EFFECT OF AN ELECTRIC CURRENT ON SUBSTANCES

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Organizer 📌

Chapter objectives

By the end of this chapter, the learner should be able to:

(a) Define the terms conductor, non-conductor, electrolyte, non-electrolyte, current and electrode.
(b) Differentiate electrolyte from conductor in terms of the particles they contain.
(c) Explain the process of electrolysis and define the terms anode and cathode.
(d) State the products of electrolysis of binary compounds.
(e) State some applications of electrolysis.

EFFECT OF AN ELECTRIC CURRENT ON SUBSTANCES

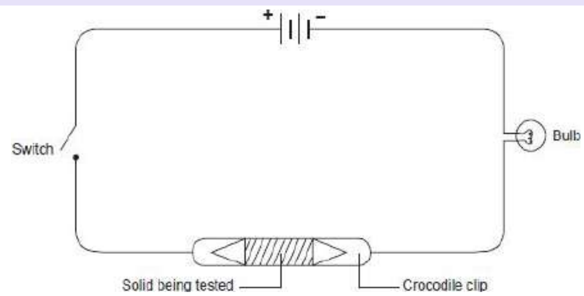
An electric current is a flow of electrons and is a form of energy.

When an electric current is passed over some substances, chemical reactions occur. Similarly, some substances can react to produce an electric current. The study of how chemical reactions produce electrical energy and in turn how electrical energy causes chemical reactions is called **Electrochemistry.**

This chapter introduces the basic concepts of electrochemistry.

Electrical Conductivity of Solids

In order to determine whether a substance will conduct an electric current or not an electric circuit which includes the substance being tested is used.

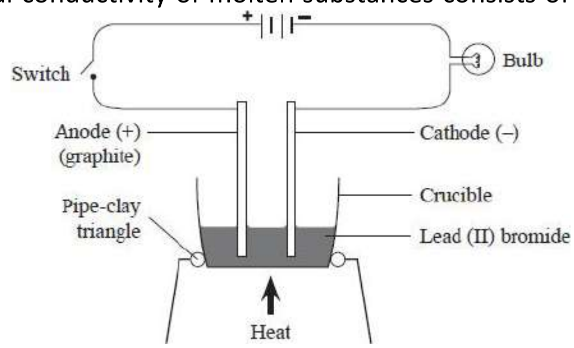


An electric circuit

- A **bulb** or **ammeter** is used **to show whether a current is flowing** when the circuit is completed. When the switch is closed, the bulb **lights up if the substance being tested allows a current to pass through it.** The bulb **does not light** if the substance being tested **does not allow a current to pass through it.**
- Substances which **allow an electric current to pass through them** are called **conductors.**
  Substances which **do not allow an electric current to pass through them** are called **non-conductors.**
- Generally, **metals are conductors of electricity.** In metals, the atoms are packed together very closely and the **delocalised electrons** move freely from one point to another within the structure.
  Graphite is a **non-metal** but **it conducts** an electric current. In graphite, the carbon atoms are bonded in such away that the resulting structure has some **delocalised electrons.**
  The **delocalised electrons** in metals and graphite are responsible for the electrical conductivity in these substances.
- **All** solid substances that do **not have delocalised electrons** in their structures are **non-conductors.**
  The battery in the circuit provides the necessary driving force which make the electrons to flow in one direction through the circuit.

Electrical Conductivity of Molten Substances

The arrangement of apparatus used to investigate the electrical conductivity of molten substances consists of two solid conductors each with one end dipped in the melt under investigation. To the other end of each solid conductor is connected a source of direct current. The solid conductors should not come into contact with each other. Either a bulb or an ammeter are used to indicate the flow of the electric current.

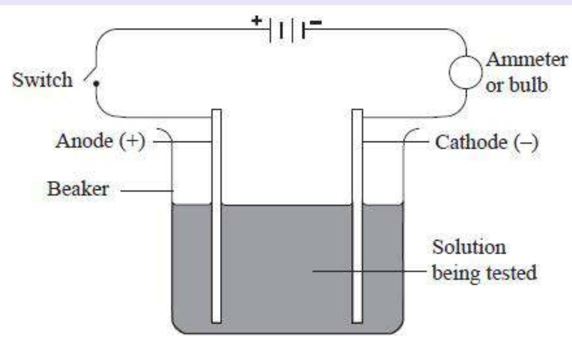


- The two solid conductors are called **electrodes**. **An electrode** is a **rod through which current enter and leave the electrolyte during electrolysis.**
  An electrode that does not influence/alter the products of electrolysis is called an **inert electrode.**
  Common inert electrodes include **platinum** and **graphite**
  Platinum is not usually used because it is very **expensive**. Graphite is **cheap** and **easily available** (e.g. from used dry cells).
- The electrode connected to the **positive terminal** of the battery is called the **anode.** The electrode connected to the **negative terminal** is called the **cathode.**
- **Ionic compounds** such as **lead (II) bromide and lead (II) iodide** do not conduct an electric current in the solid state. However, they conduct an electric current when melted.
  In the solid state, **the ions are held firmly by strong electrostatic forces and thus cannot move.** Melting **weakens these** forces **enabling the ions to move. These mobile ions in the melt are responsible for the conductivity of lead (II) bromide and lead (II) iodide.**
- Molecular substances such as sugar, sulphur and wax do not conduct an electric current both in solid and molten state. These substances have **molecular structures** and **lack charged particles**. The absence of charged particles is responsible for non- conductivity of an electric current in sugar, sulphur and wax.
- Metals are **good conductors both in the solid and molten state** because of the presence of **delocalised electrons** in their structure. When metals are melted, the delocalised electrons **remain mobile** enabling metals to be conductors in the molten state.

Electrical Conductivity of Substances in Aqueous State

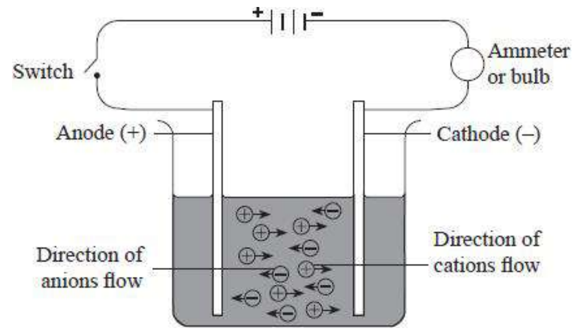
The set up shown below can be used to investigate the electrical conductivity of solutions.

Salts such as sodium chloride, copper (II) chloride and copper (II) sulphate do not conduct electricity in the solid state but when **dissolved in water they conduct.** Solutions of sulphuric (VI) acid, hydrochloric acid, sodium hydroxide and ammonia also conduct electricity.



Aqueous solutions of salts, bases and acids contain **mobile ions.** The **mobile ions are responsible for the electrical conductivity.**

When the circuit is completed, the positive ions in the solutions move towards the negative electrode (cathode) while the negative ions move towards the positive electrode (anode).



Conventionally, **an electric current is shown to move from the positive terminal to the negative terminal** even though **the electrons actually flow from the negative to the positive terminal**.

The **movement** of the ions in the solution **constitutes the current** through the solution.

Solutions of **molecular substances** such as sugar and urea **do not conduct electricity** because their solutions do **not contain ions.**

Electrolysis

Electrolysis is the process of **decomposing an electrolyte by passing an electric current through it.**

An electrolyte is a **substance which when melted or dissolved in water conducts an electric current and gets decomposed by the current.**

A compound that is **not** decomposed by an electric current is called non-electrolyte.

Solutions of salts, acids and bases are electrolytes.

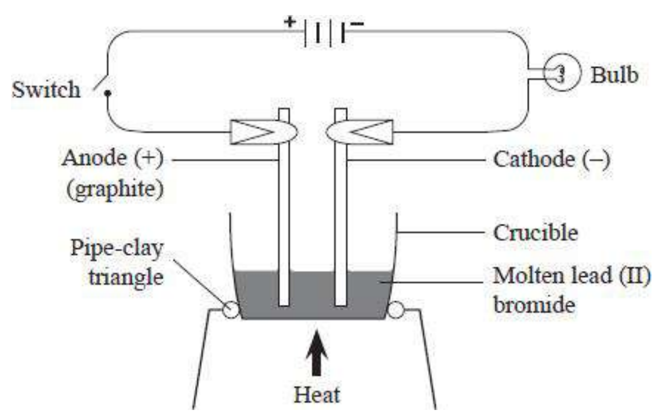
Electrolysis of binary electrolytes.

A binary electrolyte is one which **contains only one type of cation and one type of anion.**

Examples of binary electrolytes are molten halide salts such as those of lead and copper.

To electrolyse a binary electrolyte like lead (II) bromide the following procedure is used:

Fill a crucible up to a third with lead (II) bromide. Set up the apparatus as shown. Close the switch. Heat the lead (II) bromide until it melts.



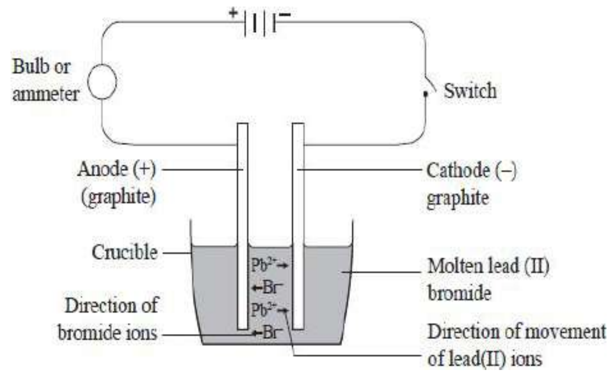
Expected Observations

A **red vapour** of bromine gas is produced at the **anode** while **grey beads** of lead metal are formed at the **cathode**

Bromine gas and lead metal are produced as a result of the decomposition of the lead (II) bromide by the electric current.

The changes that occur when lead (II) bromide is electrolysed are:

At the cathode



The positively charged lead (II) ions get attracted to the negatively charged cathode and migrate towards it. On reaching the cathode, the lead ions gain electrons to form electrically neutral atoms of lead metal. The metal is deposited as grey beads on the cathode. This change is illustrated by the following equation.

$$Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s)$$

At the anode

The negatively charged bromide ions get attracted to the positively charged anode and migrate towards it. On reaching the anode, the bromide ions lose electrons to form bromine atoms. The bromine atoms combine to form diatomic molecules of the brown bromine gas. This change is illustrated by the equation:

$$2Br^-(aq) \longrightarrow Br_2(g) + 2e^-$$

Notes:

1. **Precaution**: The experiments should be done in a fume chamber because the iodine and bromide vapors are poisonous
2. **Heating** is done to melt the electrolytes so that the ions are mobile and can then conduct electric current.
3. **For other binary electrolytes:**

Binary electrolyte	Cathode equation and Observation	Anode Equation and Observation
Lead (II) bromide ($PbBr_2$)	$Pb^{2+}(l) + 2e^- \longrightarrow Pb(s)$ Grey solid deposited	$2Br^-(l) \longrightarrow Br_2(g) + 2e^-$ Brown vapour produced
Lead (II) iodide (PbI_2)	$Pb^{2+}(l) + 2e^- \longrightarrow Pb(s)$ Grey solid deposited	$2I^-(l) \longrightarrow I_2(g) + 2e^-$ Purple vapour produced
Sodium chloride (NaCl)	$2Na^+(l) + 2e^- \longrightarrow 2Na(s)$ Grey solid deposited	$2Cl^-(l) \longrightarrow Cl_2(g) + 2e^-$ Greenish yellow fumes produced
Aluminium oxide (Al_2O_3)	$4Al^{3+}(l) + 12e^- \longrightarrow 4Al(s)$ Grey solid deposited	$6O^{2-}(l) \longrightarrow 3O_2(g) + 12e^-$ Bubbles of a colourless gas produced
Magnesium chloride ($MgCl_2$)	$Mg^{2+}(l) + 2e^- \longrightarrow Mg(s)$ Grey solid deposited	$2Cl^-(l) \longrightarrow Cl_2(g) + 2e^-$ Greenish yellow fumes produced
Copper (II) chloride ($CuCl_2$)	$Cu^{2+}(l) + 2e^- \longrightarrow Cu(s)$ Brown solid deposited	$2Cl^-(l) \longrightarrow Cl_2(g) + 2e^-$ Greenish-yellow fumes produced

Application of Electrolysis

The process of electrolysis is applied in such processes as:

(a) Extraction of reactive metals such as sodium, magnesium and aluminium by electrolysis of their molten compounds.

(b) Purification of metals.
(c) Electroplating of metals such as iron to improve their appearance and prevent corrosion.
(d) Manufacture of pure chemicals such as hydrogen gas, chlorine gas and sodium hydroxide.

Checkpoint.

1. The atomic numbers of elements C and D are 19 and 9 respectively. State and explain the electrical conductivity of the compound CD in:
(a) Solid state (1½ marks)
(b) aqueous state. (1½ marks)

2. (a) What is an electrolyte? (1 mark)
(b) State how the following substances conduct electricity.
i) Molten calcium chloride (1 mark)
ii) Graphite. (1 mark)

3. The set-up below (figure 2) was used to electrolyse a bromide of metal **D**, DBr_2.

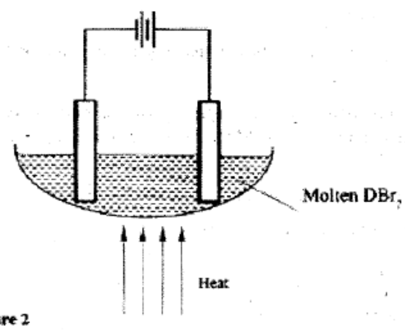


Figure 2

(i) Write equation for the reactions at the
I. cathode (1 mark)
II. anode (1 mark)
(ii) The electrodes used in the experiment were made of carbon and metal **D**. Which of the two electrodes was used as the anode? Give a reason. (2 marks)
(iii) Give a reason why this experiment is carried out in a fume cupboard. (1 mark)

4. Which one of the following compounds; urea, ammonia, sugar and copper (II) chloride will conduct an electric current when dissolved in water? Give reasons. (2 marks)

5. Explain how condition of electricity takes place in the following.
(a) Iron metal (1 mark)
(b) Molten lead (II) iodide. (1 mark)

6. An electric current was passed through several substances and the results obtained recorded in the table below.

Substance	Physical state at	Conductivity	Products

	room temperature		Anode	Cathode
A	Liquid	Does not conduct	-	-
B	Solid	Conducts	-	-
C	Liquid	Conducts	Green gas	Grey solid
D	Liquid	Conducts	Brown gas	Grey solid
E	Liquid	Conducts	-	-

Which of these substance is likely to be

(a) Magnesium; (1 mark)

(b) Hexane; (1 mark)

(c) lead (II) bromide? (1 mark)

7. A student investigated the effect of an electric current by passing it through some substances. The student used inert electrode and connected a bulb to the circuit. The table below shows the substances used and their states.

Experiment	Substances	States
1	potassium carbonate	Solid
2	copper (II) Sulphate	Solution
3	sugar	Solution
4	Lead (II) Iodide	Molten

(a) In which experiment did the bulb not light? (1 mark)

(b) Explain your answer in (a) above. (2 marks)

8. The conductivity of some substances was investigated. The observations made were recorded in Table 1. Use it to answer the questions that follow.

Table 1

Substance	Conductivity in solid state	Conductivity in molten or aqueous state
F	Does not conduct	Conducts
G	Conducts	Conducts
H	Does not conduct	Does not conduct

(i) Identify a substance that is a metal. Give a reason. (2 marks)

(ii) Substance F does not conduct electricity in solid state but conducts in molten or aqueous state. Explain. (2 marks)

9. Explain why a solution of sodium chloride conducts electricity while that of sugar does not. (2 marks)

10. Draw in the space provided a labelled diagram of the set-up of the apparatus that can be used to electrolyse molten lead(II) bromide. (3 marks)