UNIVERSITÉ Concordia UNIVERSITY

ENVIRONMENTAL HEALTH AND SAFETY

LITHIUM BATTERIES

1. Introduction

Over the past 20 years, lithium battery technology has dramatically evolved, providing increasingly greater energy density, greater energy per volume, longer cycle life and improved reliability. Lithium is the lightest of all metals, has the greatest electrochemical potential and provides the largest specific energy per weight.

Lithium batteries are now powering a wide range of electrical and electronical devices, including laptop computers, mobile phones, power tools, telecommunication systems and new generations of electric cars and vehicles.

Next to advantages, new technologies often bring new challenges and risks. Reports on incidents with lithium batteries catching fire have made the public well aware of their flammability hazard and have triggered massive research on the mechanisms initiating such events and the ways to make operation, storage, transportation and recycling safer. This document covers some of the safety related issues of lithium batteries.

2. Types of Lithium Batteries

2.1 Cell or Battery?

Although the word "battery" is a common term to describe an electrochemical storage system, international industry standards differentiate between a "cell" and a "battery".

- A cell is a single encased electrochemical unit (one positive and one negative electrode) with a voltage differential across its two terminals (Figure 1).

Figure 1: Examples of cells

- A battery is two or more cells that are electrically connected together and fitted with devices such as a case, terminals, marking and protective devices that it needs to function properly (Figure 2).

Figure 2: Examples of batteries

However, in common usage, the terms "cell" and "battery" are used interchangeably. The term "battery" will be used in this document.

2.2 Lithium-Metal Batteries

Lithium-metal batteries (Figure 3) are known as primary batteries and are usually non-rechargeable. They contain metallic lithium and feature higher charge densities (longer life) than other non-rechargeable batteries (e.g. alkaline or zinc-carbon). The most common type of lithium batteries use metallic lithium as anode, manganese dioxide as cathode and a salt of lithium dissolved in an organic solvent, usually composed of a mixture of a high-permittivity (e.g. propylene carbonate) and a low-viscosity solvent (e.g. dimethoxyethane).

Figure 3: Examples of lithium metal batteries

Having a longer life, lithium-metal batteries can replace ordinary alkaline batteries in many consumer devices, such as calculators, pacemakers, remote car locks, cameras or watches.

2.3 Lithium-Ion Batteries

Lithium-ion (Li-ion) batteries (Figure 4), also known as secondary batteries, are rechargeable batteries in which lithium ions move from the negative electrode, usually made of carbon, to the positive electrode made of a metal oxide (nickel, manganese and cobalt) during discharge, and back when charging. The electrolyte is typically a mixture of organic solvents, such as ethylene carbonate, dimethyl carbonate or diethyl carbonate, containing complexes of lithium ions, such as lithium hexafluorophosphate ($LiPF_6$), lithium hexafluoroarsenate monohydrate ($LiAsF_6$), lithium perchlorate ($LiClO_4$), lithium tetrafluoroborate ($LiBF_4$) or lithium triflate ($LiCF_3SO_3$).

Figure 4: Examples of lithium-ion batteries

Li-ion batteries have high energy density, tiny memory effect and low self-discharge. They are commonly found in home and portable electronics (e.g. laptop computers). They are also growing in popularity for battery electric vehicles or aerospace applications and are becoming a common replacement for many applications that have been using historically lead acid batteries.

Some advantages of Li-ion batteries are:

- high specific energy and high load capabilities;
- long cycle and extend shelf-life;
- maintenance-free;
- high capacity, low internal resistance, good coulombic efficiency;
- simple charge algorithm and reasonably short charge times;
- low self-discharge; less than half that of nickel-cadmium (NiCd) or nickel-metal hydride (NiMH) batteries.

However, their limitations are:

- circuit protection requirement to prevent thermal run-away if stressed;
- degradation at high temperatures and when stored at high voltage;
- no rapid charge possible at freezing temperatures (<0°C or <32°F);
- severe transportation regulations required when shipping in larger quantities.

Li-ion is a generic term used to cover several types of battery chemistries (Table 1) and several formats for various applications. Each of them has their own pros and cons.

Table 1: Characteristics of different Li-ion batteries

	LCO $LiCoO_2$	NCA $LiNiCoAlO_2$	NMC $LiNiMnCoO_2$	LMO $LiMn_2O_4$	LFP $LiFePO_4$	LTO* $Li_4Ti_5O_{12}$	Si/C*
Cathode	Lithium Cobalt Oxide	Lithium Nickel Cobalt Aluminium Oxide	Lithium Nickel Manganese Cobalt Oxide	Lithium Manganese Spinel	Lithium Iron Phosphate	Lithium Titanate	Silicon Carbon Composite
Cell Voltage (100% SOC)	4.2V	4.0V	4.2V	4.2V	3.6V	2.8V	4.2V
Energy	++	+++	+++	+	++	-	+++
Power	++	+++	++	+++	++	+	++
Calendar Life	+	+++	+	-	++	-	-
Cycle Life	+	++	++	++	++	+++	--
Safety	+	+	+	++	+++	+++	+
Cost	-	+	++	++	+	-	++

SOC = state of charge; *LTO and Si/C are anodes, which can be combined with any cathode

2.4 Lithium-Polymer Batteries

A lithium-polymer battery, or more correctly lithium-ion polymer battery (abbreviated variously as LiPo, LIP or Li-pol) is a Li-ion battery in which the electrolyte has been "plasticized" or "gelled" through a polymer additive. Even with the gelled electrolyte added, a LiPo battery is essentially the same as a Li-ion battery. Both systems use identical cathode and anode material and contain a similar amount of electrolyte.

LiPo batteries usually come in a soft package or pouch format, which makes them lighter and less rigid. LiPo batteries offer slightly higher specific energy and can be made thinner than conventional Li-ion batteries (Figure 5).

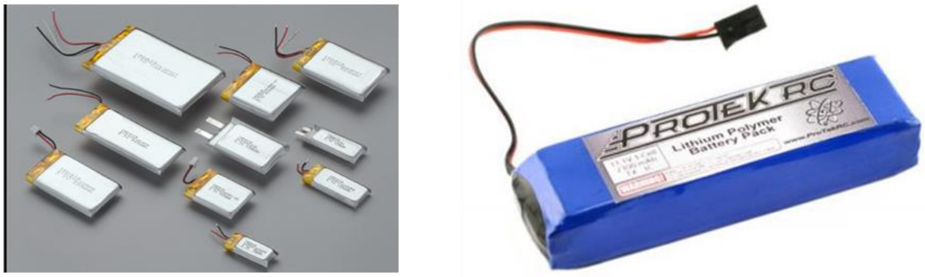

Figure 5: Examples of lithium-polymer (LiPo) batteries

3. Hazards of Li-Ion Batteries

3.1 Hazards

As for any battery system, the Li-ion technology associates electrical risks and chemical risks. Depending on the environmental stress conditions, they can eventually create potential hazards.

The potential hazards can be classified as below:

- chemical hazard;
- electrical hazard;
- thermal run-away.

3.2 Chemical Hazard

Although Li-ion batteries are designed as to not release any gases or chemical content during normal conditions of use, accidental exposure from the rupture of casing due to mechanical damages, internal pressure or other faults can happen, resulting in:

- chemical spillage of the electrolyte;
- exposure to toxic, corrosive and/or flammable solutions or gases.

Many of the currently used Li-ion battery electrolytes are volatile, toxic, irritant or harmful, in addition of being flammable (Table 2). Leaking electrolyte from a Li-ion battery usually gives a sweet or ether-like odour.

Table 2: Typical solvents used in Li-ion battery electrolytes

Solvent	Hazard	Boiling Point (°C)	Vapor Pressure (mm Hg)
Dimethyl carbonate (DMC)	Flammable	90-91	40-42
Ethyl methyl carbonate (EMC)	Flammable, Irritant	107-110	8-18
Diethyl carbonate (DEC)	Flammable	125-129	8.1-8.3
Propylene carbonate (PC)	Irritant	242	0.03
Ethylene carbonate (EC)	Irritant	247-249	0.01
Dimethoxymethane (DMM)	Flammable, Irritant	41-42	300-330
1,2-Dimethoxyethane (DME)	Flammable, Toxic	84-85	44-58.4
1,2-Diethoxyethane (DEE)	Flammable, Toxic	121-122	25.9
Tetrahydrofuran (THF)	Flammable	64-66	127.5-130
1,3-Dioxolane	Flammable	74-78	67.5-85.5
γ-Butyrolactone (γ-BL)	Harmful	204-205	0.3

For some of the highly volatile solvents, calculations showed that a spill as low as 15 mL that is allowed to evaporate in a closed room of 62 m^3 without any ventilation would result in the formation of a toxic atmosphere. In addition, many commercially available electrolytes contain various additives that may also be volatile and toxic.

Many lithium salts have been researched for use in Li-ion batteries (Table 3); most of them are known to be corrosive, toxic or irritant. Lithium hexafluorophosphate ($LiPF_6$) remains the most used salt for Li-ion batteries. Two well-known properties of $LiPF_6$ salt are its poor stability and reactivity with water. Upon contact with either atmospheric moisture or traces of water in the electrolyte, $LiPF_6$ undergoes hydrolysis forming hydrogen fluoride (HF), a very poisonous and corrosive substance both in gaseous and aqueous solution forms.

Table 3: Typical salts used in Li-ion battery electrolytes

Salt	Formula	Hazard
Lithium Hexafluorophosphate	$LiPF_6$	Corrosive, Toxic
Lithium Tetrafluoroborate	$LiBF_4$	Corrosive, Harmful
Lithium Hexafluoroarsenate	$LiAsF_6$	Toxic
Lithium Iodide	LiI	----
Lithium Trifluoromethane Sulfonate	$LiCF_3SO_3$	Irritant
Lithium Bis (Trifluoromethanesulfonyl) Imide	$LiN(CF_3SO_2)_2$	Corrosive, Toxic
Lithium Perchlorate	$LiClO_4$	Oxidizer, Irritant
Lithium Bis(Oxalato)Borate	$LiB(C_2O_4)_2$	Irritant
Tetraethyl-Ammonium Tetrafluoroborate	$(C_2H_5)_4NBF_4$	Irritant, Harmful
Triethyl-Methyl-Ammonium Tetrafluoroborate	$(C_2H_5)_3CH_3NBF_4$	Corrosive, Harmful

In case of accidental release of the battery content, the operator may be exposed to one or more of the battery constituents. A list of generic constituents of a Li-ion battery is presented below (Table 4).

Table 4: Typical Li-ion battery constituents

Battery Component	Content (wt. %)
Lithiated Metal Oxide	10-25
Organic Electrolyte	10-35
Inorganic salt in the electrolyte	1-5
Carbon, as Graphite	10-25
Copper (current collector)	1-10
Aluminium (Outer Jacket)	1-10

The composition may vary significantly between manufacturers. The chemical risks associated with the direct exposure to the substances contained in the battery are exposed in the Safety Data Sheet (SDS) of the corresponding battery. One must always refer to the manufacturer's battery SDS before its use.

3.2.1 Electrolyte Spill

In the event of a minor electrolyte spill, consult the appropriate Safety Data Sheet (SDS) for electrolyte spill containment, clean-up and disposal details. Always ensure to wear adequate protective clothing (goggles, closed shoes and gloves) during clean-up of spills. Safely dispose of any contaminated material as chemical waste by contacting hazardouswaste@concordia.ca. Advise your supervisor and complete an Injury / Near-Miss Report **(EHS-FORM-042).**

In the event of a large electrolyte spill:

1. Advise and warn co-workers.
2. Evacuate the area immediately.
3. Restrict the access to the area.
4. Notify Security at **X3717** or **(514) 848-3717**, providing them with the following information:
    a. Location of the spill
    b. Name of hazardous material
    c. Quantity involved
    d. Related health risks and precautions to be taken
5. Provide the Safety Data Sheets (SDS) or appropriate documentation.

3.2.2 Exposure to Material/Electrolyte Mixture

In the event of exposure to a Li-ion electrolyte, one must follow these actions:

i. Inhalation

- Leave area immediately, move to fresh air;
- Seek medical attention if irritation persists.

ii. Eye contact

- Rinse eyes with water for 15-30 minutes;
- Seek medical attention immediately if irritation persists.

iii. Skin contact

- Wash area thoroughly with soap and water;
- Rinse affected area with plenty of water;
- Seek medical attention if irritation persists.

In the case of injuries that require immediate medical attention, Security must be immediately contacted at **X3717**. An Injury/Near-Miss Report (EHS-FORM-042) must be sent to EHS.

3.3 Electrical Hazard

Another type of hazard observed with all batteries is linked to the electrical energy content, according to the state of charge (SOC). The SOC needs to be controlled. Most of Li-ion cells have low individual voltage; however, in case of larger electrical serial assemblies, modules and full battery may offer high voltage hazard (>36 Volts). Exposed terminals, even on disconnected batteries, always present an electrical shock hazard.

Strictly follow all manufacturer’s instructions when installing or maintaining battery systems. A Li-ion battery operates safely within the designated operating voltages. The battery may become unstable if inadvertently charged to a higher than specified voltage. Therefore, Li-ion batteries should only be recharged using recommended chargers, at voltages and for charging times recommended by the manufacturer.

Simple charging guidelines for Li-ion batteries include:

- Turning off the device or disconnecting the load on charge to allow the current to drop unhindered during saturation; the device’s electrical draw may confuse the charger;
- Charging at a moderate temperature; never charge at freezing temperature;
- Partially charging the battery. A Li-ion battery does not need to be fully charged; a partial charge is better. Not all chargers apply a full topping charge and the battery may not be fully charged when the “ready” signal appears; a 100% charge on a gauge may not reflect reality;
- Discontinuing using charger and/or battery if the battery gets excessively warm;
- Applying some charge to an empty battery before storing (40-50% SOC is ideal).

3.4 Thermal Run-Away

The current flow through the battery in a conductive path is creating heat. The heat generated by the electric current during charge/discharge processes is usually managed by different thermal management systems, such as cooling systems or heat evacuation through external battery casing. In such environments where heat can be evacuated, batteries progressively cool down.

In contrast, when the heat cannot be evacuated, the battery temperature will increase and will reach a status where new reactions can start, generating even more heat. This mechanism is known as “thermal run-away”. A thermal run-away occurs when the temperature of a cell increases in an uncontrolled manner, leading to its failure. The temperature increases to the point where the electrolyte evaporates and generates gases which need to vent when the pressure inside the cell rises above a design value.

This temperature rise can have multiple causes, including, but not limited to:

- The use of cells in high temperature environment;
- A defect inside the cell can result in an internal short circuit, which causes the cell to heat up at the location of the defect (localized hot spot);
- A surge in the charging or discharging current. When cells are charged or discharged, heat is generated. The higher the current, the higher the heat generation;
- An improper electrical connection at the tab of a battery. This causes an increased electrical resistance which generates heat at the electrical contacts;
- Mechanical damage to the battery which can also lead to internal shorts and result in heat generation.

In a battery assembly, a thermal run-away resulting in the failure of one cell component may result in fire propagation to neighboring cells. A pack can thus be destroyed in a few seconds or over several hours as each cell is being consumed. To increase safety, packs should include dividers to protect the failing cell from spreading to the neighboring ones.

The possible consequences of the thermal run-away are the following:

- Gas emission (battery venting)
- Fire
- Explosion

3.4.1 Gas Emission

The main consequences of the run-away are the emission of heat and gas which is flammable. Some cell designs include a specially designed vent that opens and releases gases. In some cases, this vent can become obstructed or may not open correctly, which may result in battery bulging, hissing or rupturing of the enclosure (Figure 7). Other cell form factors, such as pouch cells, do not include a specific vent and the gases may release at weak points of the external pouch.

Figure 7: Swollen lithium batteries

The release of vented gases avoids the catastrophic failure of the cell containment structure but creates a new hazard associated with the toxicity and flammability of the vented gases.

Gas release depends on the battery composition and SOC; the higher the SOC, the larger the amount of gases released. A general list of potential gases emitted during a thermal run away of a Li-ion battery is provided in Table 5, with indications of their relative concentration.

Table 5: Potential gases emitted during a Li-ion battery thermal run-away

Gas	Concentration (%)	Hazard
Carbon Dioxide (CO_2)	~30	Asphixyant
Hydrogen (H_2)	~30	Flammable
Carbon Monoxide (CO)	~20-25	Flammable, Toxic
Methane	5-8	Flammable
Ethylene	3-8	Flammable
Ethane	1-3	Flammable
Propylene	1-3	Flammable
C4s and others	<1	Flammable
HF	0.3	Corrosive, Toxic

The gases released by a venting Li-ion cell are mainly carbon dioxide (CO2) and hydrogen (H2). Other gases that form through heating are vaporized electrolyte, consisting of ethylene and/or propylene along with combustion products of organic solvents.

If a Li-ion battery hisses, bulges or release any gases:

- If possible, move the device away from flammable materials and place it on a non-combustible surface or outdoors to let any gases to release;
- If not possible or too dangerous, leave the room immediately;
- Contact immediately Security at **X3717**;
- Let sufficient time for the room ventilation to ventilate any gases released.

Most of the gases reported in Table 5 are flammable. In addition, carbon monoxide and some other gases can also pose significant health hazards.

3.4.2 Fire

If enough heat is produced during a thermal run away, then the battery flammable components can catch fire (Figure 8).

Figure 8: Results of lithium battery fires

A small Li-ion battery fire can be handled like any other combustible fire. Preferably, a foam, CO_2, or ABC dry chemical extinguisher should be used. Non-combustible dry media, such as sand, can also be used.

Li-ion batteries contain little lithium metal and in case of a fire, they can also be dowsed with water. Water also cools the adjacent area and prevents the fire from spreading. Most research laboratories and factories currently use water to extinguish Li-ion battery fires.

The National Fire Protection Association's (NFPA) Fire Protection Research Foundation has released a research report on a study of flammability of Li-ion batteries in bulk storage. The results of these tests will be used to define appropriate sprinkler protection in the next version of NFPA 13 for these types of products. Three types of Li-ion batteries commonly used in various consumer products were chosen for these fire tests. They were stored in rack storage configurations up to 15 ft. high.

According to the test report, "… cartoned Li-ion batteries burn similarly when compared to other cartoned commodities in the early stages of fire growth". As a result, the researchers felt "… optimistic that water-based suppression systems, similar to those that are typically recommended for a variety of storage scenarios, are a viable option for Li-ion battery storage".

When encountering a fire with a lithium-metal battery, a Class D fire extinguisher for combustible metals (Figure 9) shall be used. Lithium-metal contains plenty of lithium that reacts with water and makes the fire worse. A Class D fire extinguisher must not be used to put out other types of fires. If you need to get a Class D fire extinguisher for your respective work area, please contact the Security Department of Concordia University.

Figure 9: Class D fire extinguisher for combustible metals

In the event of any fire involving lithium batteries, contact Security at **X3717** and leave the room immediately if the fire cannot be controlled. As with all battery fires, allow ample ventilation while the battery burns itself out.

3.4.3 Explosion

During a thermal run-away, Li-ion cells can explode and eject their contents. A study found that the energy released from Li-ion cells under failure conditions, measured in a bomb calorimeter, was roughly proportional to the charge capacity of the cells. It was observed that none of the cells having zero SOC ejected their contents at failure during thermal runaway. By comparison, half of the cells at 20% SOC, most of the cells at 50% SOC and all of the cells at 100% SOC ejected their contents.

Furthermore, if the flammable gases produced during thermal run-away are ignited in a confined environment, they can present an explosion hazard. This is particularly true for large battery packs, where the battery modules are often contained in an enclosure. An explosion can occur when the uncombusted vented gases mix with remaining air in the battery enclosure, or when fresh air enters the battery enclosure from vents or openings and the resulting mixture is ignited by either the failing cells or a different ignition source within the enclosure.

Figure 10: Li-ion cells after thermal runaway: the top cell did not eject its contents (SOC = 0); the bottom cell did (SOC = 100%)

In the event of a lithium battery explosion, battery debris can be projected and the room can quickly fill with a dense white smoke that can cause severe irritation to the respiratory tract, eyes, and skin. Should a battery explode, all personnel must be evacuated from the affected area. Ventilation should be initiated and remain in place until the smoke is cleared and the odor is gone.

4. Battery Storage

The International Fire Code (IFC) covers storage requirements for stationary storage battery systems having an electrolyte capacity of more 454 kg (1,000 pounds) for Li-ion and LiPo batteries used for facility standby power, emergency power or uninterrupted power supplies. LiPo battery systems shall be provided with a device or approved method to preclude, detect and control thermal run-aways.

No special ventilation requirements are necessary for Li-ion battery storage. However, appropriate room and cabinet signage indicating the relevant electrical, chemical and fire hazards must be disclosed.

Along with regulatory guidance, the following guidelines should be followed:

- Batteries should be stored in their original containers or equivalent. LiPo shall be placed in containers that prevent any mechanical hazards, such as puncture, perforation or pressure. Fire resistant LiPo guard bags (Figure 11) are usually provided by battery manufacturers and should be use when charging, storing or transporting LiPo batteries.
- Batteries should be stored in a dry, well ventilated area. Ideally, batteries will be stored in a temperature-controlled environment at 23°C or below. High temperature may cause the battery capability loss, leakage and rustiness.

- Batteries should be segregated from other combustible or flammable materials and possibly stored into individual containers (e.g. LiPo guard bags); they should be stored in a separated cabinet made of non-combustible material or stored in a separate storage area by maintaining a distance of 2.5 m with other goods.
- Appropriate fire extinguishing means should be available.

Figure 11: LiPo batteries guard bags

- Rooms with lithium battery storage areas should be equipped with sprinklers.
- Appropriate personal protective equipment (PPE) should be available, including gloves, safety glasses and lab coat or apron.
- Batteries should be 40-60% charged for long time storage.
- Exercise caution when stacking boxes to prevent crushing of cells in lower boxes.

5. Transportation

5.1 Ground Shipments

In Canada, lithium batteries are classified as dangerous goods and their shipment and import are subject to the *Transportation of Dangerous Goods Regulations (TDGR)* in which recent amendments concerning lithium batteries were included. When lithium batteries are shipped, including those **contained in** or **packed with** devices and equipment, proper shipping requirements must be met.

These two terms have differing regulatory requirements:

- **Packed with equipment** means that the battery is not physically attached or connected to the device. An example would be a spare battery in a package containing a power tool.
- **Contained in equipment** means the battery is physically attached or connected to the device. A common example is the battery used to power a tablet or iPad which is integrated into the electronic device.

One of the key safety requirements to the shipment of all lithium batteries is short circuit protection by insulating the terminals. Preventing lithium batteries from short circuit and physical damage is very important to keep them from overheating and catching fire.

TDGR recognize the following classification for lithium batteries under the hazardous class 9:

- UN3090, LITHIUM METAL BATTERIES (including lithium alloy batteries);
- UN3091, LITHIUM METAL BATTERIES CONTAINED IN EQUIPMENT (including lithium alloy batteries) or LITHIUM METAL BATTERIES PACKED WITH EQUIPMENT (including lithium alloy batteries);
- UN3480, LITHIUM ION BATTERIES (including lithium ion polymer batteries);
- UN3481, LITHIUM ION BATTERIES CONTAINED IN EQUIPMENT (including lithium ion polymer batteries);or LITHIUM ION BATTERIES PACKED WITH EQUIPMENT (including lithium ion polymer batteries).

Shippers can determine if batteries are exempt from the regulations by referring to *Special Provision 34* of the TDGR Schedule 2. The guidelines for exemption are the followings:

1) Lithium metal or lithium alloy:
   - cell: the lithium content is not more than 1g;
   - battery: the aggregate lithium content is not more than 2g.

The lithium content, in grams (g), of a lithium metal cell can be calculated as follow:

a) If the battery's capacity in ampere-hours (Ah) is known:
   Grams (g) lithium metal = (Ah) x 0.3
b) If the capacity in milliampere-hours (mAh) is known:
   Grams (g) lithium metal = (mAh ÷ 1000) x 0.3

To calculate the lithium content of the battery, simply multiply the grams (g) of lithium metal by the number of cells in the battery.

2) Lithium ion:
   - cell: the watt-hour rating is not more than 20 Wh;
   - battery: the watt-hour rating is not more than 100 Wh.

The Wh rating must appear on the battery case if it was made on or after January 1, 2009 (Figure 12). If it is not there, you can calculate the Wh rating by using one of these formulas:

a) If you know the nominal voltage (V) and the capacity in ampere-hours (Ah), then:
   Wh = (V) x (Ah)
b) If you know the nominal voltage (V) and the capacity in milliampere-hours (mAh), then:
   Wh = (V) x (mAh ÷ 1000)

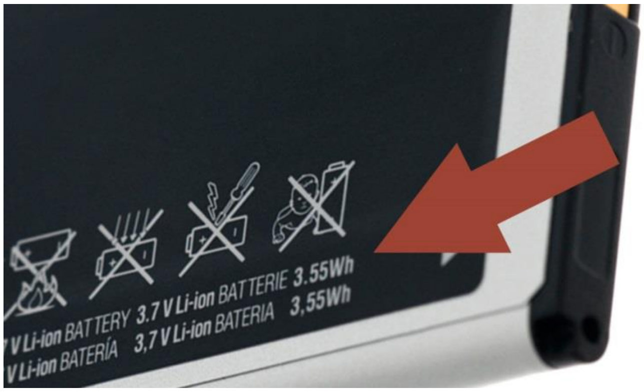

Figure 12: Watt-hour (Wh) rating indications on Li-ion battery

If a shipment of lithium batteries falls under the *Special Provision 34* exemption, UN specification packaging, shipper’s declaration and hazard label (class 9) are not required for shipment. However, each individual package (<30kg) must bear *the Lithium Battery Handling* label (Figure 13), where the following information must be present:

a) “lithium metal” or “lithium-ion”, as appropriate;
b) an indication that the means of containment must be handled with care and that a flammability hazard exists if the means of containment is damaged;
c) an indication that special procedures must be followed in the event the package is damaged, including inspection and repacking, if necessary;
d) a telephone number to call for additional information.

Figure 13: Lithium Battery Handling label

Furthermore, each package must be accompanied by a document that includes the information indicated on the package with the mention *“Exempt TDGR – Special Provision 34”*. If the criteria in Special Provision

34 cannot be met, the shipment must be declared as fully regulated dangerous goods and meet the requirements of TDGR.

5.2 Air Shipments

It is becoming more and more difficult to ship lithium batteries via air. In light of recent flight incidents involving lithium batteries, lithium metal cells/batteries (UN3090) and Li-ion cells/batteries (UN3480) are forbidden for transport as cargo on passenger aircraft when shipped by themselves. Lithium metal and Li-ion cells/batteries can be shipped on cargo-only aircraft, provided certain conditions are met, such as:

- Ensuring that battery terminals are protected;
- Ensuring a state of charge no more than 30% of capacity;
- Packing them separately from everything else.

Consequently, most courier companies may not accept packages containing lithium batteries or may have specific packing requirements for air shipments. Furthermore, defective, swollen or leaking batteries cannot be shipped. Always make sure to contact the courier or airline company prior shipping any lithium battery.

Lithium batteries packed with or in equipment (UN3091 and UN3481) may still be shipped compliantly, subject to International Civil Aviation Organization/International Air Transport Association (ICAO/IATA) regulations. Passengers may still transport their battery powered devices and spare batteries in their carry-on bags (for now…).

New ICAO/IATA regulations are currently being finalized and the new markings for lithium batteries will replace the current *Lithium Battery Handling* label. There will also be a new Class 9 label specifically for lithium batteries (Figure 14). These new labels for all lithium battery shipments will be effective as of January 1, 2019 but early adopters are free to use them voluntarily as of January 1, 2017.

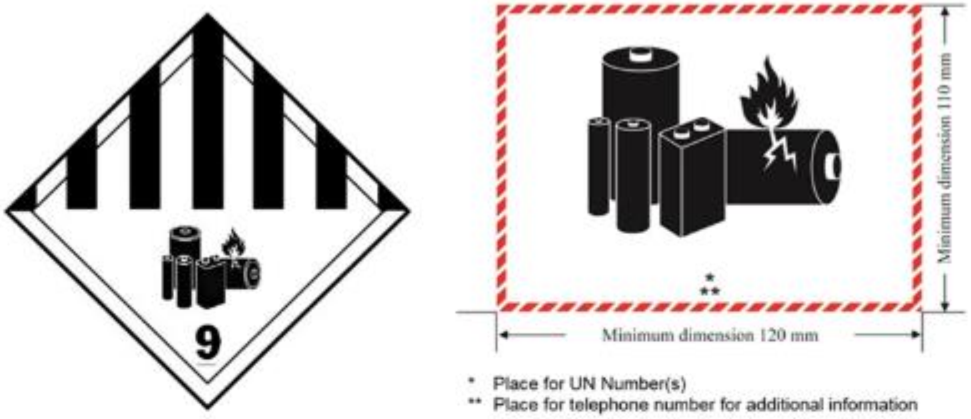

Figure 14: New Lithium Battery Class 9 and Lithium Battery Handling labels

Please contact EHS at ehs@concordia.ca for more information concerning lithium battery shipments.

6. Waste Lithium Batteries

All types of lithium batteries are considered as hazardous waste and shall not be placed into regular garbage. Lithium metal and Li-ion batteries weighing up to 5kg each can be placed into battery recycling boxes (Call2Recycle) (Figure 15), as long as they are individually bagged or have their terminals covered with tape. Please contact EHS at hazardouswaste@concordia.ca for more information concerning lithium battery disposal and recycling programs.

Figure 15: Call2Recylce battery recycling box

If you have any concerns about lithium batteries at Concordia University, please email EHS at ehs@concordia.ca

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