell. As a cell discharges, its internal resistance increases. Therefore its output voltage decreases for a given value of load current.



Defects of a simple cell: With a simple voltaic cell, the strength of current gradually diminishes after some time. This defect is mainly due to two causes.

- Local action
- Polarisation

Local action: In a simple voltaic cell, bubbles of hydrogen are seen to evolve from the zinc plate even on open circuit. This effect is termed local action. This is due to the presence of impurities like carbon, iron, lead, etc. in the

commercial zinc. This forms small local cells on the zinc plate and reduces the strength of current of the cell.

The local action is prevented by amalgamating the zinc plate with mercury. To do so, the zinc plate is immersed in dilute sulphuric acid for a short time, and afterwards, mercury is rubbed over its surface.

Polarisation: As current flows, bubbles of H_2 evolve at the copper plate on which they gradually form a thin layer. Due to this the current strength falls and finally stops altogether. This effect is called the polarization of the cell.

Polarisation can be prevented by using some chemicals which will oxidize the hydrogen to water before it can accumulate on the plate. The chemicals used to remove polarisation are called de-polarisers.

We learnt that most of the primary cell except rechargeable ones are usable once only. It does not supply current continuously. The secondary cells overcome this disadvantage.

Secondary cell: A cell that can be recharged by sending electric current in the reverse direction to that of a discharge mode is known as a secondary cell.

The secondary cell is also called a storage cell since after it is charged it stores the energy until it is used up or discharged.

In a secondary cell the charging and discharging processes are taking place according to Faraday's Laws of Electrolysis.

Comparison of primary cells				
	Carbon -Zinc	Alkaline-Manganese	Mercury	Silver oxide
Negative, Positive, Electrolyte	Zinc Carbon Ammonium Chloride	Zinc Manganese dioxide Potassium hydroxide or alkaline	Zinc Mercuric oxide Alkaline	Zinc Silver oxide Potassium hydroxide
Nominal voltage - volts Max. rated current - amperes	1.5 2-30	1.5 0.05-20	1.35 or 1.4 0.003-3	1.5 0.1
Energy output Watt-hrs Ampere-hours	22 2.0	35 3.5	46 6.0	50 8.0
Temperature range Storage °F Operating °F	-40 to 120 20 to 130	-40 to 120 -5 to 160	-40 to 140 -5 to 160	-40 to 140 -5 to 160
Shelf life in months at 68°F to 80% initial capacity Shape of discharge curve	6 to 12 Sloping	30 to 36 Sloping	30 to 36 Flat	30 to 36 Flat

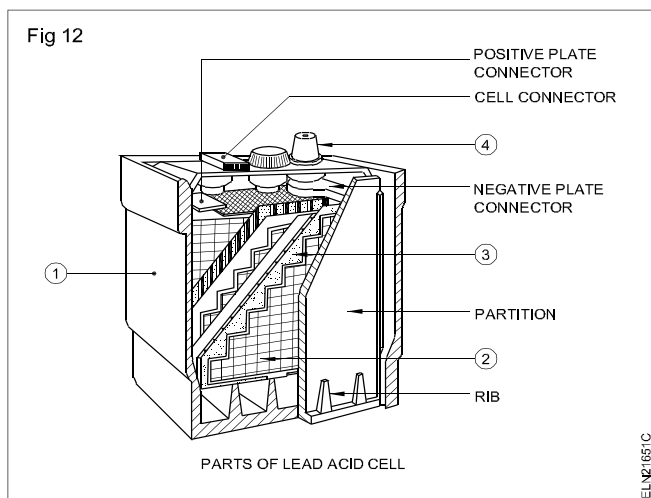
Types of secondary cells

- Lead acid cell
- Alkaline cell or nickel-iron cell

Parts of Lead acid cell (Fig 12)

- 1 Container
- 2 Plates
- 3 Separators
- 4 Post terminals

Container: The container is made of hard rubber, glass or celluloid to accommodate the active plates, separators and the electrolyte. The plates rest on ribs provided at the bottom of the container and the space between ribs is known as sediment chamber.



Plates: Positive plates are of two types.

- Plante plate or formed plates
- Faure plate

Plante plates: These are prepared by the process of repeated charging and discharging. They are made of pure lead at the beginning which changes to lead peroxide after charge.

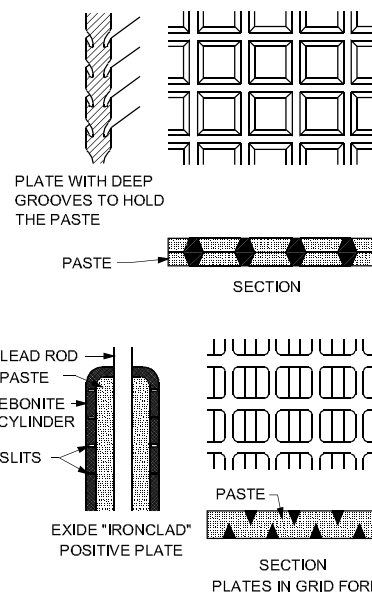
Faure plate: Pasted or Faure plates are made of rectangular lead grid into which the active material i.e. lead peroxide (PbO_2) is filled in the form of a paste (Fig 13).

Negative plates are made of rectangular lead grid, and the active material is spongy lead (Pb) which is in the form of a paste (Fig 14).

Separators: These are made of thin sheets of chemically treated porous wood or rubber. They are used to avoid short in between the positive and negative plates (Fig 15).

Post terminal: A small pole extended upward from each group of welded plates from the plate connector (Fig 16) forms the post terminal.

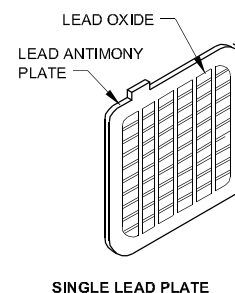
Fig 13



CONSTRUCTION OF PASTED-TYPE ACCUMULATOR PLATES

ELN2/651D

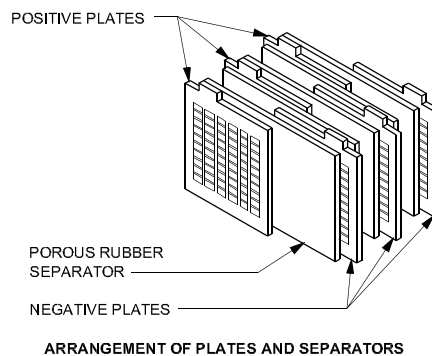
Fig 14



SINGLE LEAD PLATE

ELN2/651E

Fig 15



ARRANGEMENT OF PLATES AND SEPARATORS

ELN2/651F

Electrolyte: The electrolyte used in a lead acid cell is dilute sulphuric acid (H_2SO_4). The specific gravity of the electrolyte is 1.24 to 1.28. It varies according to the manufacturer's specification.

Working principle

The secondary cell has no significant electrochemical energy at the start. The energy must first be charged into secondary cell. Then the cell retains the stored energy until it is used up. That is, both cell electrodes are basically lead sulphate ($PbSO_4$). When the cell is charged, due to chemical reaction taking place in it, the lead sulphate electrode change to soft or sponge lead, (Pb - negative

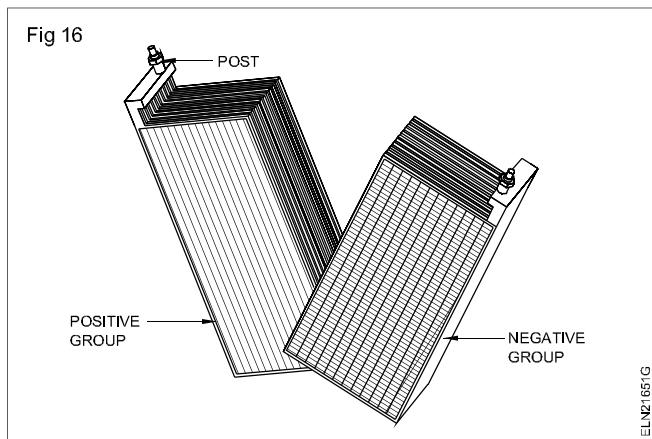
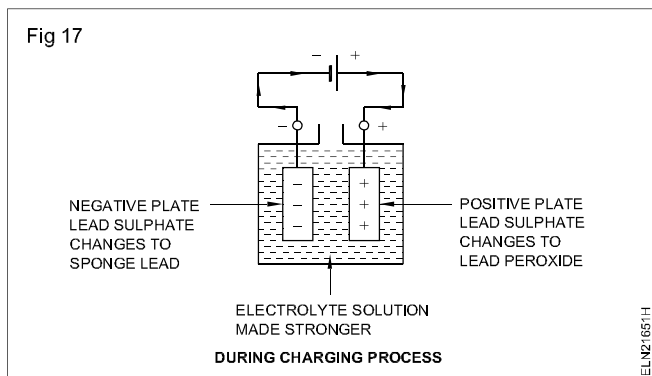


plate) and the other electrode changes to lead peroxidized (PbO_2 - positive plate).

At the same time the electrolyte solution is strengthened and becomes strong sulphuric acid (H_2SO_4) (Fig 17).



The general recommended specification of a storage cell(battery) is given below.

- Voltage/cell
- Ampere hour capacity
- No. of plates/cell
- Temperature
- Specific gravity of electrolyte
- No. of cells grouped

Voltage of a fully charged cell is 2.1 to 2.6V and the voltage falls to 1.8V after discharge.

Capacity: The unit of capacity of a storage cell is ampere-hour (AH). It is the product of the rated current of a cell/battery in amperes and the time in hours at which it can discharge that rated current,

$$\text{Capacity} = \text{Current} \times \text{Time} - \text{AH}$$

The capacity of the cell depends on the following.

- Size of the plates
- No. of plates
- Active material used
- The strength of the electrolyte

Plates: There is always one more negative plate than the number of positive plates. That is, a negative plate at both ends of the cell gives not only more mechanical strength but also ensures that both sides of the positive plate are used. It also avoids buckling of positive plates. For example a nine plate cell is having four positive and five negative plates.

Temperature and specific gravity: The temperature of the electrolyte must be kept at 27°C and the specific gravity at 1.250 ± 0.010 .

To correct the specific gravity reading to 27°C add 0.0007 to the observed hydrometer reading for each degree celsius above 27°C .

Excess temperature will cause more sulphation and buckling of the positive plate.

Defects

- Hard sulphation
- Buckling
- Partial short

Hard sulphation: Over discharging or the cell being left in a discharged condition for a long time cause sulphation on both electrodes and offers high internal resistance. The sulphation (hard) can be removed by recharging the cell for a longer period at a low rate called a trickle charge.

Buckling: The bending of electrodes due to overcharging and discharging, improper electrolyte and temperature is known as buckling.

Partial short: The sediments falling from the plates (electrodes) short- circuiting the positive and negative electrodes cause overheating of the particular cell during both charging and discharging periods. Such a cell may be replaced with a new one.

Efficiency: It is considered in two ways.

- Ampere-hour (AH) efficiency
- Watt-hour (WH) efficiency

$$\text{AH efficiency} = \frac{\text{Output in AH discharge}}{\text{Input in AH charge}}$$

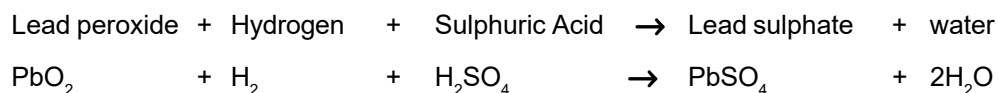
The watt-hour efficiency is always less than the ampere-hour efficiency because the potential difference during discharge is less than that during charge.

Watt - hour efficiency

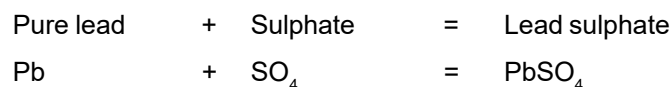
$$= \frac{\text{AH efficiency} \times \text{Average volts on discharge}}{\text{Average volts on charge}}$$

During discharge

positive plate

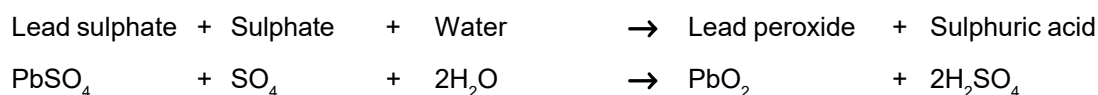


Negative plate

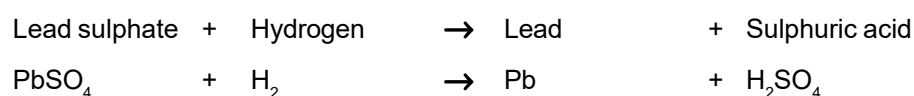


During charge

positive plate



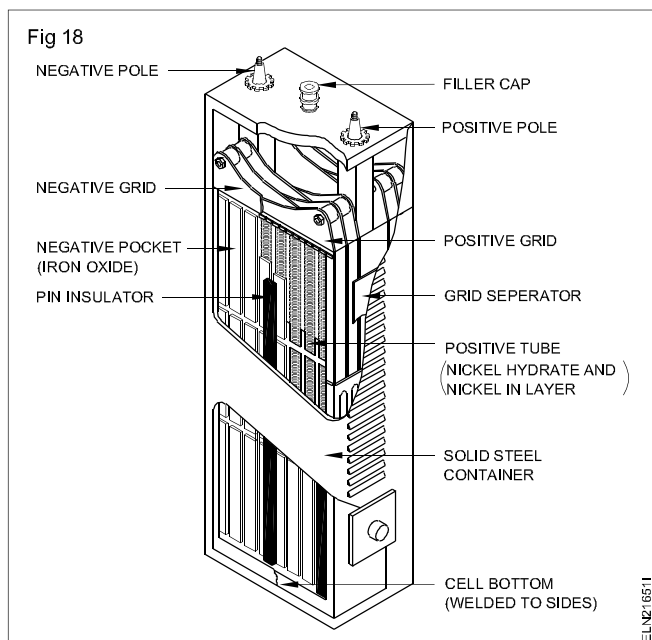
Negative plate



Nickel iron and nickel cadmium cell

In construction there is no difference between the two cells except that the negative plate of the nickel iron cell is made of iron and in the nickel cadmium cell it is of cadmium.

The nickel iron cell or Edison cell (Fig 18)



Parts

- Positive plate
- Negative plate
- Electrolyte
- Container
- Separators

The positive plate is made of Nickel hydroxide (Ni(OH)_2) tubes and perforated steel ribbon wound spirally and held together by steel ribs, and the whole lot is nickel-plated.

The negative plate is made of a nickel steel strip with fine perforation. The electrolyte is 21% solution of potassium hydroxide (KOH) along with some quantity of lithium hydrate (LiOH).

The container is made of nickel-plated steel. The separators are made of hard rubber strips and held in the nickel-plated container.

Chemical changes: On discharge, potassium hydroxide (KOH) splits up into K and (OH) ions. i.e. into potassium and hydroxide ions. OH ions travel towards the negative and oxidise the iron. K ions go to the anode and reduce Ni(OH)_2 to Ni(OH)_3 . During charging, the opposite reactions take place. The chemical changes during charging and discharging can be represented by a reversible equation.

It is seen from the equation that the electrolyte acts merely as a source for transfer of OH ions from one plate to another. It does not take part in any chemical change. As a result the density does not change to the same extent as in an ordinary lead acid cell. Thus, the density of the electrolyte remains almost the same during the action.

Characteristics: The emf of the cell when fully charged is 1.4V, and it reaches to 1.2 on discharge. If the voltage falls below 1.15, the cell is fully discharged.

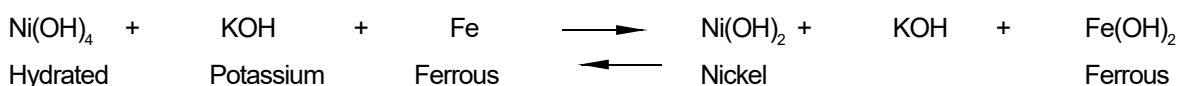
- The mechanical strength of plates is good since they are made of steel.

- The cell is portable.
- The cell can withstand heavy charge and discharge currents, and does not deteriorate even if left discharged.
- Internal resistance is large, and so the efficiency is lower than that of a lead acid cell.
- With increase in the temperature, the e.m.f. increases slightly but the capacity increases appreciably, and with a decrease in the temperature, the capacity decreases.
- It is superior to a lead acid cell in mechanical strength, durability and robustness.

Moreover, as compared to lead-acid cells, the alkaline cells operate much better at low temperatures, do not emit obnoxious fumes, have very small self-discharge and their plates do not buckle or smell.

Shelf life: Batteries are also rated for shelf life in years. Even if a cell is not being used local action takes place within the cell at all times and will eventually render the cell useless. Shelf life is defined as the time in years a stored battery will produce at least 75% of its initial capacity.

Temperature: Batteries are most often rated for a specific output capacity at room temperature or 20°C. Operating them above and below this temperature will reduce their rated output. For example, the automobile battery output drops on cold days making it more difficult to turn the engine.



Comparison : Lead-acid cell and Edison cell

Sl.No.	Particulars	Lead-acid cell	Edison cell
1	Positive plate	PbO, lead peroxide	Nickel hydroxide Ni(OH) ₄ or Nickel oxide (NiO ₂)
2	Negative plate	Sponge lead	Iron
3	Electrolyte	Diluted H ₂ SO ₄	KOH
4	Average emf	2.1 V/cell	1.2 V/cell
5	Internal resistance	Comparatively low	Comparatively higher resistance
6	Efficiency: Amp-hour Watt-hour	90 - 95% 72 - 80%	Nearly 80% About 60%
7	Cost	Comparatively less than alkaline cell	Almost twice that of Pb-acid cell (Easy maintenance)
8	Life	Gives nearly 1250 charges and discharges	Five years atleast
9	Strength	Needs much care and maintenance. Sulphation occurs often due to incomplete charge or discharge.	Robust, mechanically strong, can withstand vibration, light, unlimited rates of charge and discharge. Can be left discharged, free from corrosive liquids and fumes.

Advantages and disadvantages of nickel iron cell

(A) Advantages

- (i) It can withstand heavy charge and discharge current and does not deteriorate.
- (ii) It is robust in construction and thus it can be used even roughly.
- (iii) It is light in weight and thus it is portable.
- (iv) It can be left discharged for a long time.
- (v) It can work on higher temperatures also.
- (vi) It is used on higher temperatures also.
- (vii) It is used in electric operated vehicles, switch-gear operations etc.

(B) Disadvantages

- (i) Its EMF does not remain constant.
- (ii) Its efficiency is lower than lead-acid cell.
- (iii) It has a high internal resistance.
- (iv) Its EMF is low in comparison to lead acid cell.
- (v) If temperature is increased, its EMF will slightly reduce.

Comparison between primary and secondary cells

Primary Cell	Secondary Cell
1 It is an instant EMF producing device.	1 It is charged with electric supply first, then it produces EMF.
2 It cannot be recharged.	2 It can be recharged again and again.
3 It is light in weight.	3 It is heavy in weight.
4 It can supply a low current at a low voltage.	4 It can supply more current at comparatively more voltage.
5 It is cheap.	5 It is costly.
6 It has a short life.	6 It has a long life.
7 It transforms chemical energy into electrical energy.	7 In it, electrical energy produces certain actions in the chemicals and then chemical reactions reproduce electricity.