Teen Workshop Course Proposal Form

Thank you for your interest in partnering with the City of Cupertino's Teen Commission to offer a workshop to the Cupertino community. Please be detailed when lling out this form and feel free to submit any supplemental items (e.g., additional sheets, course material) with your proposal form. Submission of a proposal does not guarantee it will be accepted. The Cupertino Teen Commission will connect with you if your proposal is selected for follow up.

Once you have submitted a form, please email the Teen Commission and Staff Liaison at the following email addresses: danielm@cupertino.org and teencommission@cupertino.org. Google forms does not send us noti cations and we would like an expedited process. Upon reaching out, we will schedule a time with you to come present your workshop proposal at a Teen Commission meeting.

Requirements for minors (under 18 years of age):
* Complete a volunteer application.

Email address *

Full Name *

Niranjan Bhatia

Address *

What high school do you attend? *

Monta Vista

Age *

Note: those over 18 years or older will be required to meet different requirements than those under age. Proof of age will be required if we move forward with your proposal.

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Primary Phone Number *

Please give us the best number to text/call you at.

E-mail *

Please input an email that you check regularly.

What is the name of the workshop you will be conducting? *

Introduction to Lithium Ion Rechargeable Batteries

Describe the workshop you will be conducting in detail. Please include who your target audience is and why this will be helpful or what education gaps you are trying to fill. *

This workshop will teach the participants the fundamentals of Li-ion Rechargeable Batteries like those used in Tesla cars. Knowledge of these is very important since they are the future sources of energy storage and will be used in all forms of electric vehicles. The target audience will be kids, students, and people of all ages. It is a very important topic since the future is going to be all-electric (that is green). The workshop material includes details of Tesla batteries, fast charging, issues in the usage of Li-ion batteries, and what the consumers can expect. Since Li-ion batteries are going to pervade our lives, this workshop is very important and essential.

Upload any course materials here (Example: syllabus, powerpoint, Prezi, etc.)

While not required, uploaded course materials will help us come to a quicker decision.

Intro_to_Li-ion_Rec...

Write a 40-word description of your workshop that the City may use in promotional content. *

This workshop will teach you the fundamentals of Li-ion Rechargeable Batteries like those used in Tesla cars. Knowledge of these is very important since they are the future sources of energy storage and the future is going to all-electric, that is, green.

What days are you available to conduct your workshop? *

- [ ] Monday
- [ ] Tuesday
- [ ] Wednesday
- [ ] Thursday
- [ ] Friday
- [x] Saturday
- [x] Sunday

What age groups would your workshop be open for? *

- [x] 6-10
- [x] 10-14
- [x] 14-18
- [x] Other: Adults

How many students are you expecting at your workshop? *

40+

What potential materials would you need to be provided for you to conduct your workshop? *

- [x] Wi-Fi
- [x] Tables & Chairs
- [x] Whiteboard
- [x] Projector
- [ ] TV/DVD player
- [ ] Other: _____

How would you handle a situation in which a student in your workshop was being disruptive and distracting everyone around them? What if they questioned you and the information you were teaching? (max 150 words) *

I will try to handle the situation in a calm manner. I will ask the student if there is something troubling him or if he needs something. If he has a question, I will calmly answer. If the behavior continues, I will tell him that we have a time limit in which the course material needs to be covered and his cooperation will be appreciated else others will also not be able to understand the facts. If the student questions me, I will answer to the best of my knowledge. I will happily
explain all facts. If the student has a valid question which I do not know or understand, I will admit it. I will then tell the student that I will be happy to discuss with him offline. I will also tell the class that I will look up the facts and share the answer via email.

Why do you want to have your own workshop with the city of Cupertino? (max 150 words) *

I love Physics and like to learn more. I put learning over everything else. I have completed college-level courses in Physics and Math from Harvard and Stanford University. I have contributed to the Physics community by publishing one paper in Astrophysics in a Physics journal. A second paper is under peer-review for publication in a Physics journal. I have also participated in the 2018-2019 Google Science Fair and the 2019 Science Breakthrough Junior Challenge by Khan Academy (see video https://www.youtube.com/watch?v=XPV9H0kVSCQ). I want to educated the community on Physics. Since I live in Cupertino, I would like to start by educating the teens in our community in Physics. I have also become the Director of Operations of the Physics and Engineering Club at Monta Vista High School during the 2019-2020 school year. Hence, I hope you can appreciate my interest and motivation in this effort.

Please leave any other questions or comments here.

The Li-Ion Rechargeable Battery Introduction

Niranjan Bhatia

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1 Introduction to Batteries in General

There are many cells in a battery.
Electrical energy is stored as chemical energy in electrodes. The 2 electrodes are the anode and the cathode.

Anode - The reductant. - The donor of electrons when charging.
Cathode - oxidant. -Receives electrons when charging. Electrons travel from the anode to the cathode.

The two electrodes are separated by an electrolyte. In a lithium ion battery is it will transform the lithium ions from the anode to the cathode and visa versa.

Currently Li/TS2 rechargeable batteries have more potential than sodium sulfur and zebra batteries but dendrites grow across the electrolyte from the anode to the cathode which can cause short circuits! Lowering the voltage would lower the benefits of using this battery so it was abandoned.

Oxide cathodes offered larger voltages.

Current L-ion batteries fall short of desired specifications for automobiles and storage of energy for wind and solar power.

There are any disadvantages of fossil fuels.

2 How to Solve Problem in Cars

1. Replace combustion engines with electric traction motors.

2. Usually the traction batteries are Li-ion ones.

3. Can the Li-ion be a sustainable energy source?

3 The Electrochemical Cell

Electrodes are separated by electrolyte-permeable separator. This separator is put inside the electrolyte. This is put in the battery in case the electrolyte melts due to high temperatures. This will allow lithium ions to go to their stable state but electrons won't be able to pass through.

An electrolyte is a substance that when dissolved generates ions. The electrolyte allows the Li-ions inside the cell but the electrons have to pass through the circuit causing a current.

Discharge - electrons flow from anode to cathode.
Charge - Electrons are forced to flow from cathode to anode by electric field.
Rechargeable batteries are capable of over 30,000 cycles.
Internal resistance in cell which reduces discharge voltage.

$$V_{dis} = V_{oc} + \eta(q, I_{dis}) \tag{1}$$

$$V_{ch} = V_{oc} + \eta(q, I_{dis}) \tag{2}$$

We can infer from this that the voltage required to charge is increased as a result of this.
The discharge and charge efficiency is calculated as:

$$100 * \int_0^Q V_{dis} dq / \int_0^Q V_{ch}(q) dq \tag{3}$$

$$E = P\Delta t = \int_0^{\Delta t} IV(t) dt \tag{4}$$

With graphite as the charged anode and $LiCoO_2$ as the discharged cathode:

$$C + xe^- + xLi^+ = Li_xC(anode) \tag{5}$$

$$LiCoO2 - xe^- - xLi^+ = Li_{1-x}CoO_2(cathode) \tag{6}$$

In the Lithium cell there are two safety issues.

1. O_2 forms inside the cell which creates safety problems. Al^{3+} can be added so the oxides against electrolyte reactions are stabilized but capacity is reduced.

2. Lithium can penetrate across the separator or with contact with the electrodes through small holes or thermal shrinkage. To block this you can add Al_2O_3 and polymeric binders on separator. These bind nicely to the lithium and provide a membrane to prevent dendrites. However, these are also not perfect.

Energy density of battery needs to increased. It's necessary to find a way to raise the voltage while retaining a large cathode charge.

Poor electronic conductivity reduces rate of charge and discharge.

Lithium membrane is ideal since it would maximize the cell voltage and anode capacity. Need air or liquid cathode to increase capacity. However, we will need a ceramic component to block dendrites.

Graphite is a very popular anode because it's very stable.

4 Capacity Fade and Types of Capacity Loss

1. Capacity fade: Through cycles changes in the volume of electrodes, chemical reactions with electrolytes, and/or decomposition of electrodes can cause a loss of capacity(irreversible). This process is called capacity fade.

2. If there is less diffusion and loss of Lithium at high rates of charge or discharge, the loss of capacity will be reversible.

5 The Electrolyte

The window of an electrolyte is the energy gap between the LUMO and the HOMO.

LUMO - lowest unoccupied molecular orbital.
HOMO - Highest occupied molecular orbital. Has non-bonding pair of electrons.
LUMO - Lowest unoccupied molecular orbital. Has more energy than HOMO.
In order to maximize the voltage of the stable cell, the electrochemical potentials of the anode and the cathode must be equal to the voltage difference between the LUMO and the HUMO.
u_a = anode potential
u_c = cathode potential Where you place your cathode potential is very important as it is the main factor in how much voltage you get. If u_c is below the HOMO or u_a is above the HOMO, then voltage is lowered.

6 Aqueous Electrolytes

In an aqueous electrolyte, the window is 1.23 eV. So voltage is limited to 1.5V. Even if ions like H^t are extremely mobile in aqueous electrolytes the voltage is too low.

Reversible intercalation: The reversible inclusion of molecules into layered structures. The cathode in the lithium battery has graphite layers thus making it the source of reversible intercalation. The lithium ions move the graphite during charging and move out during discharging.

Reversible insertion reaction: Intercalation of the working ion(in Li-ion batteries;the electron) between layers.
Sodium sulfur battery has fast Na^+ ion transport. Has $V_{oc} = 2.58V$

7 Organic Liquid-Carbonate Electrolytes

Li^+ form an SEI layer on a lithium anode since Li salts dissolve on organic liquid carbonate solvents.

TiS_2 was suggested as a cathode due to its Van der Vaals bonding between layers. However, recharging the cell causes dendrites to grow from the anode to the electrolyte being able to cause explosions. Dendrites formed because there was lots of Li deposit on the anode which grew. Intercalation into graphite became another possible solution. This solution was found to be more safe than TiS_2.

The limiting reversible voltage by the HOMO is different from the voltage limit of the u_c. You can put a limit for the extended cycle life by irreversible reaction of the salt with the carbon in the cathode.

Capacity of cathode is defined as how much Li atoms can be inserted into by many cycle times(reversibly). Capacity is reduced based on when SEI layer forms on an anode surface. This causes Li atoms to flow irreversibly.

8 Using a Lithium Solid Electrolyte as a Separator

Using lithium solid electrolytes with high conduction and a low valence bond would allow increased cathode voltage and less irreversible LI loss. Thus SEI layer doesn't become as bad.

Have an Li^+ separator with two different liquids on either side having a lithium anode on one side and an aqueous solution on the author. The challenge is to discover electrolyte stable enough with lithium and an aqueous solution with a stable temperature.

9 Good Points to Make or to Clarify

Switch from aqueous electrolyte to organic liquid carbonate electrolyte increased energy density. However, fossil fuels are still more consistent these days.

An Na-ion battery has a large potential and is cheaper but Na ions are large and are only ideal in batteries with large volumes.

The SEI layer is formed from electrode-electrolyte reaction.
The SEI layer causes more resistance in the cell since it lowers the surface area of the electrodes. Less capacity due to lithium consumption.
Li undergoes lots of side reaction reducing the lithium available for intercalation.

10 Types of Batteries

Anode of most 18650 li-on batteries are the same: Carbon/silicon and graphite. The $LiCoO_2$ cathode delivers the highest specific energy of any 18650 battery chemistry but are also the most dangerous.

Comparison of 18650 vs 21700:

1. Volume: 21700 has a large volume. It has about 47% more volume than the 18650.
   (a) 18650: 16532 cubic mm
   (b) 21700: 24,233 cubic mm
2. There is more energy in a 21700 than an 18650.
   (a) General Purpose 21700 Battery: 6Ah - 8 Ah
   (b) General Purpose 18650 Battery: 4Ah to 6Ah.

Thus you will go with a 21700 if you need extra energy density. However, these batteries are way larger. The 21700 is also 15% more energy efficient.
In terms of the material for the cathode of the 21700, you would use a normal $Li-CoO_2$ for cellphones, laptops, or cameras. But for electrical vehicles or grid storage you could use Lithium Nickel Cobalt Aluminum Oxide($LiNiCoAlO_2$) or Lithium Titanate($LiTi_5O_12$). FOr 18650 batteries, the cathodes for vehicles are either Lithium Nickel Cobalt Aluminum Oxide($LiNiCoAlO_2$) or Lithium Iron Phosphate($LiFePO_4$).

11 Degradation Mechanisms

1. Loss of primary material(Li^+).
   (a) SEI layer formation is the main cause of this. It increases resistance and prevents Li-ions from passing.
2. Loss of Cathode
   (a) Contact with electrolyte can cause disordering.
   (b) Cracks or holes can reduce capacity for Li-ions.
   (c) Volumetric changes - reduces capacity for ions.
3. Loss of Graphite
   (a) Loss of active material from solvent molecules intercalating with the graphite layers.
   (b) Loss also by volumetric expansion and contact.

   ‘
4. Increased impedance of Cell and Electrodes
   (a) Film formation and thickening on electrodes and cell. This can be caused by SEI layer and electrolyte oxidation.

12 Charging above 3C

This kind of charging is called ultra-fast battery charging.
If charging exceeds the rate of LI intercalation, there is more Li deposit on the anode. Charging above 3C however is possible. But there are some requirements to be met:

1. Anode must have large surface area with small graphite particles to maximize capacity.
2. Intercalation must be uniform throughout anode. If more Li-ions are going to one side, moss and dendrites form.
3. Ultra fast charging must be done in first phase of charging and the current must be smaller when 70% charge threshold is met.
4. Safety precautions need to be met.
5. Should be at room temperature since chemical reaction rate can't slow down.
6. Resistance needs to be considerably low.