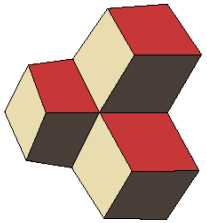
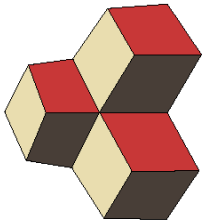


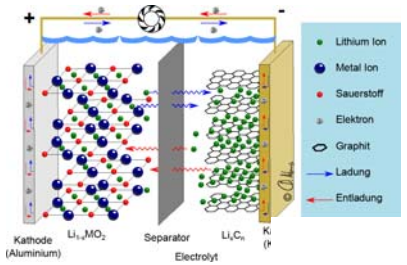
Les incendies causés par des batteries

essentiellement de type lithium

Dr. Donat ADAMS
Co-fondateur de Batterie-Werk Schweiz AG
Chargé de cours à la FHNW Technik, Windisch AG

Overview

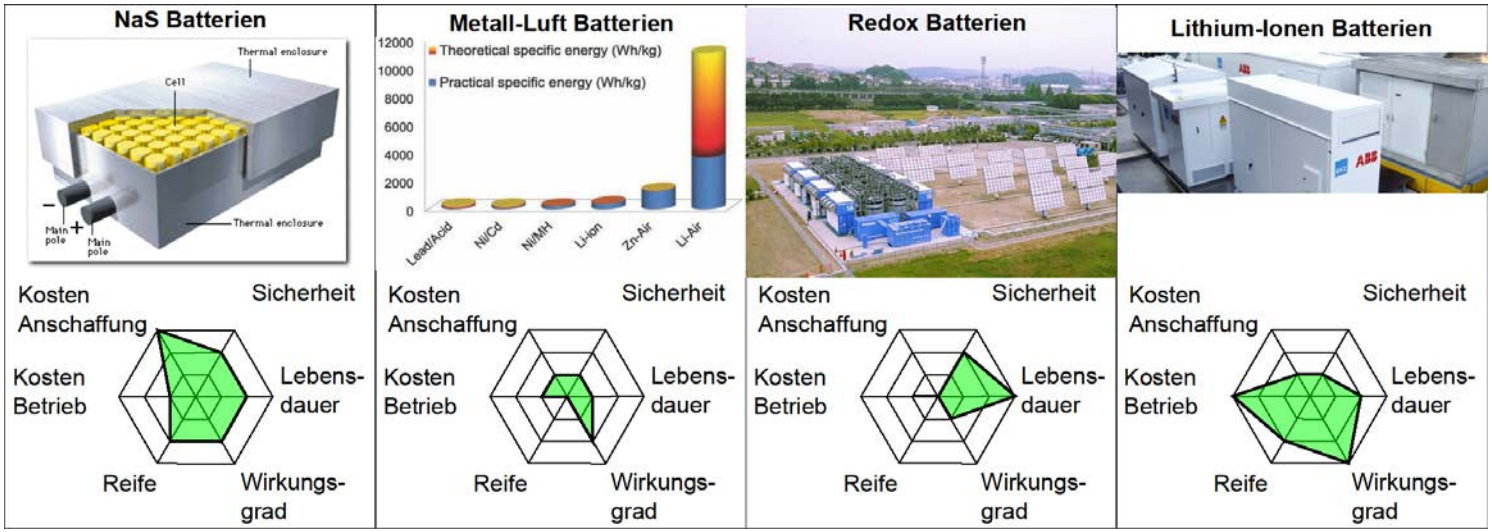




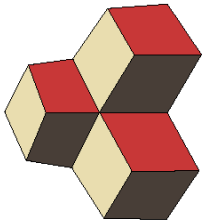
1. Principes de fonctionnement
2. Typologie de batteries et domaines d'utilisation
3. Éléments de sécurité des batteries (composition chimique, plombs, infrastructure de recharge, etc.)
4. Les batteries comme source de chaleur
5. Les différents accident et scénarios d'échauffement des batteries

Introduction

- Le stockage d'énergie est important en combinaison avec des sources d'energies alternatives (vent, marée, solaire, etc.)
- L'énergie n'est pas produite au moment où elle est consommée.
- Alternatives de stockage : air comprimé, hydrolique, production d'hydrogène (H_2) ou d'autres gaz.



1 Principes de fonctionnement

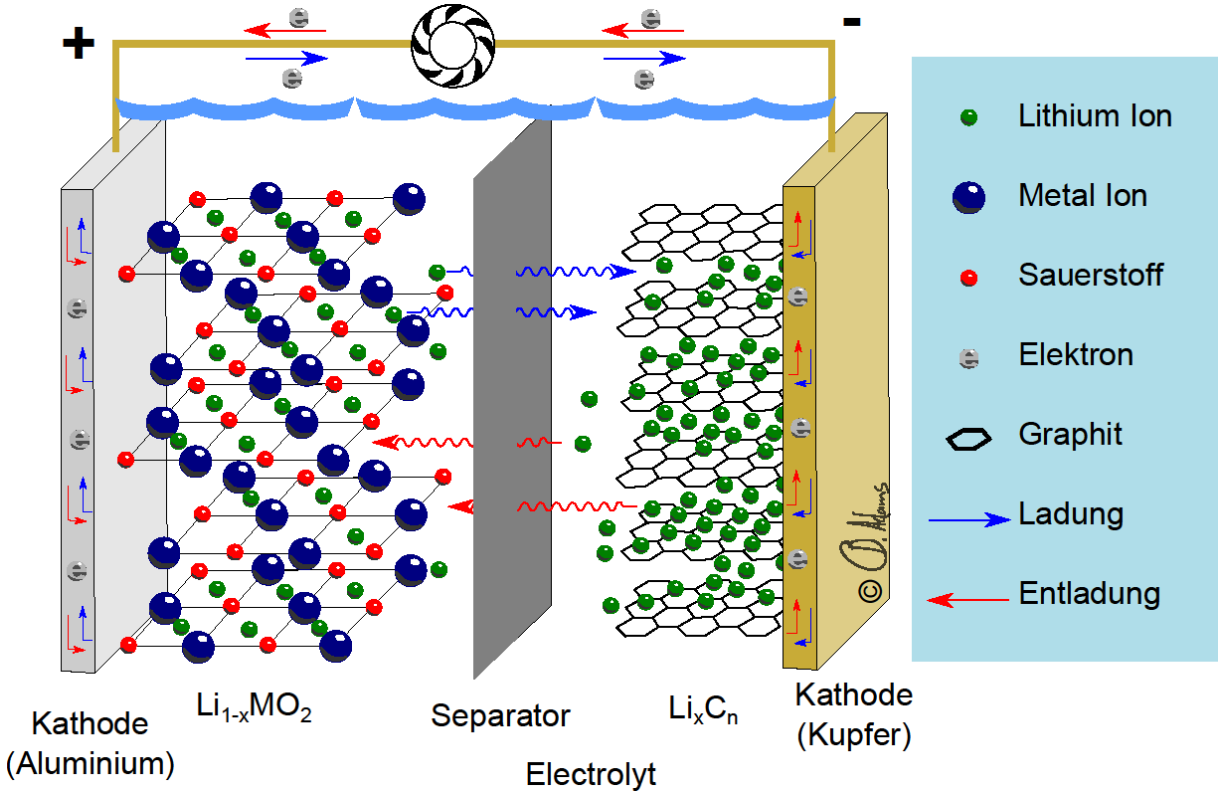


- Elements of Li-Ion battery
- Electro-Chemical energy storage

- Intercalation vs. dissolution
  - Lead acid, alkaline batteries, NiCd and NiMH dissolve some of the active materials and recrystalize new materials on the other electrode
  - Drawback: variable voltage, low energy density compared to Li-Ion

Vocabulaire : dissolution – la dissolution d‘un matériel ; drawback - inconvénient

Elements of Li-Ion battery



- anode: Graphit
- cathode: p. ex. LiFePO4
- Elektrolyte: organic molecules + LiPF6 (salt)
- Additives (small quantities, large effect)

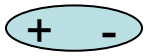
- Formation of Solid-Electrolyte Interface (SEI) on anode

Vocabulaire : Ladung - charge; Entladung – décharge; Sauerstoff – oxygène; salt - sel

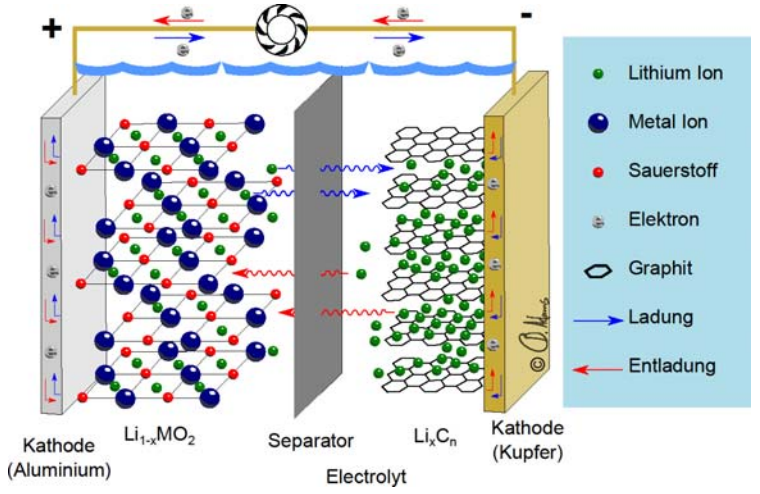
Working principle Li-Ion battery

- Low electro chemical potential of graphite / high potential of oxide (cathode)
- Li stored in cathode (oxide, discharged state) or anode (graphite, charged state)
- Electrical contact is between cathode-anode hindered due to *electrolyte*

- Polar organic electrolyte (e.g. ethylen-carbonate)



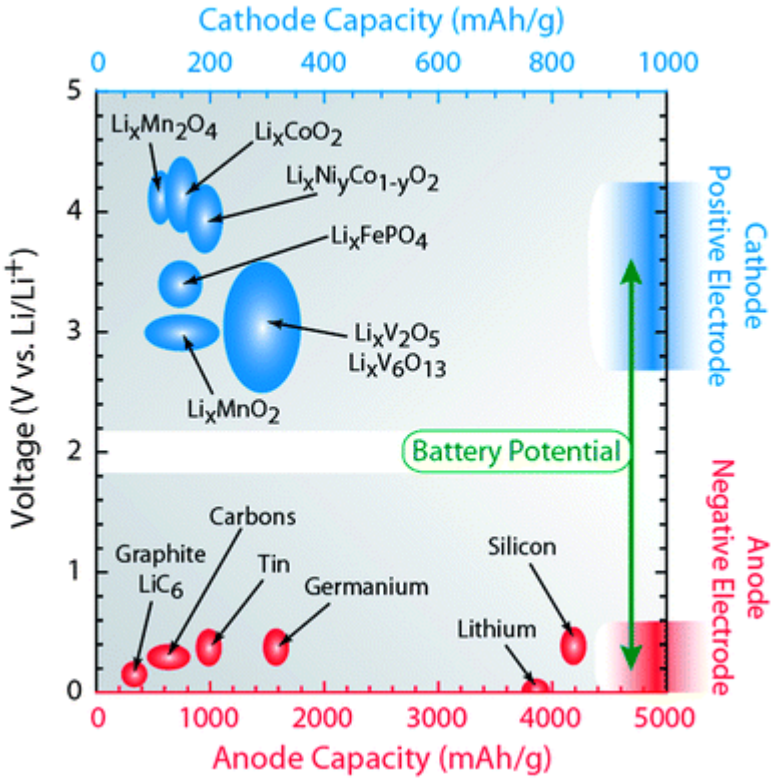
- Salt allows dissolution of Li in electrolyte



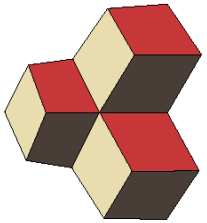
Vocabulaire : hinder – empêcher;

Cathode Materials

- Cathode material determines properties of battery => gives name of to battery
- Development of cathode materials, targets
  - High potential (LiCoO2)
  - Low cost LiV2O5
  - Safety LiFePO3
  - High capacity
- Develpment of anode materials
  - Safe: Li vs. Graphite
  - High capacity: Si
  - Stability: Germanium
  - Cost: Graphite



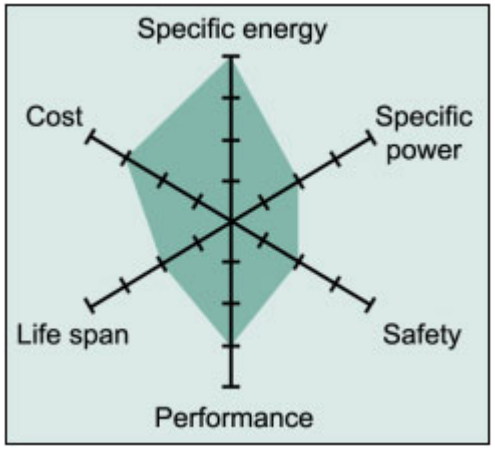
2 Typologie de batteries et domaines d'utilisation



- Cathodes:
  - **Lithium Cobalt Oxide:** $LiCoO_2$
  - **Lithium Manganese Oxide:** $LiMn_2O_4$
  - **Lithium Nickel Manganese Cobalt Oxide:** $LiNiMnCoO_2$
  - **Lithium Iron Phosphate:** $LiFePO_4$
  - **Lithium Nickel Cobalt Aluminum Oxide:** $LiNiCoAlO_2$
- Anodes
  - **Lithium Titanate:** Li4Ti5O12
- Li polymer: No liquid electrolyte!
- Specification
  - Voltage V: „strength" of battery; in V
  - Capacity C: How much charge (current) fits into battery; in Ah (specific capcity c; in Ah/kg)
  - Energy density: E=V * c ; in Wh/kg
  - C-Rate: speed of charge/discharge

Téléphones portables, électroménager

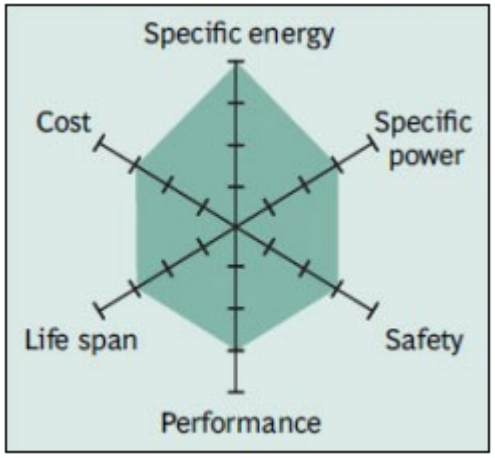
- **Lithium Cobalt Oxide: LiCoO2**
- High voltage (3.8 V) => high energy density
- Specific energy (capacity) 150–200Wh/kg
- Low thermal stability
- High cost (Co is expensive)
- Limited charge/discharge rate: 0.7–1C, / Discharge 1C
- Cycle life 500–1000
- Thermal runaway 150° C (302° F)



Véhicules électriques

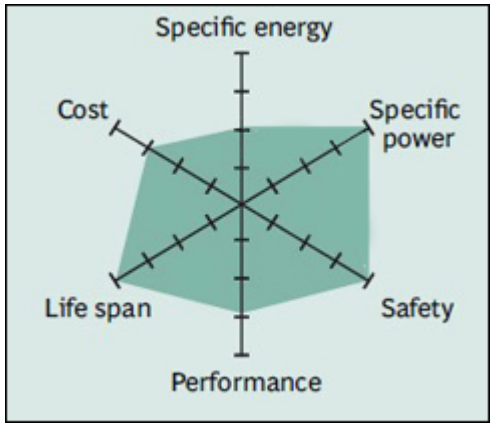
- **LiNiMnCoO2 (NMC) and LiNiCoAlO2 (NCA)**
- High stability, tunable voltage
- Voltage 3.60V
- Specific energy (capacity) 150–220Wh/kg
- Charge (C-rate) 0.7–1C ; discharge 1C; 2C
- Cycle life 1000–2000

- Vélo électrique, etc.
- Used for cells by Leclanché SA, Yverdon
- Sauf : Tesla cars!



Local storage

- **LiFePO4**
- Voltages 3.20V
- Low specific energy (capacity) 90–120Wh/kg, low capacity
- Relatively low cost
- Charge (C-rate) 1C ; discharge 1C-25C
- Cycle life 1000–2000
- Thermal runaway 270° C (518° F);
- Very safe battery even if fully charged
- Applications: (Portable) and stationary needing high load currents and endurance
- Very flat voltage discharge curve



Maquettes

- **Li-polymer**

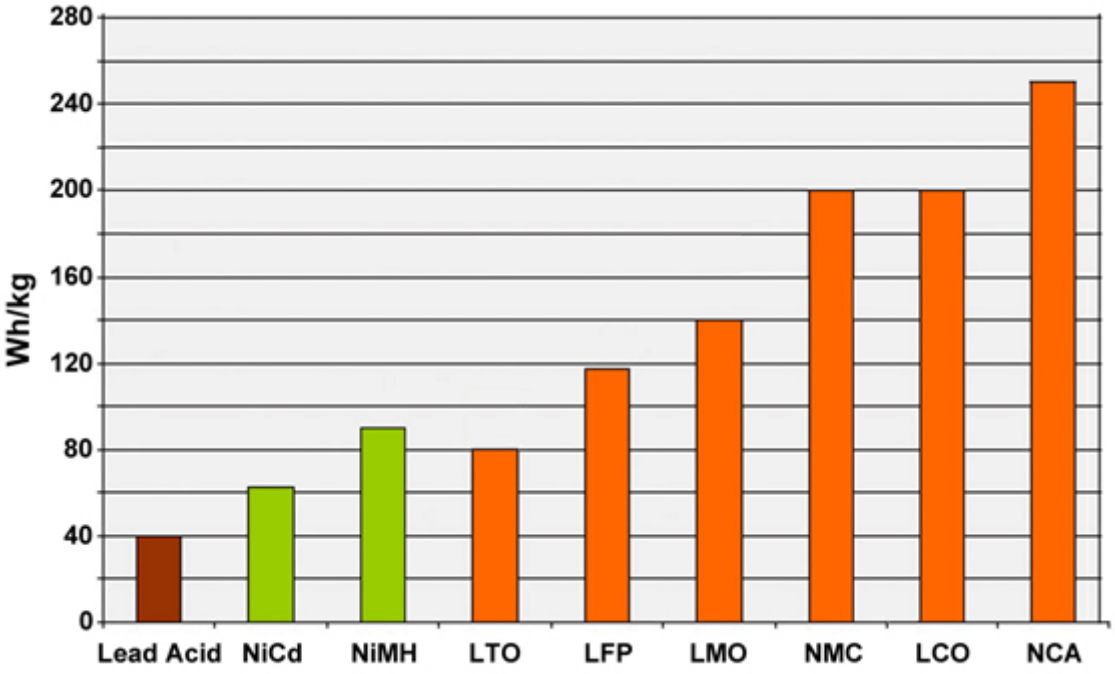
- Liquid electrolyte replaced by polymer (solid plastic)
- Normally combined with LiCoO2 and graphite anode
- No separator needed
- High safety, reduced discharge current
- Spcification determined by chemistry!

Local storage

- **Lithium titanate**

- Low voltage, 2.3 V => low energy density (70Wh/kg)
- Fast charge/discharge 3C/3C
- Long cycle life (15000-20000 cycles)
- Combination with further safety elements: Extremly safe technology
- Applications: Grid storage, local storage

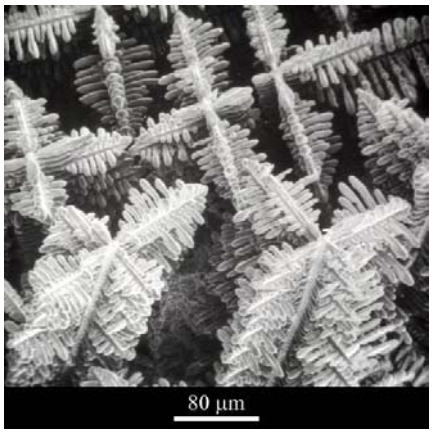
Comparison energy denisty



3. Éléments de sécurité des batteries

- Chemical composition
- Battery management systems (BMS)

Metallic dendrites:



- Flame retarding additives
- Thermal fuses, electric fuses
- Current breaker
- Rated break point / vents
- Separators (shut down separators/ ceramic separators)

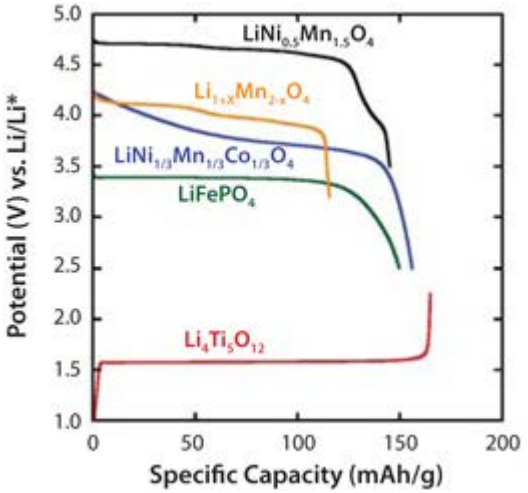
Vocabulaire: Fuse – plomb; Rated break point – point de rupture; vent - échappement

Battery management systems (BMS)

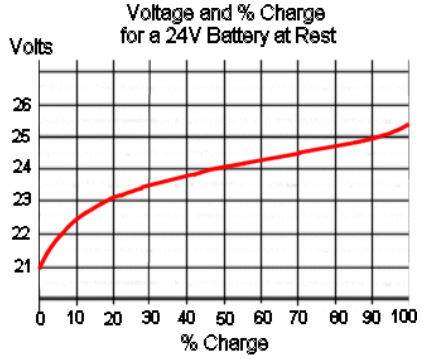
- Controls voltage and current during operation (discharge) and charge
- Due to flat voltage characteristics coulomb-counting and modelling of cell need (BMS simulates cell)
- BMS specific for cell chemistry
- BMS integrated in customer-electronics
- Overcharge can lead to dendrites => short circuit

- Over discharge can lead to destabilization of cathode material (no accident, battery damaged)

Li-Batteries:

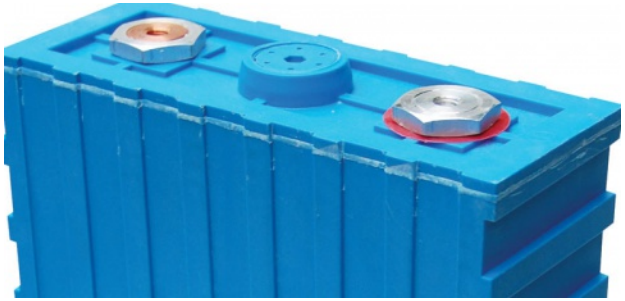


Lead acid:



Safety elements

- Target minimize damage:
  1. temporary failure (current breaker)
  2. permanent failure (some fuses)
  3. venting
  4. fire
  5. explosion
- Safety elements:
  1. current breaker
  2. thermal fuses, electric fuses
  3. separators (shut down separators/ ceramic separators)
  4. flame retarding additives
  5. rated break point / vents



Vocabulaire: Fuse – plomb; Rated break point – point de rupture; vent - échappement

4. Les batteries comme source de chaleur

- Many components with different properties
- Normally stable up to 80° C
- At higher temperature Solid-Electrolyte-Interface starts to dissolve => reacton of graphite with electrolyte => heat

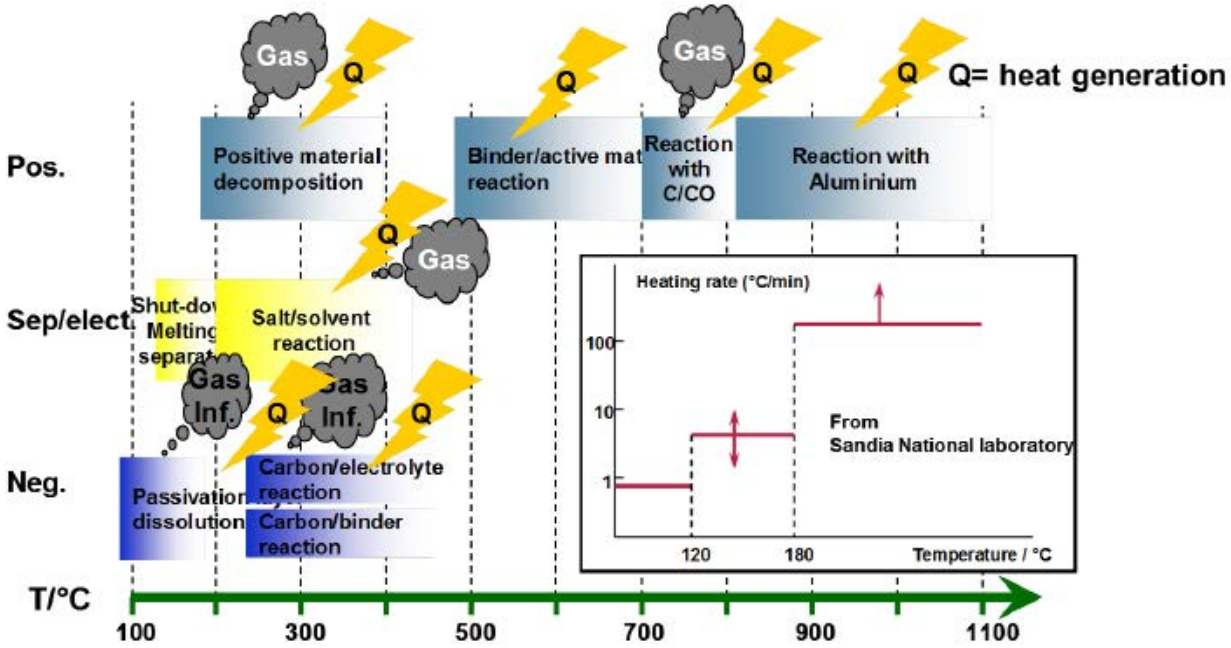
Activation temperatures and reaction energies

- In order to activate most chemical reation an activation energy is needed
- Matches: (Ignition: phosphorus sesquisulfide =>

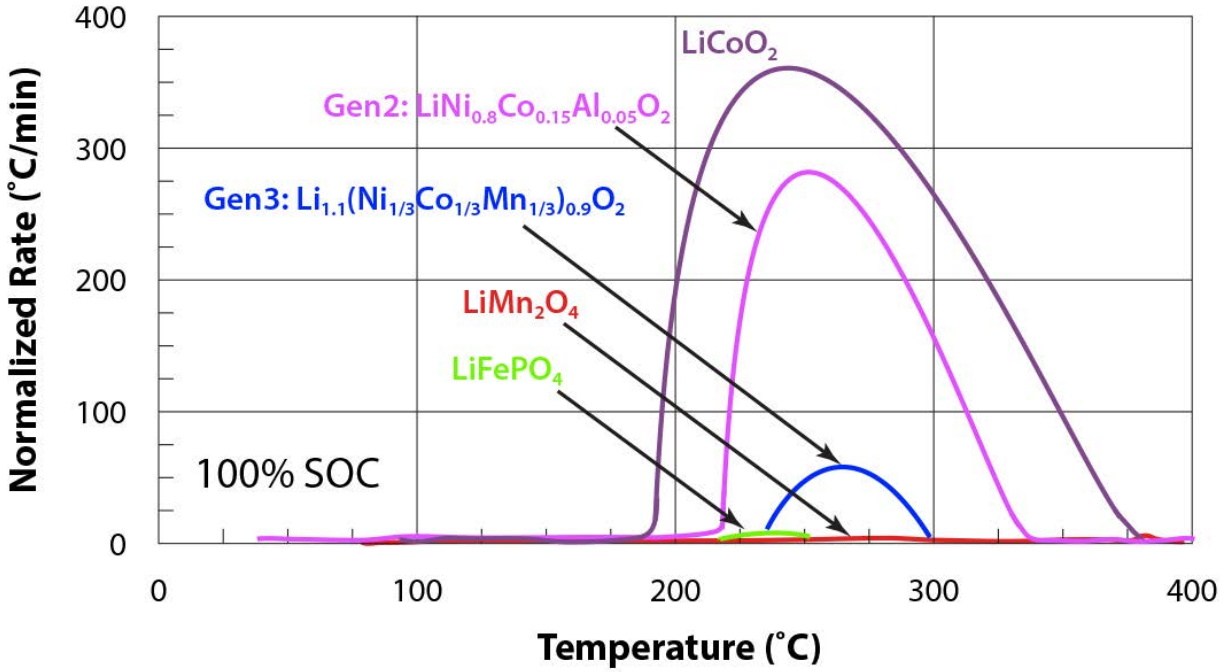
Temp (°C)	Reaction identified	Energy (J/g)	Comment
120-130	Passivation layer	200-350	Passive layer breaks Solubilisation starts below 100°C
130-140	PE separator melts	-90	Endothermic
160-170	PP separator melts	-190	Endothermic
200	Solvents-$LiPF_6$	300	Slow kinetic
240-250	LiC_6 + binder	300-500	
240-250	LiC_6 + electrolyte	1000-1500	
200-230	Positive material decomposition	1000	O_2 emission reacts with solvents

Vocabulaire: match – allumette;

Thermal runaway

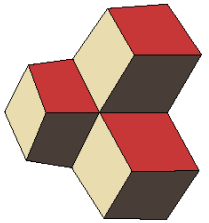


Thermal stability cathode materials



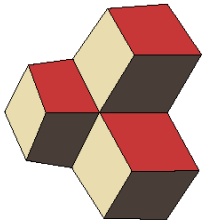
- Heat generation per minute
- Shows a) at which temperature ignition is induced
- b) how much energy is generated

How extinct fire in Li-Ion batteries



- Main problem: reactants are *in* cell
- Water can be dangerous combined with electric voltage
- Cooling (water/sand) can stop further heating
- CO2-extincter can stop external fire/flames

5. Les différents scénarios d'accidents et d'échauffement des batteries



- Electic failure => heat => chemical reaction
- Heating => chemical reaction => failure

- Known problems and accidents with Li-Ion batteries
  - Boeing dreamliner
  - DXP tricylce (Swiss poste)
  - Samsung Galaxy Note 7

Boeing dreamliner

- 2013 battery overheats in empty Japan Airlines airplane
- 24 airplanes grounded between january and april 2013
- Batteries ordered in 2005, when only $LiCoO_2$ was available for lithium aerospace batteries
- Strong internal heating (160° C) when discharged at low temperatures (-20 – 0° C) => separators melt

Battery after thermal runaway

Tricycle (Poste suisse)

- First model were charged with infrastructure of Lead-acid batteries (voltage maintained after charge!)
- Overcharge of Li-Ion batteries => venting
- Problems with construction of battery print
- Print not insulated => sparks => fire

- Solution:
  - Change if infrastructure
  - Insulation on battery print

Samsung Galaxy Note 7

- August 31, 2016 battery issues (fire, exploation when charging)
- September, 2016 recall of telephones
- Samsung spent 17 billion US$ for recall
- No official information
  - Separators not thick enough?
  - Impurities/dust from production?
  - Mechanical strain causes short-circuit?

https://www.srf.ch/play/tv/10vor10/video/rennen-um-immer-bessere-handy-akkus-birgt-gefahren?id=5f190467-8354-4cd0-9ca0-c281b3134aa6

Merci pour votre attention

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- High efficiency for Stop&Go-mode due to energy recupueration
- Batteries can be recycled to 98%
- Impact on image of owner: ecologic town/company