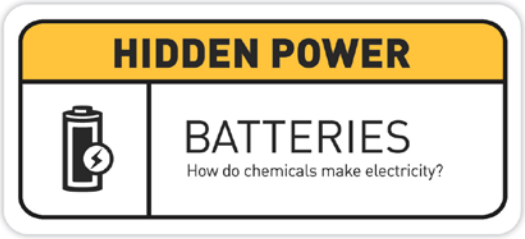

Question & Answer Fact Sheet

What is a battery?

A battery is a device that stores chemical energy and when needed, converts this energy into electricity.

How does a battery work?

All batteries have three main components: a cathode, an anode, and an electrolyte. The cathode is an electrode where reduction occurs. (Positively charged ions – cations – migrate towards this electrode, take electrons, and become reduced to a lower energetic state.) Conversely, the anode is the electrode where the oxidation occurs. (Negatively charged ions – anions – migrate to this electrode and lose electrons.) The cathode and anode are separated by an electrolyte, a substance through which the charged ions move inside the battery.

The flow of electrons between the anode and cathode to accomplish the oxidation and reduction of the ions occurs outside the battery. When being used to provide power, electrons are collected from anions at the anode, travel through the electrical circuitry and wiring (doing whatever work is required along the way), and then are consumed by the cations at the cathode to end their journey.

Why are some batteries rechargeable and others not?

In rechargeable batteries, the chemical reactions that occur at the electrodes are reversible. When fully charged, the battery can supply electricity to an external device. Once depleted, the cations and anions can be recreated by applying electrical energy from another source back into the system. In the case of Lithium-ion batteries, Li cations are reversibly transported between the anode and cathode and there is no anion transport.

Unfortunately, not all chemical reactions are easily reversible. In disposable batteries, the internal chemical reaction only occurs in one direction. Therefore, once this chemical reaction is completed, the battery no longer contains the potential energy to create electricity and is considered “dead.”

Batteries differ depending upon the types of chemicals and materials used to create them, and the structure with which they are built.

What is the significance and social impact of this technology?

Batteries are portable, making electricity accessible wherever you need it. The watch on your wrist, cars traveling down the street, the cell phone in your pocket, a laptop carried between work and home, cameras, flashlights, and countless other devices are all powered by batteries inside.

Additionally, batteries provide a means of storing energy for later usage, when the original source of energy is not currently available or intermittent (such as solar and wind power).

What are the limitations of using batteries?

Batteries, by their nature, can only store a limited amount of energy and face the inevitable challenge of deterioration. If used, stored, or disposed of improperly, they also pose threats such as fire, explosion,

and serious environmental contamination. It is important for consumers to understand the proper way of handling batteries so that their lifespan can be maximized and safety is assured.

In 2008, while being recharged, a lithium ion battery used within the Navy's Advanced Seal Delivery System (ASDS) caught fire and destroyed this one-of-a-kind mini-submarine. The vehicle was designed to stealthily transport Navy SEALS in a dry-deck environment, saving their physical strength for the mission ahead. (http://op-for.com/2008/11/asds_fire.html)

What are the scientists and engineers doing to make batteries better?

Due to the important need for sustainable, clean, and efficient energy production and storage, tremendous effort and money are being invested to improve every aspect of batteries, including lifespan, safety, portability (power-to-weight ratio), charge-discharge performance, energy density, etc.

At Penn State University, the Battery and Energy Storage Technology (BEST) Center has been created to focus on green and efficient energy storage technologies for sustainable electric vehicles, intermittent renewable energy sources (such as wind and solar), and smart grids. The Center includes the Battery Manufacturing Laboratory (BML), where experimental high-density batteries can be fabricated from scratch for the purpose of research and development of new materials and designs.

(http://www.research.psu.edu/news/2011/new-center-to-focus-on-battery-energy-storage-technology)

The BEST center specializes in large-scale batteries that can power buildings or city blocks. These types of batteries are needed to establish renewable energy as a reliable source of energy. The batteries being developed at BEST must be inexpensive and last a long time – up to 20 years!

On the other end of the size spectrum, the size of the battery often determines how small a device can be. Battery materials must have enough energy per unit volume (energy density) to power the needed device, but the required energy density is difficult to create on the small scale. This limiting factor is what is keeping most cell phones, mp3 players, pacemakers, and computers from getting any smaller. However, currently there is research being done, using nanotechnology, to print batteries onto paper. These cellulose batteries are stackable, and foldable, and could allow us to power devices with much smaller, more flexible, and less toxic batteries.

Can you describe some common batteries?

Primary batteries (disposable, non-rechargeable)

- Alkaline battery: Composed of a manganese dioxide (MnO_2) cathode and zinc (Zn) powder anode; name derived from the potassium hydroxide (KOH) electrolyte, an alkaline substance.

Secondary Batteries (rechargeable) – lower total cost and environmental impact

- Lead acid batteries: Moderately expensive with moderate capacity; high discharge rate and maintains a high power-to-weight ratio; features make them attractive for use in motor vehicles to provide the high current required by automobile starter motors; environmental hazard due to lead.
- NiMH batteries (Nickel Metal Hydride batteries): Composed of a nickel oxyhydroxide (NiOOH) cathode and a hydrogen absorbing metal alloy anode; inexpensive and performs better than alkaline batteries in higher-drain devices; very popular for rechargeable AA or AAA batteries.
- Lithium ion batteries: Expensive, but has a very high energy density; can be very volatile when short-circuited (see ASDS story above); one of the most popular batteries for small portable devices.