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# Comparison of commercial battery types

## Contents



## Common characteristics

| Cell chemistry | Also known as | Electrode | | Re-charge-able | Com-mercial-ized | Voltage | | | Energy density | | Specific power | Cost† | Discharge efficiency | Self-discharge rate | Shelf life |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Anode | Cathode | | | Cutoff | Nominal | 100% SOC | by mass | by volume | | | | | |
| | | | | | year | V | V | V | MJ/kg (Wh/kg) | MJ/L (Wh/L) | W/kg | Wh/$ ($/kWh) | % | %/month | years |
| **Lead-acid** | SLA VRLA | Lead | Lead dioxide | Yes | 1881[1] | 1.75[2] | 2.1[2] | 2.23–2.32[2] | 0.11–0.14 (30–40)[2] | 0.22–0.27 (60–75)[2] | 180[2] | 6.48–16.67 (60–154)[2] | 50–92[2] | 3–20[2] | |
| **Zinc-carbon** | Carbon-zinc | Zinc | Manganese (IV) oxide | No | 1898[3] | 0.75–0.9[3] | 1.5[3] | | 0.13 (36)[3] | 0.33 (92)[3] | 10–27[3] | 2.96 (337)[3] | 50–60[3] | 0.32[3] | 3–5[4] |
| **Zinc-air** | PR | | Oxygen | No | 1932[5] | 0.9[5] | 1.45–1.65[5] | | 1.59 (442)[5] | 6.02 (1,673)[5] | 100[5] | 2.59 (386)[5] | 60–70[5] | 0.17[5] | 3[5] |
| **Mercury oxide-zinc** | Mercuric oxide Mercury cell | | Mercuric oxide | No | 1942–[6] 1996[7] | 0.9[8] | 1.35[8] | | 0.36–0.44 (99–123)[8] | 1.1–1.8 (300–500)[8] | | | | | 2[6] |
| **Alkaline** | $Zn/MnO_2$ LR | | Manganese (IV) oxide | No | 1949[9] | 0.9[10] | 1.5[11] | 1.6[10] | 0.31–0.68 (85–190)[12] | 0.90–1.56 (250–434)[12] | 50[12] | 0.46 (2160)[12] | 45–85[12] | 0.17[12] | 5–10[4] |
| **Rechargeable alkaline** | RAM | | | Yes | 1992[13] | 0.9[14] | 1.57[14] | 1.6[14] | | | | | | <1[13] | |
| **Silver-oxide** | SR | | Silver oxide | No | 1960[15] | 1.2[16] | 1.55[16] | 1.6[17] | 0.47 (130)[17] | 1.8 (500)[17] | | | | | |
| **Nickel-zinc** | NiZn | | | Yes | 2009[13] | 0.9[13] | 1.65[13] | 1.85[13] | | | | | | 13[13] | |
| **Nickel-iron** | NiFe | Iron | | Yes | 1901[18] | 0.75[19] | 1.2[19] | 1.65[19] | 0.07–0.09 (19–25)[20] | 0.45 (125)[21] | 100 | 3.94–5.26 (190–254)[1] | | 20–30 | 30–[22] 50[23][24] |
| **Nickel-** | NiCd | Cadmium | | Yes | c. | 0.9– | 1.2[27] | 1.3[26] | 0.11 | 0.36 | 150– | | | 10[13] | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **cadmium** | NiCad | | Nickel oxide hydroxide | | 1960[25] | 1.05[26] | | | (30)[27] | (100)[27] | 200[28] | | | | |
| **Nickel-hydrogen** | $NiH_2$<br>$Ni-H_2$ | Hydrogen | | Yes | 1975[29] | 1.0[30] | 1.55[28] | | 0.16–0.23<br>(45–65)[28] | 0.22<br>(60)[31] | 150–<br>200[28] | | | | 5[31] |
| **Nickel-metal hydride** | NiMH<br>Ni-MH | Metal hydride | | Yes | 1990[1] | 0.9–<br>1.05[26] | 1.2[11] | 1.3[26] | 0.36<br>(100)[11] | 1.44<br>(401)[32] | 250–<br>1000 | 3.15<br>(317)[1] | | 30[33] | |
| **Low self-discharge nickel-metal hydride** | LSD NiMH | | | Yes | 2005[34] | 0.9–<br>1.05[26] | 1.2 | 1.3[26] | 0.34<br>(95)[35] | 1.27<br>(353)[36] | 250–<br>1000 | | | 0.42[33] | |
| **Lithium-manganese dioxide** | Lithium<br>$Li-MnO_2$<br>CR<br>Li-Mn | Lithium | Manganese dioxide | No | 1976[37] | 2[38] | 3[11] | | 0.54–1.19<br>(150–330)[39] | 1.1–2.6<br>(300–710)[39] | 250–<br>400[39] | | | 1 | 5-10[39] |
| **Lithium-carbon monofluoride** | $Li-(CF)_x$<br>BR | | Carbon monofluoride | No | 1976[37] | 2[40] | 3[40] | | 0.94–2.81<br>(260–780)[39] | 1.58–5.32<br>(440–1,478)[39] | 50–<br>80[39] | | | 0.2–0.3[41] | 15[39] |
| **Lithium-iron disulfide** | $Li-FeS_2$<br>FR | | Iron disulfide | No | 1989[42] | 0.9[42] | 1.5[42] | 1.8[42] | 1.07<br>(297)[42] | 2.1<br>(580)[43] | | | | | |
| **Lithium–titanate** | $Li_4Ti_5O_{12}$<br>LTO | | Lithium manganese oxide or Lithium nickel manganese cobalt oxide | Yes | 2008[44] | 1.6-<br>1.8[45] | 2.3-<br>2.4[45] | 2.8[45] | 0.22–0.40<br>(60–110) | 0.64<br>(177) | 3,000-<br>5,100[46] | 0.47<br>(2131)[46] | 85[46] | 2-5[46] | 10–<br>20[46] |
| **Lithium cobalt oxide** | $LiCoO_2$<br>ICR<br>LCO<br>Li-cobalt[47] | Graphite‡ | Lithium cobalt oxide | Yes | 1991[48] | 2.5[49] | 3.7[50] | 4.2[49] | 0.70<br>(195)[50] | 2.0<br>(560)[50] | | 2.63<br>(380)[1] | | | |
| **Lithium iron phosphate** | $LiFePO_4$<br>IFR<br>LFP<br>Li-phosphate[47] | | Lithium iron phosphate | Yes | 1996[51] | 2[49] | 3.2[50] | 3.65[49] | 0.32–0.58<br>(90–160)[50][52][53] | 1.20<br>(333)[50][52] | 200 [54] | | | 4.5 | |
| **Lithium manganese oxide** | $LiMn_2O_4$<br>IMR<br>LMO<br>Li-manganese[47] | | Lithium manganese oxide | Yes | 1999[1] | 2.5[55] | 3.9[50] | 4.2[55] | 0.54<br>(150)[50] | 1.5<br>(420)[50] | | 2.63<br>(380)[1] | | | |
| **Lithium nickel cobalt aluminium oxides** | $LiNiCoAlO_2$<br>NCA<br>NCR<br>Li-aluminium[47] | | Lithium nickel cobalt aluminium oxide | Yes | 1999 | 3.0[56] | 3.6[50] | 4.3[56] | 0.79<br>(220)[50] | 2.2<br>(600)[50] | | | | | |
| **Lithium nickel manganese cobalt oxide** | $LiNi_xMn_yCo_{1-x-y}O_2$<br>INR<br>NMC[47]<br>NCM[50] | | Lithium nickel manganese cobalt oxide | Yes | 2008[57] | 2.5[49] | 3.6[50] | 4.2[49] | 0.74<br>(205)[50] | 2.1<br>(580)[50] | | | | | |

^† Cost in USD, adjusted for inflation.

^‡ Typical. See Lithium-ion battery § Negative electrode for alternative electrode materials.

## Rechargeable characteristics

| Cell chemistry | Charge efficiency | Cycle durability |
|---|---|---|
| | % | # cycles |
| **Lead-acid** | 50–92[2] | 500 typical, 800 max[2] |
| **Rechargeable alkaline** | | 5–100[13] |
| **Nickel-zinc** | | 100 to 50% capacity[13] |
| **Nickel-iron** | 65–80 | 5000 |
| **Nickel-cadmium** | | 500[25] |
| **Nickel-hydrogen** | | 20000[31] |
| **Nickel-metal hydride** | 66 | 300–800[13] |
| **Low self-discharge nickel-metal hydride battery** | | 500–1500[13] |
| **Lithium cobalt oxide** | 90 | 500–1000 |
| **Lithium–titanate** | 85-90 | 6000–10000 to 90% capacity[46] |
| **Lithium iron phosphate** | 90 | 3000–7000 to 80% capacity |
| **Lithium manganese oxide** | 90 | 300–700 |

## Thermal runaway

Under certain conditions, some battery chemistries are at risk of thermal runaway, leading to cell rupture or combustion. As thermal runaway is determined not only by cell chemistry but also cell size, cell design and charge, only the worst-case values are reflected here.[58]

| Cell chemistry | Overcharge | Overheat | | |
|---|---|---|---|---|
| | Onset | Onset | Runaway | Peak |
| | SOC% | °C | °C | °C/min |
| **Lithium cobalt oxide** | 150[58] | 165[58] | 190[58] | 440[58] |
| **Lithium iron phosphate** | 100[58] | 220[58] | 240[58] | 21[58] |
| **Lithium manganese oxide** | 110[58] | 210[58] | 240[58] | 100+[58] |
| **Lithium nickel cobalt aluminium oxide** | 125[58] | 140[58] | 195[58] | 260[58] |
| **Lithium nickel manganese cobalt oxide** | 170[58] | 160[58] | 230[58] | 100+[58] |

## NiCd vs. NiMH vs. Li-ion vs. Li-polymer vs. LTO

| Types | Cell Voltage | Self-discharge | Memory | Cycles Times | Temperature | Weight |
|---|---|---|---|---|---|---|
| NiCd | 1.2V | 20%/month | Yes | Up to 800 | -20°C To 60°C | Heavy |
| NiMH | 1.2V | 30%/month | Mild | Up to 500 | -20°C To 70°C | Middle |
| Low Self Discharge NiMH | 1.2V | 1%/month - 3%/year [59] | No | 500 - 2000 | -20°C To 70°C | Middle |
| Li-ion (LCO) | 3.6V | 5-10%/month | No | 500-1000 | -40°C To 70°C | Light |
| LiPo (LCO) | 3.7V | 5-10%/month | No | 500-1000 | -40°C To 80°C | Lightest |
| Li-Ti (LTO) | 2.4V | 2-5%/month[46] | No | 6k-20k | -40°C To 55°C | Light |

[60]

## See also

- Battery nomenclature
- Experimental rechargeable battery types
- Aluminum battery
- List of battery sizes
- List of battery types
- *Search for the Super Battery* (2017 PBS film)

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