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Voltaic Cells (Batteries)*

Unit: DC Circuits

NGSS Standards/MA Curriculum Frameworks (2016): N/A

AP® Physics 2 Learning Objectives/Essential Knowledge (2024): N/A

Mastery Objective(s): (Students will be able to…)

- Explain how a battery works.
- Identify the components of a battery and their function.

Success Criteria:

- Descriptions are accurate and components are identified correctly

Language Objectives:

- Explain how a battery works. (Domains: speaking, writing)
- Identify the components of a battery and their function (Domains: speaking, writing)

Tier 2 Vocabulary: battery, current

Labs, Activities & Demonstrations:

- building a voltaic cell

Notes:

voltaic cell: (also called a galvanic cell) a chemical apparatus that uses an electrochemical reaction to produce electricity. (A battery is a type of galvanic cell.)

electrochemistry: using chemical oxidation & reduction (redox) reactions to produce electricity or vice-versa. In an electrochemical reaction, oxidation and reduction reactions occur in separate containers, and electrons travel from one container to the other. In physics, the chemical energy from the combination of the two reactions is the potential difference (voltage) that moves those electrons through an electric circuit.

electrolytic cell: a cell similar to a galvanic cell, except that the reaction is nonspontaneous, and electricity is used to add the energy needed to make the reaction occur. (Electrolysis of water is an example.)

electrode: a solid metal strip where either oxidation or reduction occurs. The metal strips also conduct the electrons into or out of the electric circuit.

* Voltaic cells are taught in AP® Chemistry as part of the topic of electrochemistry. The topic is presented here in order to explain where the electric potential in a battery comes from.

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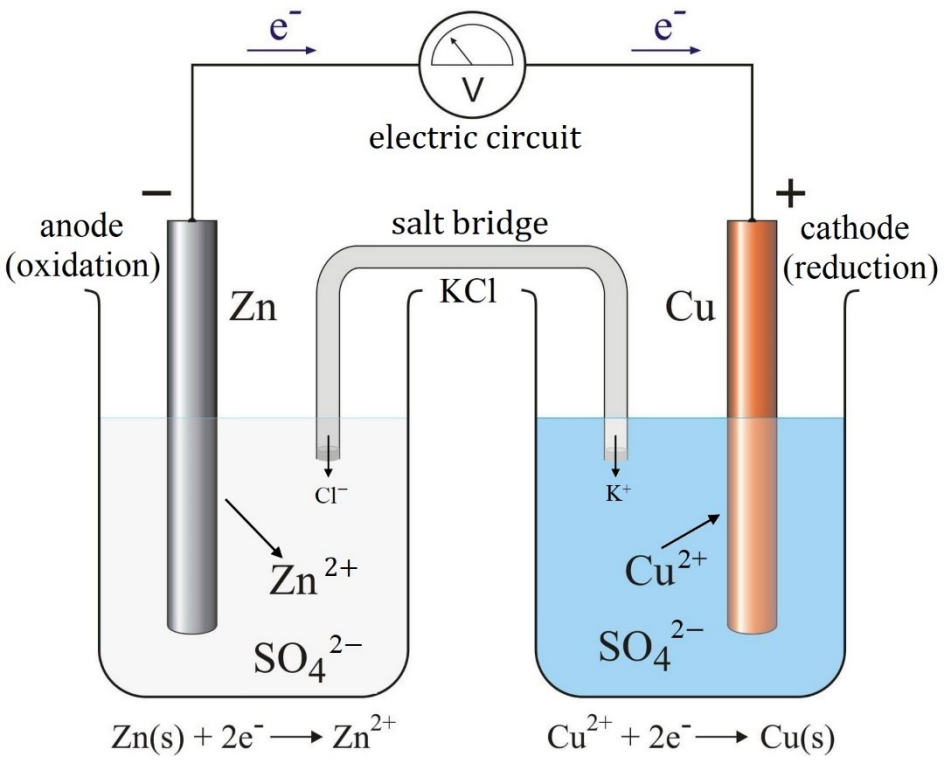
anode: the negatively (−) charged electrode. At the anode:

- Oxidation occurs. (Atoms from the anode are oxidized into positive ions.)
- These positive ions are released into the solution. (*I.e.,* the anode loses mass.)
- The electrons produced by oxidation are forced through the wire toward the cathode via the electric circuit.

cathode: the positively (+) charged electrode. At the cathode:

- Reduction occurs. (Ions from the solution are reduced to neutral metal atoms.)
- These metal atoms are deposited onto the cathode. (*I.e.,* the cathode gains mass.)
- The electrons needed for reduction are brought in through the wire from the anode via the electric circuit.

salt bridge: a salt solution that is connected to both half-cells. The salt bridge provides ions for the two half-cells in order to keep the charges balanced. (If the charges are not allowed to balance, opposite charges would build up in both cells and the reaction would stop.) The salt solution must be made of ions that do not take part in the reactions at the cathode or anode. (KNO_3 is commonly used.)



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standard voltage (*E*°): the voltage (electric potential) of an electrochemical reaction under "standard conditions".

- "Standard conditions" means temperature is 25 °C, all ion concentrations are $1\frac{\text{mol}}{\text{L}}$, and all gas pressures are 1 atm.*
- The actual voltage of the cell, *V*, depends on the temperature, ion concentrations and gas pressures. At standard conditions, $V = E^o$.
- *E*° values for reduction reactions are published in tables of Standard Reduction Potentials.
- *E*° for an oxidation reaction is the negative of the *E*° for the reverse (reduction) reaction. *(I.e.,* if you reverse the reaction, change the sign of *E*°.)
- The standard voltage of a cell is the sum of the standard voltages for the oxidation and reduction half-cells:
  - $E^o = E^o_{reduction} + E^o_{oxidation}$
- If $E^o > 0$, then the reaction happens spontaneously. This is what happens when a battery is used to power a circuit.
- If $E^o < 0$, the reaction does not occur spontaneously, and energy is required to force the reaction to occur. This is what happens while a battery is charging.

* You can tell that "standard conditions" were defined by chemists. If they were defined by physicists, standard pressure would be 1 bar rather than 1 atm.