Batteries

pranjoto utomo

Dry Cell / le Clanche Cell

Voltage : 1,5 V

Cathode : carbon

Anode : zinc

Electrolyte : pasta (MnO_2, NH_4Cl, $ZnCl_2$)

Dry Cell / le Clanche Cell

Reaction :

anode : $Zn\ (s) \rightarrow Zn^{2+}(aq) + 2e^-$

cathode :

$NH_4^+(aq) + 2e^- \rightarrow 2NH_3(g) + H_2(g)$

$2MnO_2(s) + H_2(g) \rightarrow Mn_2O_3(s) + H_2O(\ell)$

$Zn^{2+}(aq) + 2NH_3(g) + 2Cl^-(aq)$

$\rightarrow Zn(NH_3)_2Cl_2(s)$

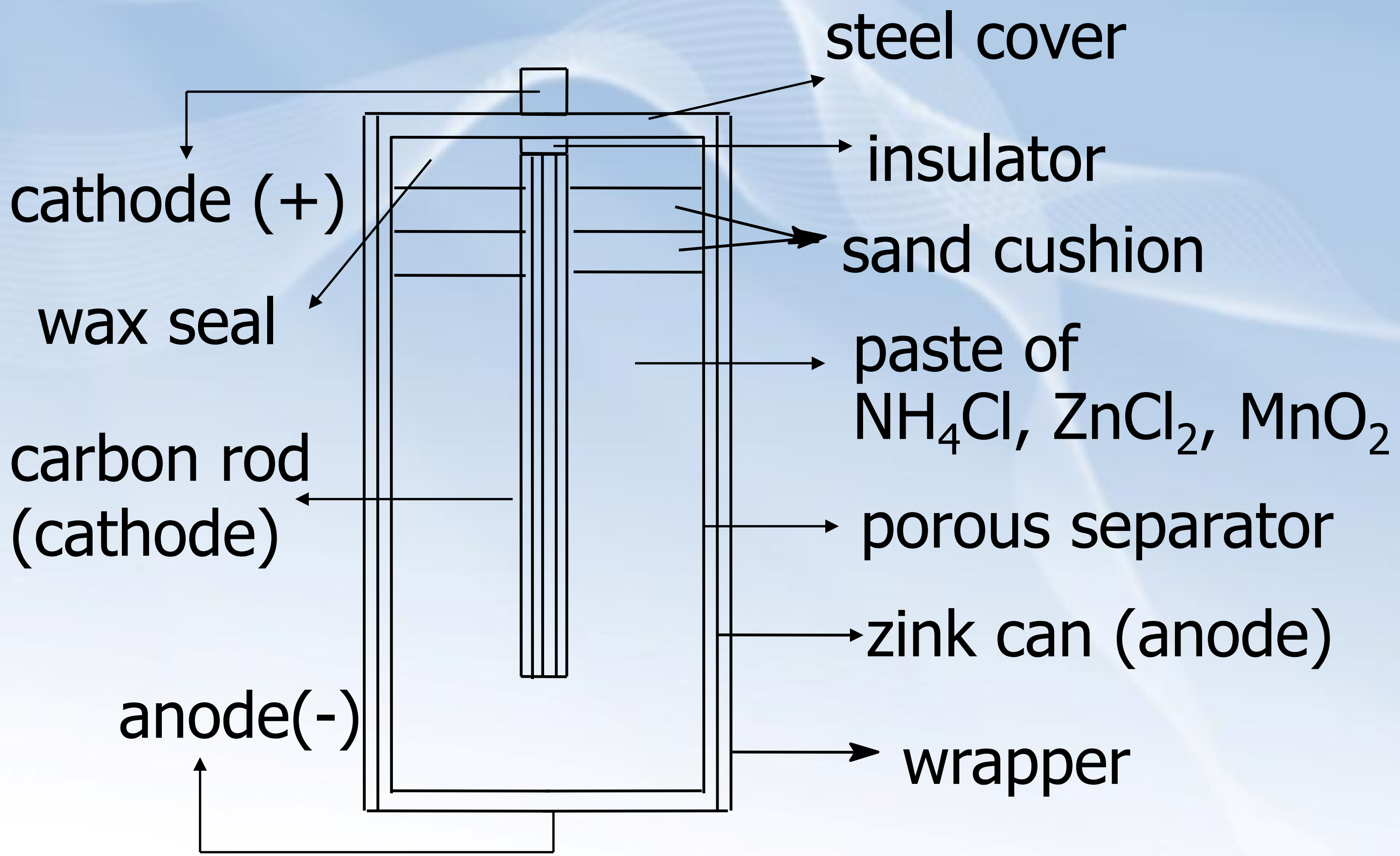
Dry Cell / le Clanche Cell

net reaction:

$2\ MnO_2(s) + NH_4Cl\ (s) + Zn(s)$

$\rightarrow Zn(NH_3)_2Cl_2(s) + H_2O(\ell) + 2Mn_2O_3(s)$

Dry Cell / le Clanche Cell



Dry Cell / le Clanche Cell

Gas produced : $H_2(g)$ & $NH_3(g)$

Uses: flashlight, portable radios, toys, etc

Dry Cell / le Clanche Cell

Disadvantages :

- if current is drawn rapidly → gaseous products cannot be consumed rapidly enough → voltage drops
- there is spontaneous (but slow) direct reaction between zinc electrode & ammonium ion → further deterioration → battery has a poor “shelf life”

Alkaline Battery

Voltage	: 1,54 V
Cathode	: mixture of graphite & MnO_2
Anode	: zinc
Electrolyte	: KOH

Alkaline Battery

Reaction : based on the oxidation of zinc, under basic (alkaline) condition

anode :

$Zn(s) + 2OH^{-}(aq) \rightarrow ZnO(s) + H_2O(\ell) + 2e^{-}$

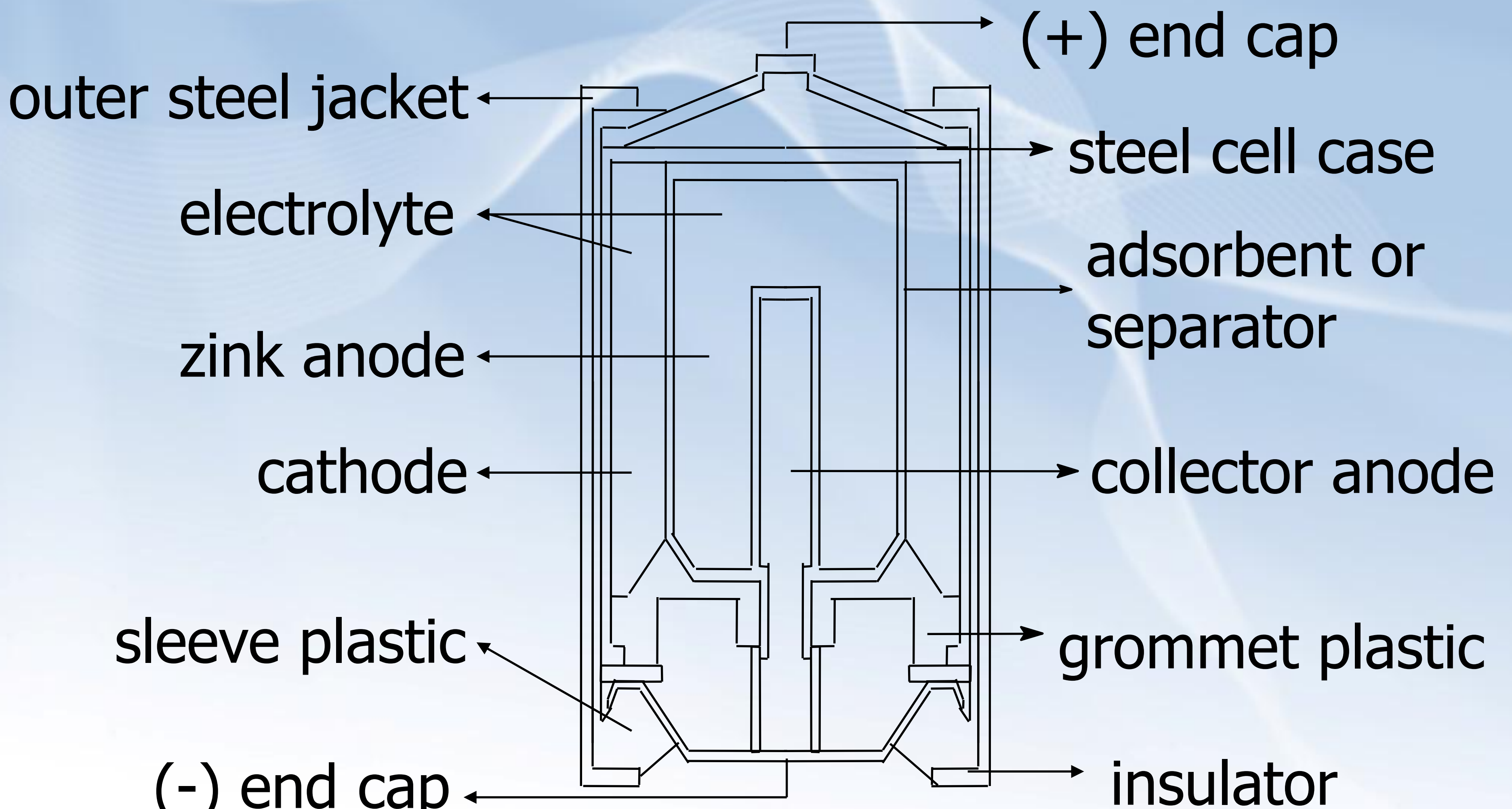
cathode :

$2MnO_2(s)+H_2O(\ell)+2e^{-} \rightarrow Mn_2O_3(s)+2OH^{-}(aq)$

net reaction :

$Zn(s) + 2\ MnO_2(s) \rightarrow ZnO(s) + Mn_2O_3(s)$

Alkaline Battery



Mercury Battery

Voltage	: 1,35 V
Cathode	: mercury(II) oxide / HgO
Anode	: powdered zinc + electrolyte gel
Electrolyte	: NaOH or KOH
Separator	: moist paste of HgO containing NaOH or KOH as salt bridge

Mercury Battery

Reaction : based on the oxidation of zinc, under basic condition

anode :

$Zn(s) + 2\ OH^{-}(aq) \rightarrow ZnO(s) + H_2O(\ell) + 2e^{-}$

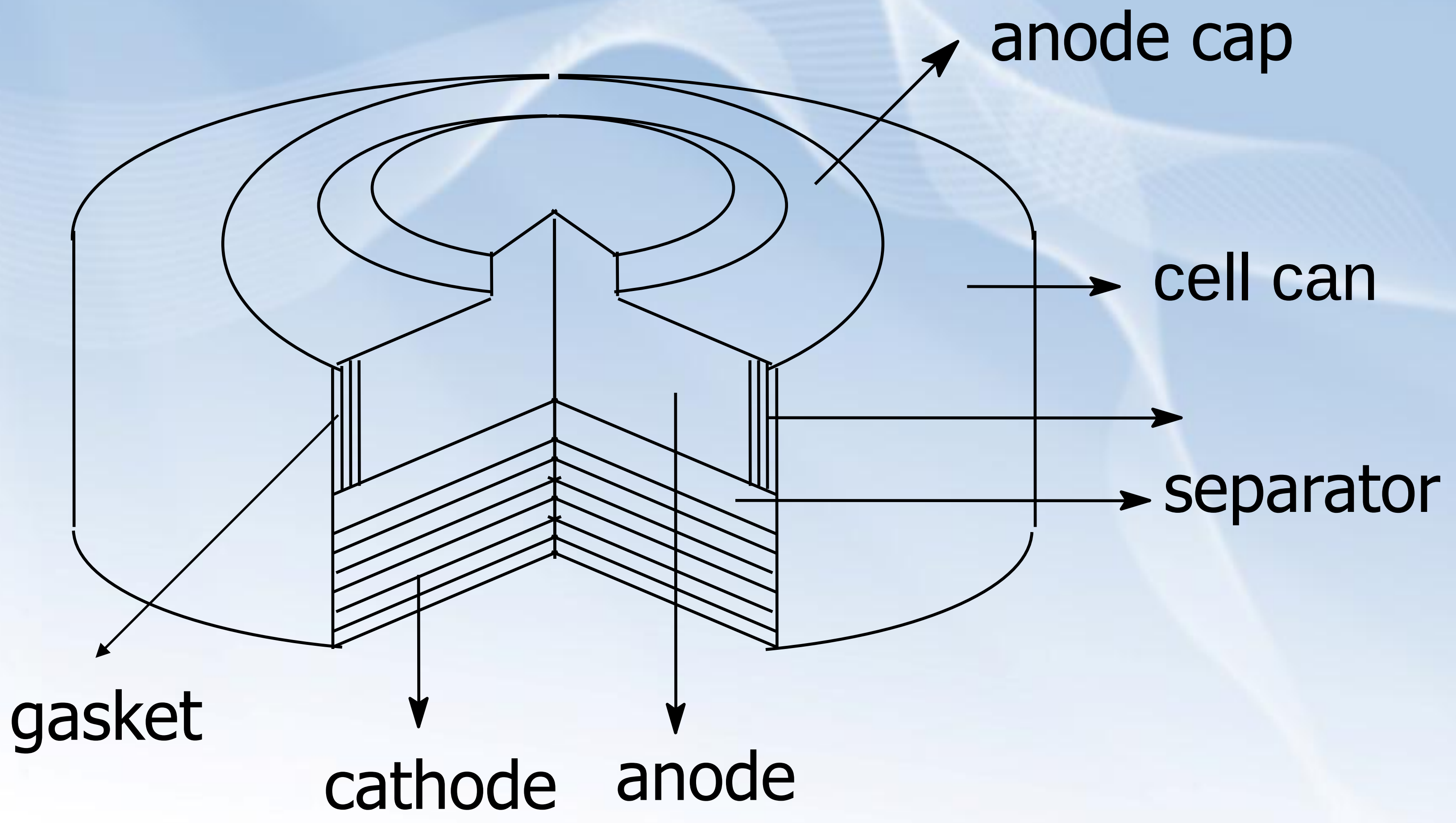
cathode :

$HgO(s) + H_2O(\ell) + 2e^{-} \rightarrow Hg(\ell) + 2OH^{-}(aq)$

net reaction :

$Zn(s) + HgO(s) \rightarrow ZnO(s) + Hg(\ell)$

Mercury Battery



Mercury Battery

Gas produced :

- none
- there is no decline in voltage under high current loads.

Uses : calculator, camera, watches, etc

Mercury Battery

Advantages:

- Extremely constant voltage over its useful life
- Suitable for low drain and intermittent high drain applications
- Long shelf life → up to 3 years.

Mercury Battery

Disadvantage :

- Contains mercury → highly toxic to humans and animals
- Leads to some environmental problems
- Should be reprocessed to recover the metal when the battery is no longer useful

Lead Acid Battery

- Voltage: 2 V per cell → enormously large initial current
- Cathode : PbO_2 (white) → as positive electrode
- Anode : Pb (porous structure) → as negative electrode
- Electrolyte : H_2SO_4

Lead Acid Battery

Reaction :

anode :

$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

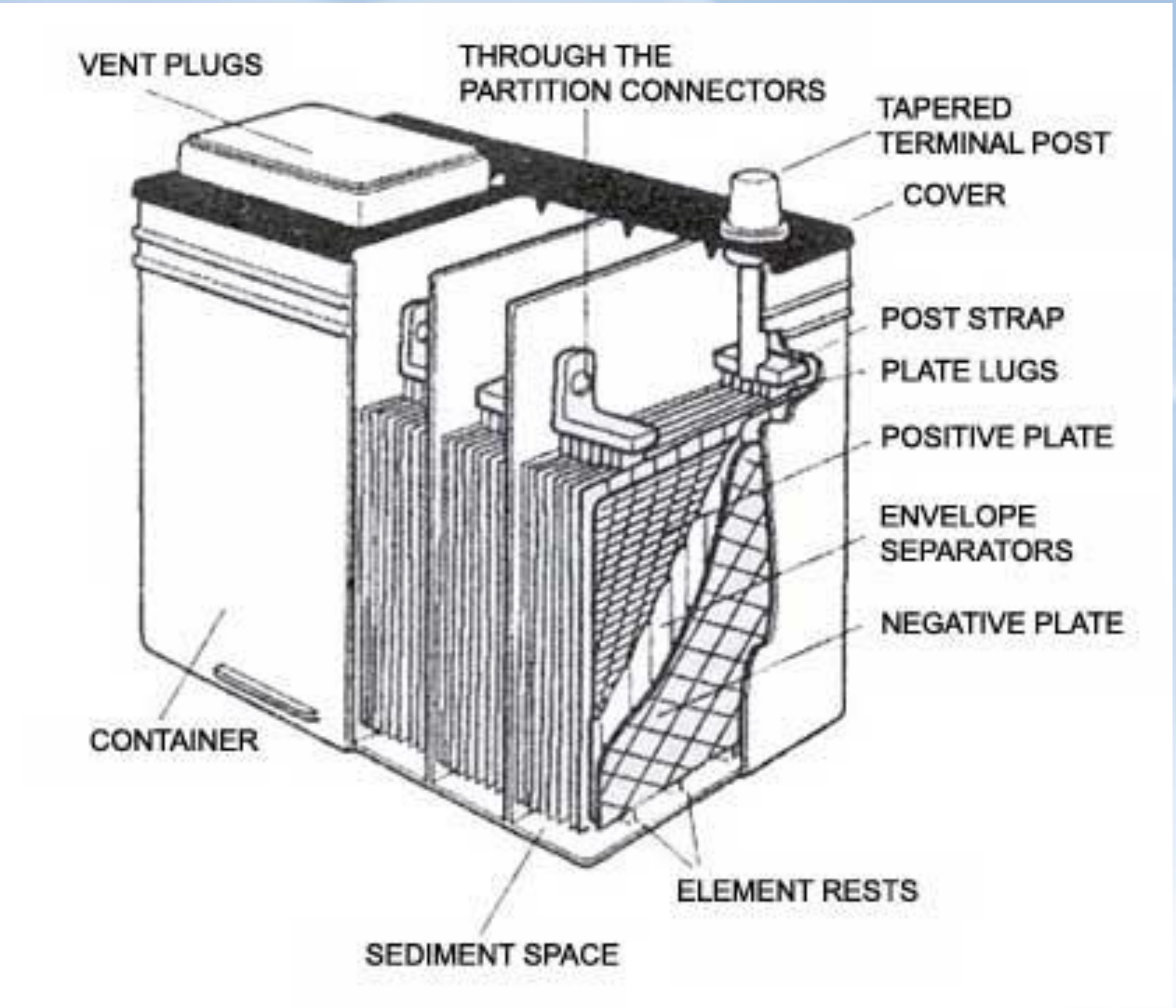
cathode :

$PbO(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$
$\rightarrow PbSO_4(s) + 2H_2O(\ell)$

net rxn :

$Pb(s) + PbO(s) + 2H_2SO_4(aq)$
$\rightarrow 2PbSO_4(s) + 2H_2O(\ell)$

Lead Acid Battery



Lead Acid Battery

Anodic reaction

- Pb is oxidized to $2PbSO_4$(*s*) that adheres to the surface of the electrode
- Electron move through PbO_2 electrode
- Electron cause reduction of lead(IV)

Lead Acid Battery

Current using:

- Both electrode coated by $PbSO_4$ (white)
- Decreasing of [H_2SO_4]

Lead Acid Battery

Recharging:

- Reverse of the current using
- $PbSO_4$ is converted back to Pb and PbO_2
- Regeneration of H_2SO_4

Lead Acid Battery

Uses : vehicles battery

Advantages : rechargeable

Disadvantage :

- Large and heavy
- Produce a relative low power for their mass

Nickel-cadmium (Ni-cad) Battery

Voltage : 1,4 V

Cathode : NiO(OH)

Anode : cadmium

Electrolyte : KOH

Nickel-cadmium (Ni-cad) Battery

Reaction:

anode :

Cd(*s*) + $2OH^-$(*aq*) → $Cd(OH)_2$(*s*) + $2e^-$

cathode :

NiO(OH)(*s*) + $2H_2O$(ℓ) + $2e^–$

→ 2 $Ni(OH)_2$(*s*) + $2OH^-$(ℓ)

net reaction :

Cd(*s*) +: NiO(OH)(*s*)

→ $Cd(OH)_2$(*s*) + $2Ni(OH)_2$(*s*)

Nickel-cadmium (Ni-cad) Battery

Uses : hand phone battery

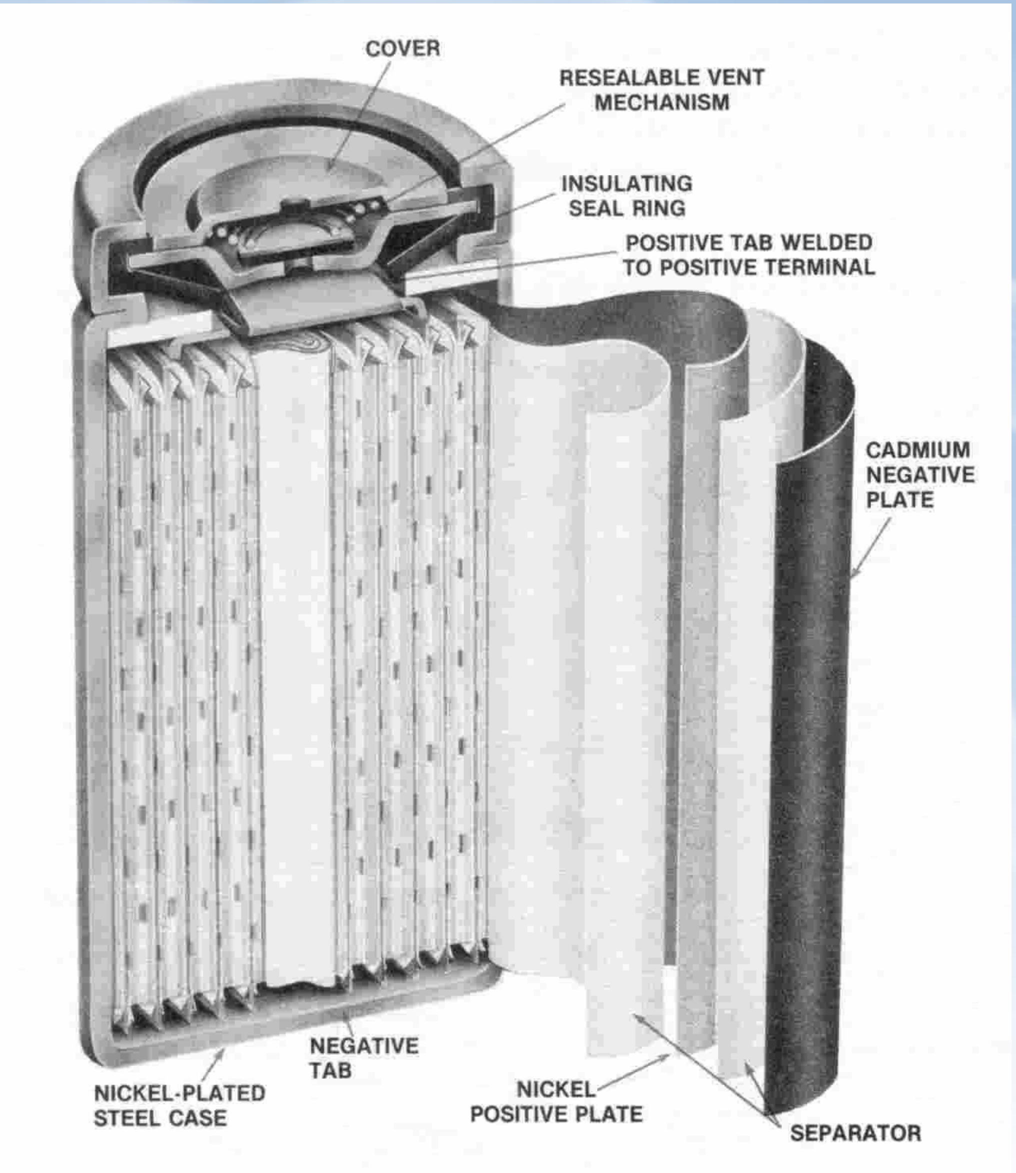
Advantages : rechargeable

Disadvantages :

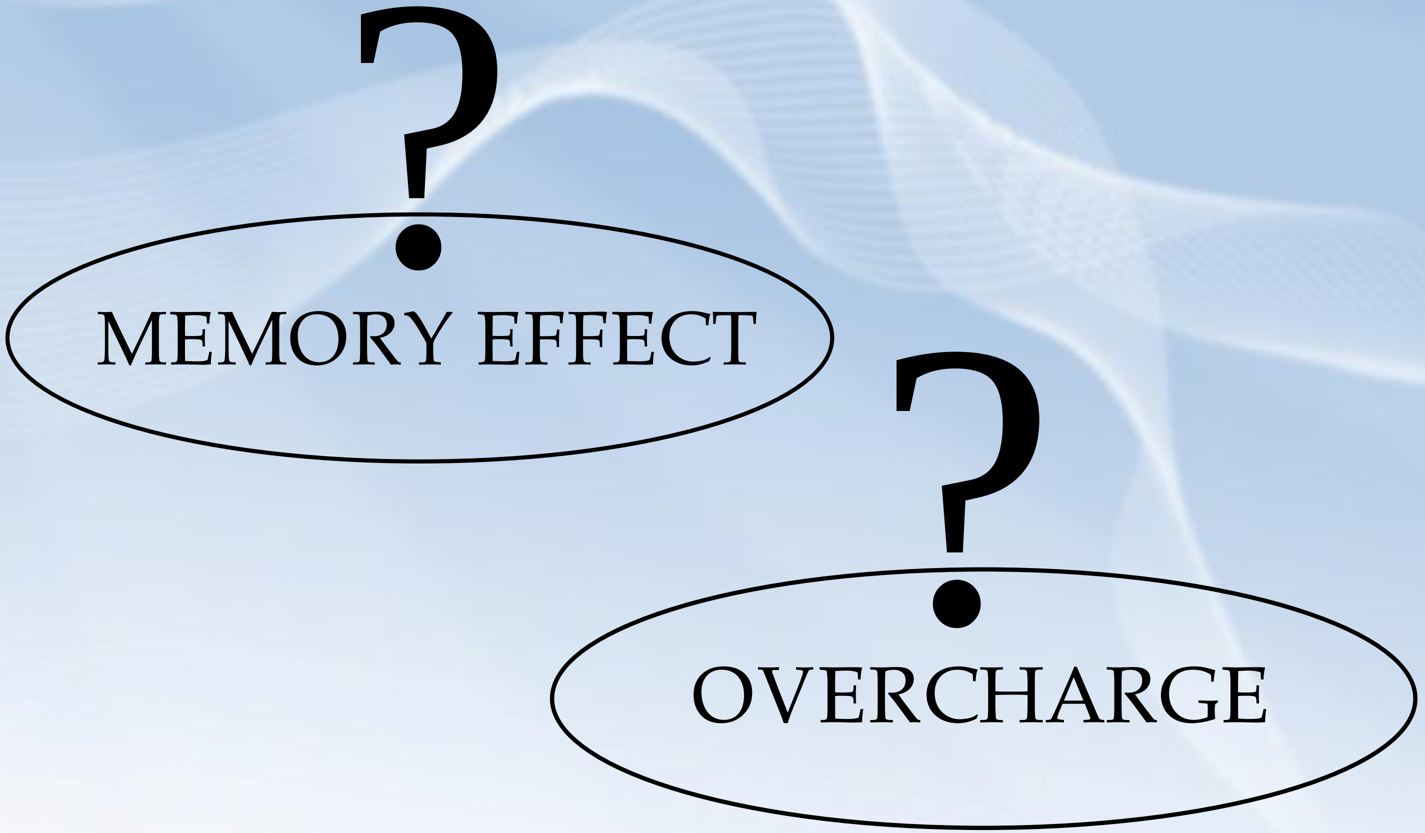
Suffer from memory effect

Contains heavy metal → toxic

Nickel-cadmium (Ni-cad) Battery



Nickel-cadmium (Ni-cad) Battery



Nikel-Metal Hydride (Ni-MH)

Voltage	: 1,4 V
Cathode	: NiO(OH)
Anode	: alloy MH (metal-hydride)
Electrolyte	: KOH

Nikel-Metal Hydride (Ni-MH)

Reaction :

anode :

$MH (s) + OH^-(aq) \rightarrow M(s) + H_2O(\ell) + e^-$

cathode :

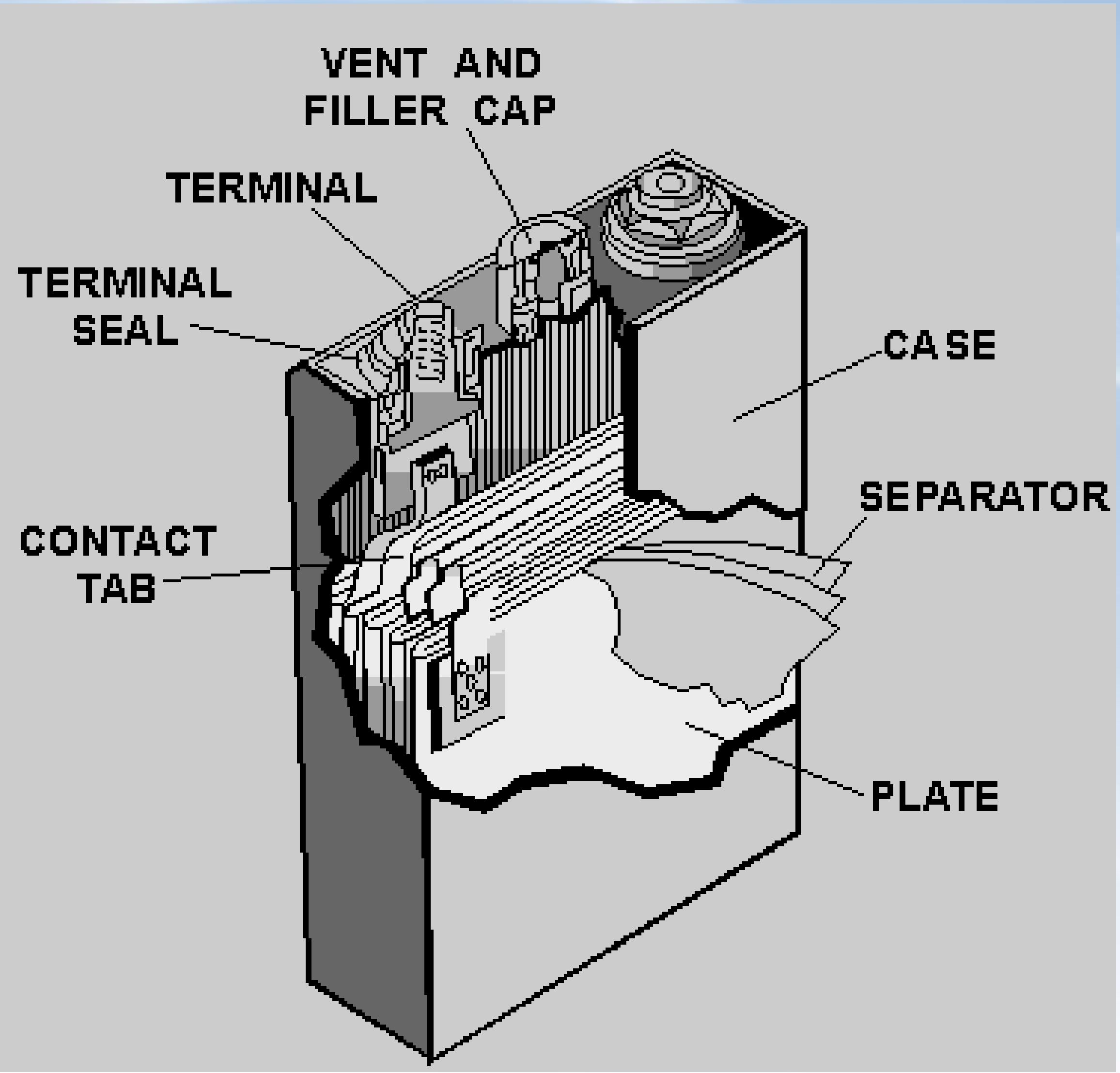
$NiO(OH)(s) + H_2O(\ell) + e^-$

$\rightarrow Ni(OH)_2(s) + OH^-(aq)$

net reaction :

$MH(s) + NiO(OH)(s) \rightarrow M(s) + Ni(OH)_2(s)$

Nikel-Metal Hydride (Ni-MH)



Nikel-Metal Hydride (Ni-MH)

Advantages

safe, high power, light weight, long life, good thermal performance, environmentally friendlier than Ni-Cad (do not contain heavy metals)

Disadvantages

high self discharge rate (on the storage), relatively expensive

Lithium-ion (Li-ion) Battery

Voltage : 3,7 V

Cathode : lithium in graphite /Lix(gr)

Anode : lithium manganese dioxide ($LiMn_2O_4$)

Electrolyte: 1M $LiClO_4$ in etylene carbonate (organic solvent)

Lithium-ion (Li-ion) Battery

Reaction :

anode :

$Lix(gr)(s) \rightarrow xLi+ + xe^{-}$

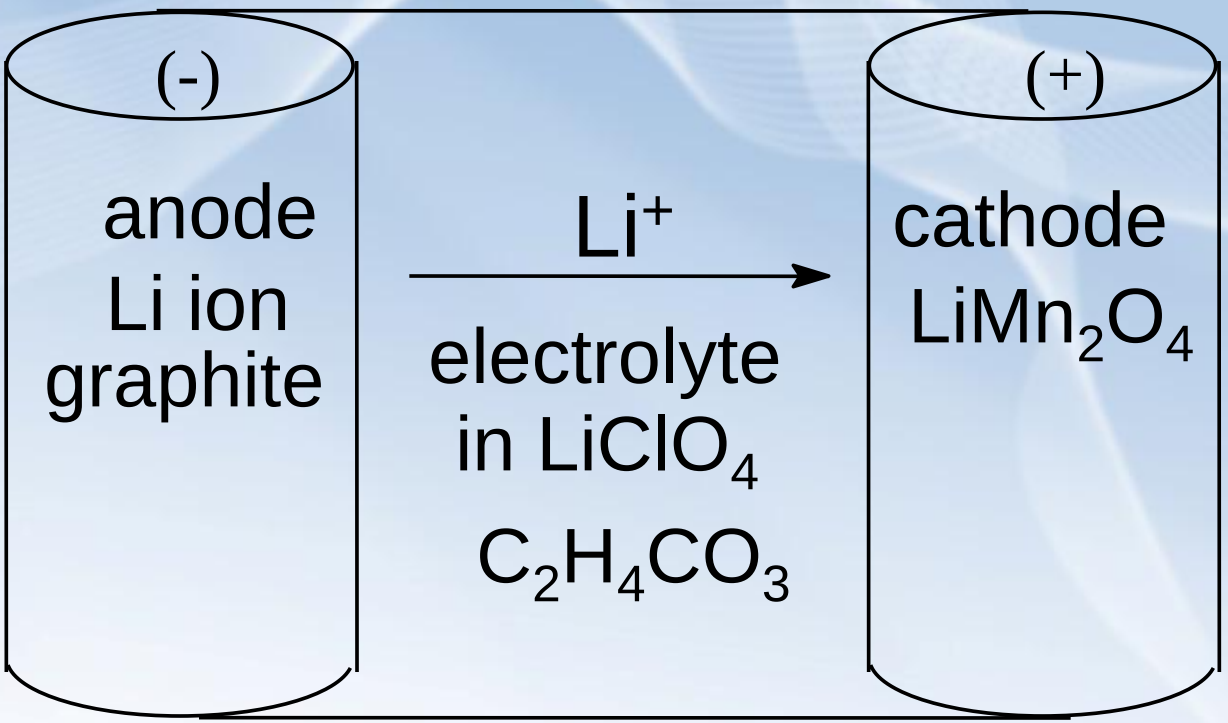
cathode :

$Li_{1-x}Mn_2O_4\ (s) + xLi+ + xe_{-} \rightarrow LiMn_2O_4(s)$

net reaction:

$Lix(gr)(s) + Li_{1-x}Mn_2O_4\ (s) \rightarrow LiMn_2O_4(s)$

Lithium-ion (Li-ion) Battery



Li-ion battery

Lithium-ion (Li-ion) Battery

Advantages :

- high energy-mass ratio (20-35% less weight than NiMH),
- do not suffer from the memory effect environmentally friendly (they don't contain toxic materials such as Cd or Hg)

Lithium-ion (Li-ion) Battery

- Disadvantages :
  - expensive,
  - the organic solvent could be burned

Prolong Li-ion battery

- A lithium-ion battery provides 300-500 discharge/charge cycles.
- The battery prefers a partial rather than a full discharge.
- Frequent full discharges should be avoided when possible.

Prolong Li-ion battery

- Instead, charge the battery more often or use a larger battery.

- There is no concern of memory when applying unscheduled charges.

Prolong Li-ion battery

- Although lithium-ion is memory-free in terms of performance deterioration, batteries with fuel gauges exhibit what engineers refer to as "digital memory".

Prolong Li-ion battery

- Short discharges with subsequent (next) recharges do not provide the periodic calibration needed to synchronize the fuel gauge with the battery's state-of-charge.
- A deliberate full discharge and recharge every 30 charges corrects this problem.

Prolong Li-ion battery

- Avoid frequent full discharges because this puts additional strain on the battery.
- Several partial discharges with frequent recharges are better for lithium-ion than one deep one.

Prolong Li-ion battery

- Recharging a partially charged lithium-ion does not cause harm because there is no memory. (In this respect, lithium-ion differs from nickel-based batteries.)

- Short battery life in a laptop is mainly cause by heat rather than charge / discharge patterns.

Prolong Li-ion battery

- Batteries laptops should be calibrated by applying a deliberate full discharge once every 30 charges.
- Keep the lithium-ion battery cool. Avoid a hot car. For prolonged storage, keep the battery at a 40% charge level.

Prolong Li-ion battery

- Consider removing the battery from a laptop when running on fixed power. (Some laptop manufacturers are concerned about dust and moisture accumulating inside the battery casing.)

Prolong Li-ion battery

- Avoid purchasing spare lithium-ion batteries for later use. Observe manufacturing dates. Do not buy old stock, even if sold at clearance prices.

- If you have a spare lithium-ion battery, use one to the fullest and keep the other cool by placing it in the refrigerator. Do not freeze the battery. For best results, store the battery at 40% state-of-charge.

Fuel Cell

Fuel cell

- electrochemical device → it does not involve a reversible reaction (in contrast to storage battery)
- the reactant are continually supplied from external reservoir

Fuel Cell

Fuel cell

- gases are not made to react directly and produce energy in the form of heat
- the energy produced can be tapped by an electrical device

Fuel Cell

Voltages : 0,9V (at 70 – 140^{o}C)

Electrolyte : concentrated KOH

Fuel Cell

Reaction :

anode :

$2H_2(g) + 4\ OH^-(aq) \rightarrow 4H_2O(g) + 4e^-$

cathode :

$O_2(g) + 2H_2O(\ell) + 4e^- \rightarrow 4OH^-(aq)$

net reaction :

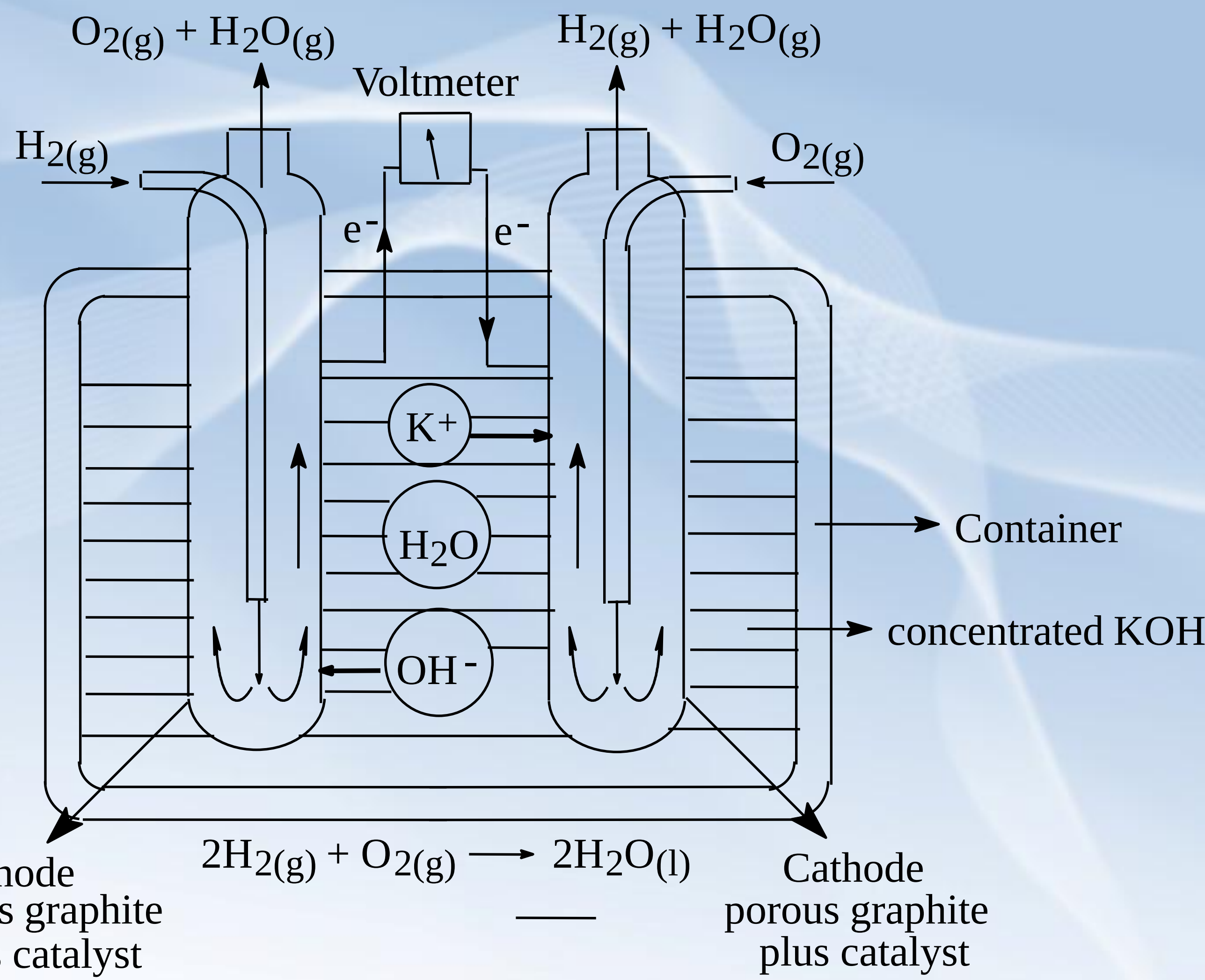
$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

Fuel Cell

Efficiency : ± 95% → not all the energy available has been tapped as electrical energy)

Uses : Gemini, Apollo and Apace Shuttle program

HYDROGEN - OXYGEN FUEL CELL



$2H_{2(g)} + 4OH^-_{(aq)} \longrightarrow 4H_2O_{(l)} + 4e^-$

Oxidation

$O_{2(g)} + 2H_2O_{(l)} + 4e^- \longrightarrow 4OH^-_{(aq)}$

Reduction