KLiB

Scheme for the Classification of Secondary Battery Types
(Version 15.12.2025, Dominik Sollmann et al.)

rechargeable?
- no → **Primary battery**
- yes → **Secondary battery**

Solid electrolyte or solid enough to still act as a mechanical barrier in the sense of a separator (can be picked up with tweezers, may contain liquid, but which does not act independently as electrolyte) **and no other liquid components at operating temperature?**
- yes → **Solid(-state) battery (SB, SSB)**

Note 1: "Solid(-state) batteries" that contain liquids that are bound as a gel, for example, are only counted as solid-state batteries if the liquids are not the actual electrolyte and are enclosed in such a way that they do not escape when the cell is opened (self-standing electrolyte, can be picked up with tweezers). This distinguishes them from commercially available lithium-ion polymer batteries, as the actual liquid electrolyte (!) is embedded in a polymer "carrier matrix".

Note 2: The solid electrolyte can become soft, especially in (S)SBs with polymer electrolyte and heating device, which means that a clear distinction as a solid can no longer be made. It is therefore important here that the electrolyte can still function as the mechanical barrier of a solid even at elevated operating temperatures.

All-Solid (no liquid components in operation)?
- yes → **All-solid(-state) battery (ASB, ASSB)**
- no → **Liquid-assisted solid(-state) battery (LSB, LSSB)**

Deposition of the electrolyte and other materials **from gas phase or plasma** in the production process?
- yes → **Thin-film all-solid(-state) battery (thin-film ASB, thin-film ASSB)**
  - Lithium thin-film all-solid(-state) battery
  - ...
- no → **Thick-film all-solid(-state) battery (thick-film ASB, thick-film ASSB)**
  - Lithium thick-film all-solid(-state) battery
  - Sodium thick-film all-solid(-state) battery
  - ...

Anolyte and catholyte (the electrochemical reactants) **are present as flowing media** (liquid, suspension or gaseous) at least **during charging or discharging** and **the active material is circulated outside the cell and stored in tanks?**
- yes → **Flow battery,** battery with flow architecture **(FB)**

Note: Battery types in which only the electrolyte is pumped (to prevent dendrite growth, for example) are referred to as "flow-assisted" or "pumped". Flow batteries have a flow architecture and are therefore similar in structure to redox flow batteries such as all-vanadium RFBs (tanks and stacks)

Anolyte and catholyte are present as flowing media during charging and discharging (liquid, suspension or gaseous)?
- yes → **Redox flow battery (RFB)**

Note: An important criterion here is that the performance can be influenced by the stack and the capacity by the tank size.

Metal-free, organic redox couple?
- yes → **Organic redox flow battery (O-RFB)**
- no → **Inorganic redox flow battery (I-RFB)**
  - All-vanadium (I-)RFB
  - ...

- no → **Hybrid flow batteries (HFB)**
  - Zinc – bromine HFB
  - Zinc – cerium HFB (Zn/Ce_2)
  - Iron salt HFB
  - ...

Note: An important criterion here is that performance and capacity cannot be influenced by the stack and tank size, as is the case with RFB.

Increased operating temperature (actively supplied, above room temperature (25 °C))?
- yes → **High- and medium-temperature battery (TB, HMTB)**
  - Sodium – sulfur HMTB
  - Sodium – nickel chloride HMTB
  - Lithium – "lead-antimony" HMTB
  - ...

Note: There are solid(-state) batteries that operate at 60 to 80 degrees Celsius (actively supplied) as the polymer-based BlueSolutions from Bolloré). There are also flow batteries that are operated at elevated temperatures (zinc – cerium at 20 to 50 degrees Celsius). These were differentiated here by "branching off" solid(-state) batteries and flow batteries beforehand in this flow chart.

Operating temperature higher than (190 to) 200 °C (may vary depending on battery type)?
- yes → **High-temperature battery (HTB)**
  - Sodium – sulfur HTB
  - Sodium – nickel chloride HTB
  - ...
- no → **Medium-temperature battery (MTB)**
  - Sodium – sulfur MTB
  - Sodium – nickel chloride MTB
  - ...

Note: Medium-temperature batteries are (often) to be understood as the next generation of the first generation(s) of HTBs, which are associated with a significant reduction in operating temperature and thermal losses. This development is more important than rigid temperature limits when classifying these batteries. A lower operating temperature limit of 60 degrees Celsius is proposed for MTBs.

At least 1 redox-active component is gaseous?
- yes → **Metal – gas battery (MGB)**

1 redox-active component is oxygen/ air, the other a metal?
- yes → **Metal – air battery, metal – oxygen (MAB, MOB)**
  - Lithium – air (MA-)battery
  - Zinc – air (MA-)battery
  - ...
- no
  - Nickel – hydrogen (MG-)battery
  - ...

Note: The individual battery types are named after the corresponding gas

2 insertion, conversion or alloy electrodes?
- yes → **Ion battery,** rocking-chair battery **(IB)**

Note: Stored = insertion or intercalation, conversion or alloy formation.

Anions and cations are stored?
- yes → **Dual-ion battery,** rocking-chair dual-ion battery **(D-IB, DIB)**
- no

Are **only cations** responsible for ionic charge transfer?
- yes → **Cation battery,** rocking-chair cation battery **(C-IB, CIB)**
  - Lithium-ion battery
  - Sodium-ion battery
  - ...
- no → ***Anion battery,*** *rocking-chair anion battery* ***(A-IB, AIB)***
  - Fluoride-ion battery (Anion: fluoride)
  - Chloride-ion battery (Anion: chloride)
  - Magnesium – sulfide AIB (Anion: sulfide)
  - ...

- no → **AE battery,** amorphous electrode battery, beanbag battery **(AEB)**

1 redox-active component is (elemental) sulfur?
- yes → **Metal – sulfur (AE) battery (MSB, RT-MSB, S-AEB)**
  - Lithium – sulfur (AE-)battery
  - Sodium – sulfur (AE-)battery
  - Magnesium – sulfur (AE-)battery
  - Lithium-metal – sulfur catholyte suspension "semi-flow" battery
  - ...

Note: To distinguish MSBs more clearly from HMTBs, it may be useful to prefix the battery type with "RT" (for room temperature), i.e. RT metal – sulfur batteries or RT-MSBs.

Do cations transfer the ionic charge?
- yes → **Cation AE battery,** beanbag cation battery **(C-AEB, CAEB)**
  - Lithium-metal (anode) AEB
  - Sodium-metal (anode) AEB
  - ...
- no → **Anion AE battery,** beanbag anion battery **(A-AEB, AAEB)**
  - Lead – acid A-AEB (anion: sulfate)
  - Zinc – silver A-AEB (anion: hydroxide)
  - Rechargeable alkaline manganese (RAM) A-AEB (anion: hydroxide)
  - Nickel – cadmium A-AEB (anion: hydroxide)
  - Nickel – metal hydride (NiMH) A-AEB (anion: hydroxide)
  - Nickel – iron A-AEB (anion: hydroxide)
  - Nickel – zinc A-AEB (anion: hydroxide)
  - ...