23CHT101 – APPLIED CHEMISTRY

1 – ELECTRO CHEMISTRY

1.4 – GALVANIC CELL

A Galvanic cell, also known as a voltaic cell, is an electrochemical cell that generates electrical energy from a spontaneous redox (oxidation-reduction) reaction. It converts chemical energy into electrical energy, which can be used to power external devices.

1. Structure and Components of a Galvanic Cell

A typical galvanic cell consists of two half-cells connected by a salt bridge or a porous disk, along with an external circuit. Each half-cell contains an electrode submerged in an electrolyte solution. The cell is arranged as follows:

- Anode: The electrode where oxidation (loss of electrons) occurs. It is negatively charged in a galvanic cell.
- Cathode: The electrode where reduction (gain of electrons) occurs. It is positively charged in a galvanic cell.
- Salt Bridge: A U-shaped tube containing a salt solution (e.g., KCl or NaNO3) that completes the circuit and allows ions to move between the half-cells, maintaining electrical neutrality.
- External Circuit: Connects the anode and cathode, allowing electrons to flow from the anode to the cathode, creating an electric current.

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2. Working Principle of a Galvanic Cell

The galvanic cell operates on the principles of oxidation and reduction:

1. Redox Reaction: In a galvanic cell, a spontaneous redox reaction occurs between the two half-cells.
   - Oxidation at the Anode: The anode undergoes oxidation. For example, if zinc is the anode, the reaction would be: $Zn \rightarrow Zn^{2+} + 2e^-$
   - Reduction at the Cathode: The cathode undergoes reduction. If copper is the cathode, the reaction would be: $Cu^{2+} + 2e^- \rightarrow Cu$
2. Electron Flow: Electrons are released during oxidation at the anode and travel through the external circuit toward the cathode, where they are used in the reduction reaction.

3. Ion Movement and Salt Bridge:
    - As oxidation occurs at the anode, positive metal ions (Zn^{2+}) are released into the solution, leaving behind excess negative charge.
    - The salt bridge releases anions into the anode half-cell to balance the positive charge, while cations from the salt bridge migrate to the cathode to counterbalance the negative charge accumulated as reduction occurs. This maintains electrical neutrality in each half-cell and allows the reaction to continue.
4. Cell Potential (EMF): The potential difference between the two electrodes is known as the electromotive force (EMF) or cell potential (Ecell), measured in volts (V). The EMF drives the flow of electrons through the external circuit and is given by:

$$E_{cell} = E^\circ_{cathode} - E^\circ_{anode}$$

The cell potential depends on the nature of the electrodes and the concentration of ions in the solutions.

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3. Example of a Galvanic Cell: The Daniell Cell

The Daniell cell is a common example of a galvanic cell, which consists of a zinc electrode in a zinc sulfate solution and a copper electrode in a copper sulfate solution.

- Anode Reaction (Oxidation): At the zinc electrode, $Zn\ (s) \rightarrow Zn^{2+}(\ aq) + 2e$
- Cathode Reaction (Reduction): At the copper electrode, $Cu^{2+}(aq) + 2e^- \rightarrow Cu\ (s)$

In this setup, zinc loses electrons (oxidized) at the anode, and copper gains electrons (reduced) at the cathode. The overall cell reaction is:

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

The EMF generated by this cell is approximately 1.1 V under standard conditions.

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4. Applications of Galvanic Cells

Galvanic cells are used in various applications, primarily in situations where portable and steady sources of electrical energy are required.

- Batteries: Many primary and secondary batteries are based on galvanic cells, including alkaline batteries, lead-acid batteries, lithium-ion batteries, and nickel-cadmium batteries.
- Portable Electronic Devices: From phones to laptops, galvanic cells in rechargeable batteries are widely used for their efficiency and ability to deliver consistent power.

- Corrosion Prevention: Galvanic cells play a role in corrosion, especially in metals exposed to electrolyte solutions. Galvanic cells can be used to create a "sacrificial anode" to prevent corrosion in pipelines and ships.
- Fuel Cells: Fuel cells are galvanic cells that generate electricity through the reaction of hydrogen with oxygen, offering an environmentally friendly energy source.

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5. Advantages of Galvanic Cells

- Portable and Reliable Power: They provide a portable and reliable source of electrical energy for various devices.
- Rechargeable Designs: Some galvanic cells (e.g., lithium-ion cells) are rechargeable, enhancing their longevity.
- High Energy Density: Many galvanic cells have a high energy density, providing significant power in a compact size.

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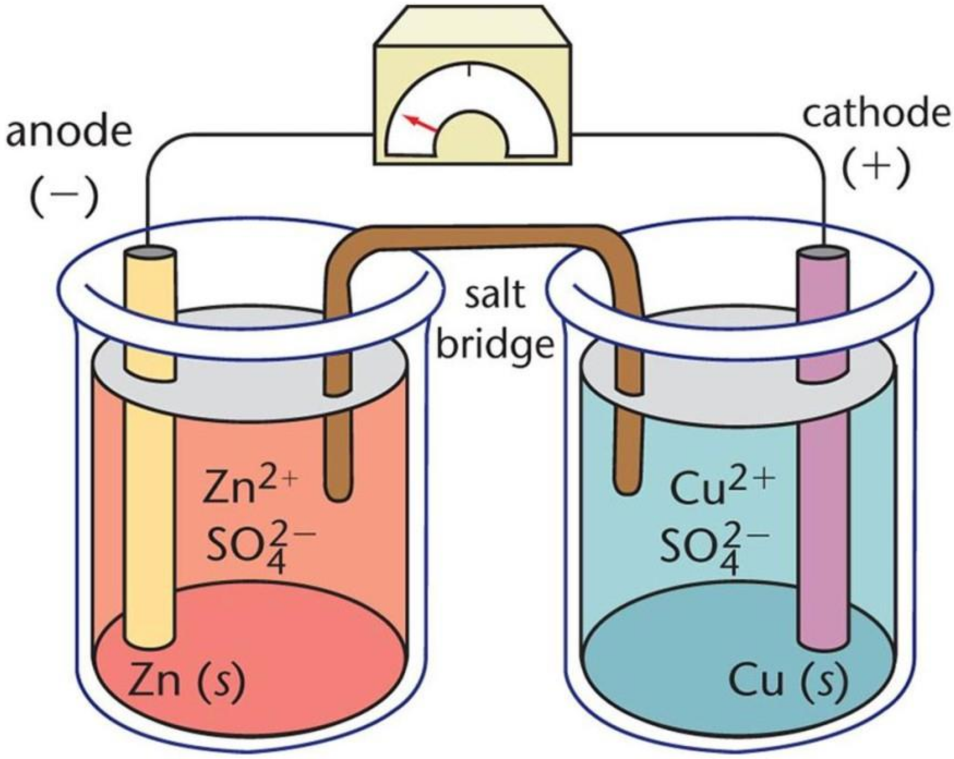
6. Limitations of Galvanic Cells

- Limited Lifespan: Non-rechargeable galvanic cells, once exhausted, must be replaced, which can generate waste.
- Corrosion: The chemical reactions within some galvanic cells can lead to corrosion, impacting performance and longevity.
- Environmental Impact: Disposal of certain types of galvanic cells (e.g., lead-acid or cadmium-based) requires careful handling due to toxic components.

Summary

Galvanic cells play a foundational role in energy storage and delivery in modern technology. They work by using spontaneous redox reactions to produce electrical energy, finding applications in everything from small electronics to industrial power systems. Their design and versatility make them essential in both consumer and industrial applications.


anode
(−)
cathode
(+)
salt
bridge
Zn2+
SO42−
Cu2+
SO42−
Zn (s)
Cu (s)