1. What is the Lithium metal battery and Lithium ion battery?

2. What kind of the features the batteries have?

3. What is the safety concept for the batteries?

4. What is the results of safety testing to the batteries?

5. In where are the batteries used?
1. What is the Lithium metal battery and Lithium ion battery?

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3. What is the safety concept for the batteries?

4. What is the results of safety testing to the batteries?

5. In where are the batteries used?

1-1. Battery types

- Batteries
- Chemical batteries
  - Chemical energy
  - Electric energy
- Secondary batteries
  - (Rechargeable)
- Lead-acid batteries
  - Ni-Cd Alkaline batteries
  - Ni-MH batteries
- Lithium ion batteries
- Others
- Zinc-carbon batteries
  - Alkaline manganese batteries
- Lithium metal batteries
- Others
- Fuel cells
  - (Power generation by supplying Chemical energy from outside)
- Solar cells
  - (Power generation from solar light)
- Nuclear power batteries
  - (power generation from radiation) and others
1-2. UN Number of Battery type

<table>
<thead>
<tr>
<th>UN Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN2794</td>
<td>Batteries, wet, filled with acid</td>
</tr>
<tr>
<td>UN2795</td>
<td>Batteries, wet, filled with alkali</td>
</tr>
<tr>
<td>UN2796</td>
<td>Battery fluid, acid</td>
</tr>
<tr>
<td>UN2797</td>
<td>Battery fluid, alkali</td>
</tr>
<tr>
<td>UN2798</td>
<td>Batteries, wet, non spillable</td>
</tr>
<tr>
<td>UN3028</td>
<td>Batteries, dry, containing potassium hydroxide solid</td>
</tr>
<tr>
<td>UN3090</td>
<td>Lithium metal batteries</td>
</tr>
<tr>
<td>UN3091</td>
<td>Lithium metal batteries contained in equipment</td>
</tr>
<tr>
<td></td>
<td>Lithium metal batteries packed with equipment</td>
</tr>
<tr>
<td>UN3480</td>
<td>Lithium ion batteries</td>
</tr>
<tr>
<td>UN3481</td>
<td>Lithium ion batteries contained in equipment</td>
</tr>
<tr>
<td></td>
<td>Lithium ion batteries packed with equipment</td>
</tr>
<tr>
<td>UN3171</td>
<td>Battery-powered vehicle</td>
</tr>
<tr>
<td></td>
<td>Battery-powered equipment</td>
</tr>
<tr>
<td>UN3292</td>
<td>Batteries, contained sodium</td>
</tr>
</tbody>
</table>

1-3. Naming of Lithium Batteries

- **Lithium metal battery**
  - Lithium primary battery
  - Lithium metal primary battery

- **Lithium ion battery**
  - Lithium rechargeable battery
  - Lithium ion rechargeable battery
1. What is the Lithium metal battery and Lithium ion battery?

2. What kind of the features the batteries have?

3. What is the safety concept for the batteries?

4. What is the results of safety testing to the batteries?

5. In where are the batteries used?

2-1. Chemical Reaction of Lithium metal cell (UN3090)

- Positive Electrode Reaction
  \[ \text{Mn}^{IV} \text{O}_2 + \text{Li}^+ + e^- \xrightarrow{\text{Discharge}} \text{Mn}^{II} \text{O}_2 (\text{Li}^+) \]

- Negative Electrode Reaction
  \[ \text{Li} \xrightarrow{\text{Discharge}} \text{Li}^+ + e^- \]

- Total Reaction
  \[ \text{Mn}^{IV} \text{O}_2 + \text{Li} \xrightarrow{\text{Discharge}} \text{Mn}^{III} \text{O}_2 (\text{Li}^+) \]
2-2. Chemical Reaction of Lithium ion cell (UN3480)

- Positive Electrode Reaction
  \[ \text{LiCoO}_2 \xrightarrow{\text{Charge}} \text{Li}^{1-x}\text{CoO}_2 + x\text{Li}^+ + xe^- \]

- Negative Electrode Reaction
  \[ \text{Cy} + x\text{Li}^+ + xe^- \xrightarrow{\text{Charge}} \text{CyLi}_x \]

- Total Reaction
  \[ \text{LiCoO}_2 + \text{Cy} \xrightarrow{\text{Charge}} \text{Li}^{1-x}\text{CoO}_2 + \text{CyLi}_x \]

2-3. Structure of Lithium ion cells (UN3480)

Cylindrical

- Positive terminal
- Positive lead
- Separator
- Gasket
- Insulator
- Positive electrode
- Negative electrode
- Trouser
- PTC
- Container

Prismatic

- Positive terminal
- Insulator
- Positive electrode
- Separator
- Negative electrode
- Cell can
2-4. Structure of Lithium metal cell UN3090 (Coin Type)

- Negative cap
- Collector
- Negative electrode (Li)
- Separator
- Gasket
- Positive electrode (MnO₂)
- Positive can

2-5. Structure of Lithium ion UN3480 (Polymer type)

- Casing / Aluminum laminate film
- Positive electrode collector
- Positive electrode
- Gel type electrolyte
- Separator
- Negative electrode
- Negative electrode collector
### 2-6. Major Constitution of Lithium metal batteries (UN3090)

**Manganese Dioxide Lithium Battery (CR)**

- **Positive Electrode**: Manganese Dioxide (MnO₂)
- **Negative Electrode**: Lithium Metal
- **Electrolyte**: Propylene Carbonate - Solvent
  - 1,2-Dimethoxyethane - Solvent
  - Lithium Triflate - Salt or Lithium Perchlorate - Salt
- **Separator**: Polyethylene, Polypropylene

**Carbon Monofluoride Lithium Battery (BR)**

- **Positive Electrode**: Carbon Monofluoride (CF₃)
- **Negative Electrode**: Lithium Metal
- **Electrolyte**: γ-Butyrolactone - Solvent
  - 1,2-Dimethoxyethane - Solvent
  - Lithium Tetrafluoroborate - Salt
- **Separator**: Polypropylene

### 2-7. Major Constitution of Lithium metal batteries (UN3090)

**Thionyl Chloride Lithium Battery (ER)**

- **Positive Electrode**: Thionyl Chloride (SOCL₂)
- **Negative Electrode**: Lithium Metal
- **Electrolyte**: Thionyl Chloride

**Sulfur Dioxide Lithium Battery**

- **Positive Electrode**: Sulfur Dioxide (SO₂)
- **Negative Electrode**: Lithium Metal
- **Electrolyte**: Sulfur Dioxide
  - Acetonitrile
  - Lithium Bromide - Salt
2-8. Major Constitution of Lithium ion batteries (UN3480)

**Lithium ion battery**

Positive Electrode: Lithium cobalt oxide LiCoO₂ (IEC Designation: ICR, ICP)
- Lithium nickel oxide LiNiO₂
- Lithium manganese oxide LiMn₂O₄ (IEC Designation: IMR, IMP)

Negative Electrode: Cylindrical, Prismatic & coke, hard carbon, graphite

Electrolyte: Ethylene carbonate, Propylene carbonate - Solvent
- Hexafluoro lithium phosphate - salt
- Lithium perchlorate - salt

Separator: Polyethylene

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Seminar on Safe Transport of Lithium Battery by Air

1. What is the Lithium metal battery and Lithium ion battery?
2. What kind of the features the batteries have?
3. What is the safety concept for the batteries?
4. What is the results of safety testing to the batteries?
5. In where are the batteries used?
### 3-1. UN Classification according to content of lithium

<table>
<thead>
<tr>
<th>Classification</th>
<th>Lithium Content</th>
<th>Transportation Test</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Cell</td>
<td>≤ 1 g (Metal UN3090)</td>
<td>Yes</td>
<td>UN38.3</td>
</tr>
<tr>
<td></td>
<td>≤ 1.5g (Ion UN3480)</td>
<td>Yes</td>
<td>Non Dangerous Goods Transportation</td>
</tr>
<tr>
<td>Battery</td>
<td>≤ 2 g (Metal UN3090)</td>
<td>Yes</td>
<td>1 Jan.2009~</td>
</tr>
<tr>
<td></td>
<td>≤ 8 g (Ion UN3480)</td>
<td>Yes</td>
<td>100Wh</td>
</tr>
<tr>
<td>Large Cell</td>
<td>≤ 12 g (Metal UN3090)</td>
<td>Yes</td>
<td>UN38.3</td>
</tr>
<tr>
<td></td>
<td>(Ion UN3480)</td>
<td>Yes</td>
<td>Class 9 DG</td>
</tr>
<tr>
<td>Battery</td>
<td>≤ 500 g (Metal UN3090)</td>
<td>Yes</td>
<td>(Ion UN3480)</td>
</tr>
<tr>
<td></td>
<td>(Ion UN3480)</td>
<td>Yes</td>
<td>(Metal UN3090)</td>
</tr>
<tr>
<td></td>
<td>(Metal UN3090)</td>
<td>Yes</td>
<td>(Ion UN3480)</td>
</tr>
<tr>
<td></td>
<td>(Ion UN3480)</td>
<td>Yes</td>
<td>(Metal UN3090)</td>
</tr>
</tbody>
</table>

Note:
- Cell: Manufacturer semi-product
- Battery: Consumer product

**Wh=Rated Capacity(Ah) x voltage (V)**

Lithium metal and Lithium ion batteries
### 3-3. UN Tests and Requirements 38.3

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1. Altitude simulation</td>
<td>11.6 kPa, 6hours</td>
</tr>
<tr>
<td>Test 2. Thermal Test</td>
<td>+75 deg.C ~ - 40 deg.C, 6 hours, 10 Times</td>
</tr>
<tr>
<td>Test 3. Vibration</td>
<td>7 Hz ~ 200 Hz, 3 hours, 12 Times</td>
</tr>
<tr>
<td>Test 5. External Short Circuit</td>
<td>0.1 ohm, 55 deg.C, 6 hours</td>
</tr>
<tr>
<td>Test 6. Impact</td>
<td>R15.8 mm rod is placed on the battery, A 9.1 kg mass is to be dropped from 61 cm.</td>
</tr>
<tr>
<td>Test 7. Overcharge</td>
<td>2 times the max. charge voltage or 22 V</td>
</tr>
<tr>
<td>Test 8. Forced Discharge</td>
<td>12 V</td>
</tr>
</tbody>
</table>

*: Serious Test (no gas, no fire, no explode)

### 3-4. Safety Concept – Safety Features within a Cell

- **First level (PTC)**
  - Reversible protector operation
  - No damage remain

- **Second level (Gasket & Separator)**
  - Ultimate emergency activation
  - ‘Fail-safe’ operation
3-5. PTC and Gasket Device (Current Interrupt)

Positive Cap with Current Shutdown Mechanism

PTC (Positive Temperature Coefficient)

Positive Cap 1
Gas Release Vent
Positive Cap 2
Welding
Current Interrupt Device
Sealing Cap Gasket

3-6. First Level Safety - PTC Operation Test

Ambient temperature: 20°C

PTC works
Test Start

Time / Sec.
Current / A
3-7. First Level Safety - Characteristics of PTC

The Relation between Resistance and Temperature

3-8. First Level Safety - PTC Mechanism

(a) Normal Temp. (b) Hot Temp.
- Dotted line: pass
3-9. Second Level Safety within a Cell –
SEM photographs of PE separator

Before short-circuit test

After short-circuit test

SEM : Scanning Electron Microscope
PE   : Polyethylene

3-10. Additional Safety Features for Batteries (>= 1 cell)-
Safety unit mount of Lithium ion battery (UN3480)

Top view

Safety unit part
1. What is the Lithium metal battery and Lithium ion battery?

2. What kind of the features the batteries have?

3. What is the safety concept for the batteries?

4. What is the results of safety testing to the batteries?

5. In where are the batteries used?

---

4-1. External short circuit test of UN38.3 test 5

Model: ICR18650

Fully-charged state

- MAX. Temp.: 76°C
- No fire, No smoke, No leakage
- 30~40A flows at short - PTC works

<table>
<thead>
<tr>
<th>Time / min.</th>
<th>Voltage / V</th>
<th>Current / A</th>
<th>Temperature / ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.6</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>30</td>
<td>3.4</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>60</td>
<td>3.2</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>90</td>
<td>3.0</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>120</td>
<td>2.8</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>150</td>
<td>2.6</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>180</td>
<td>2.4</td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>
4-2. Internal short circuit test of UN38.3 test 6 (Battery)

Model: ICR18650

- Fully-charged state
- Short
- Meltdown of Separator
- MAX. Temp.: 117°C
- No fire, No smoke

Model: ICR18650

- Fully-discharged state
- Protection circuit board works
- No fire, No smoke, No leakage
- MAX. Temp.: 18°C

4-3. Over charge test of UN38.3 test 7
4-4. External short test of UN38.3 Test 5 (coin type)

<table>
<thead>
<tr>
<th>CR2450</th>
<th>Ave. of 5 sample. Ambient temp.=20 deg.C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface temperature rise (deg.C)</td>
</tr>
<tr>
<td></td>
<td>Time after short in minutes</td>
</tr>
</tbody>
</table>

Seminar on Safe Transport of Lithium Battery by Air

1. What is the Lithium metal battery and Lithium ion battery?

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3. What is the safety concept for the batteries?

4. What is the results of safety testing to the batteries?

5. In where are the batteries used?
5-1. Application of Lithium metal batteries UN3090 (Coin Type)

- Copy machine (CR2450)
- Personal computer (CR2430)
- Calculator (CR2016, CR2032)
- Camera (remote control unit CR1220, CR2016, CR2025)

5-2. Application of Lithium metal batteries UN3090 (Cylindrical Type 1)

- Spiral structure
- Auto hand washer (2CR5)
- APS Camera (CR2)
- Camera (CR123A)
- DSC (CR-V3)
5-3. Application of Lithium metal batteries UN3090 (Cylindrical Type 2)

Water meter (CR17335SE, CR17450SE) → (Bobbin structure) → Personal computer (CR12600SE, CR14250SE) → NCU (CR17335SE, CR17450SE)

5-4. Application of Lithium ion batteries UN3480

Lithium ion batteries are suitable for mobile products.

<Feature>
- High energy density
- High voltage (three times higher than Ni-Cd and Ni-MH)
- Light weight
- No memory effect

Digital Video Camera
(Camcorder)

Mobile Phone

Mobile DVD

Mobile PC

Digital Still Camera
5-4. Class 9 DG or Not?

<table>
<thead>
<tr>
<th>Classification</th>
<th>Li content(g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li cells/batteries (Exempted)</td>
<td>≤1</td>
</tr>
<tr>
<td>Li-Ion cells/batteries (Exempted)</td>
<td>≤1.5 (20Wh)</td>
</tr>
<tr>
<td>Li and Li-Ion cells/batteries (Class 9)</td>
<td>≤12 (500)</td>
</tr>
<tr>
<td>Large cells/batteries (Class 9)</td>
<td>≤500</td>
</tr>
</tbody>
</table>

5-5. Lithium ion battery UN3480 (Watt hour overview)

- May be shipped as general cargo
- Class 9 DG

- Notebook computer battery
- Li-Ion cell for Electrical Vehicle (EV)
- Li-Ion cell for Hybrid EV
- Li-Ion for portable equipment
- Li-Metal for industrial gas meter
- Li-Ion battery for pro-use video
- 0 Wh to 30 Wh
- 30 Wh to 100 Wh
5-6. Comparison of energy density

C: Cylindrical type, P: Prismatic type

* Based on bare cell

Gravimetric energy density (Wh/kg) vs. Volumetric energy density (Wh/l)

- Ni-Cd(C)
- Ni-Cd(P)
- Ni-MH(C)
- Ni-MH(P)
- Li-ion (C)
- Li-ion (P)