Department of biology

((Biophysics))

Stage 1

LEC 3

Law of Conservation of Charge

By

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Law of Conservation of Charge:

Electric charge can neither be created nor destroyed; it can only be transferred from one object to another. The total charge in a closed system always remains constant.

Key Points of the Law:

1. Charge Conservation:

- Electric charge is a conserved quantity, meaning it cannot be created out of nothing or destroyed. Instead, charge is transferred between objects.

- Example: When a glass rod is rubbed with silk, electrons transfer from the rod to the silk, leaving the rod positively charged and the silk negatively charged. The total charge remains the same.

2. Closed System:

- In a closed system (where no charge enters or leaves the system), the total net charge remains constant, regardless of any interactions or processes occurring within the system.

- Example: Inside a capacitor, charges are separated but the total charge (positive + negative) remains the same.

3. Implications:

- If an object gains a positive charge, an equal amount of negative charge must appear elsewhere.

- This principle applies universally, from atomic interactions to large-scale electrical systems.

4. Most objects in our everyday experience are electrically neutral, meaning they have equal amounts of positive and negative charge.

The smallest unit of charge is the charge of an electron, denoted by 'e'. Any charge 'q' can be expressed as:

$$q = n.e$$

where '**n**' is an integer.

Example:

Imagine a system with two objects:

- Object A has a charge of +5 C.

- Object B has a charge of -3 C.

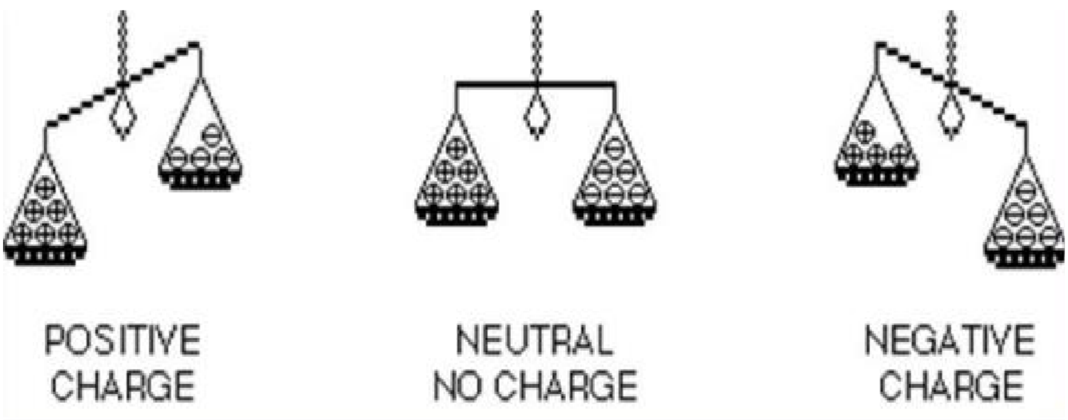
If 2 C of charge is transferred from A to B:

- New charge on A = +3 C.

- New charge on B = -1 C.

The total charge of the system remains +2 C, demonstrating conservation of charge.

The ****Law of Conservation of Charge**** underscores the importance of balance in nature, ensuring that electric charge is always conserved, regardless of the physical or chemical processes involved.



Importance of the Law of Conservation of Charge

1. **Foundation of Electrical Phenomena**:
    - The law highlights that all electrical processes depend on the transfer of charge, not its creation or destruction.
    - This understanding is essential in explaining phenomena such as static electricity, current flow, and chemical reactions.
2. **Applicability Across Scales**:
    - It applies universally, from microscopic interactions in atoms and molecules to macroscopic systems like electrical circuits.
    - For example:
        - **Microscopic level**: During ionization, electrons are transferred, but the total charge remains unchanged.
        - **Macroscopic level**: In circuits, current flow represents the transfer of charge, but the total charge in the system remains constant.
3. **Predictability and Stability**:
    - Ensures consistency in scientific principles, enabling reliable predictions and engineering designs.
    - For instance, capacitors and batteries rely on the conservation of charge for their functionality.
4. **Scientific and Practical Significance**:
    - The principle is fundamental in fields like **electrostatics**, **electrodynamics**, and **chemistry**.
    - It supports technological advancements in energy storage, electronics, and telecommunications.

Mathematical Formulation

The conservation of charge can be expressed mathematically as:

$$Q_{initial} = Q_{final}$$

Where:

- $Q_{initial}$: Total charge in the system before the interaction.
- Q_{final}: Total charge in the system after the interaction.

This equation asserts that **the total charge within a closed system remains constant**, irrespective of the processes or interactions occurring inside the system.

Question:
A carbon atom has **6 protons** in its nucleus. Each proton carries a positive elementary charge ($e=1.602\times10^{-19}$ C). What is the total charge of the carbon nucleus?

Solution:

To calculate the total charge of the carbon nucleus, multiply the number of protons (n) by the charge of a single proton (e).

q= n.e

Where:

- n=6n_p = 6 (number of protons in the carbon nucleus).
- $e=1.602\times10^{-19}$ C , (charge of a single proton).

Substitute the values:

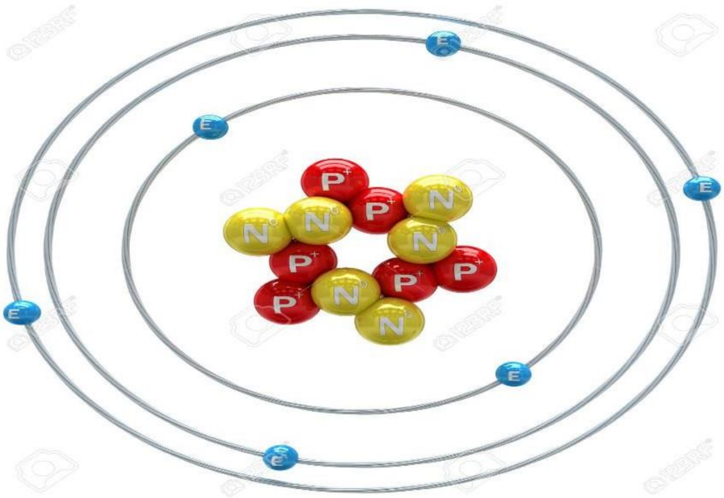
$$Q_{nucleus}=6\cdot(1.602\times10^{-19})$$
$$Q_{nucleus}=9.612\times10^{-19}\ C$$

Answer:

The total charge of the carbon nucleus is:

$Q_{nucleus}=9.612\times10^{-19}$ Coulombs (C).

This charge is **positive** because it comes from protons in the nucleus.



Multiple Choice Questions (MCQs)

1. **What does the Law of Conservation of Charge state?**
a) Electric charge can be created and destroyed.
b) Electric charge can only be transferred, not created or destroyed.
c) Electric charge can disappear in a closed system.
d) Total electric charge depends on external energy sources.

2. **Which of the following is a correct example of charge conservation?**
a) A neutral atom becomes an ion by gaining or losing electrons.
b) A charged object generates charge spontaneously.
c) Positive and negative charges cancel each other and vanish.
d) Electrons are destroyed when two objects collide.

3. **In a closed system, if one object gains a positive charge, what must happen?**
a) The total charge in the system decreases.
b) The system becomes electrically neutral.
c) An equal amount of negative charge must appear elsewhere.
d) The object creates more charge to balance.

4. **The smallest unit of charge is represented by which value?**
a) 1 C
b) $e = 1.6 \times 10^{-19}$ C
c) 10^{-9} C
d) $n \times e$

5. **What happens when a glass rod is rubbed with silk?**
a) The rod gains electrons and becomes positively charged.
b) The rod loses electrons and becomes positively charged.
c) The silk becomes positively charged by gaining electrons.
d) Both objects lose electrons.

6. **Which of the following best describes a closed system in the context of charge conservation?**
a) A system where charge is lost to the surroundings.
b) A system where charge can neither enter nor leave.
c) A system where only positive charges exist.
d) A system where charge changes depending on interactions.

7. **If a system has a total initial charge of +6 C and 3 C of charge is transferred between objects within the system, what is the final total charge of the system?**
a) +3 C
b) +6 C
c) 0 C
d) Cannot be determined.

8. **What is the equation that represents the Law of Conservation of Charge?**
   a) Qinitial × Qfinal = 0
   b) Qinitial + Qfinal = 0
   c) Qinitial = Qfinal
   d) Qinitial - Qfinal = 0

9. **Which of the following is a practical application of the Law of Conservation of Charge?**
   a) Ensuring proper functionality in capacitors.
   b) Generating new charges in circuits.
   c) Allowing charge to disappear in chemical reactions.
   d) Violating conservation principles in energy storage.

10. **What is the role of the Law of Conservation of Charge in ionization?**
    a) It ensures charge is created during electron transfer.
    b) It confirms the total charge remains unchanged even as electrons are transferred.
    c) It allows the destruction of positive charges.
    d) It supports the creation of electrons in ionized atoms.