

# The Impact of Partial vs. Full Discharge on AA Lithium-Ion Battery Longevity

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## **Abstract:**

This study is related to an environmentally friendly way to keep the longevity of your batteries. Lithium-ion batteries are becoming more and more relevant because of their high energy density and low weight. It's important to keep the batteries captivated because it will make your battery last longer. The Lithium-ion batteries can make their way to contaminate water supplies and ecosystems. We can reduce the amount of batteries disposed improperly in landfills by using the batteries to their fullest. The lithium-ion batteries work by an electrochemical cell. In that cell there is an anode and a cathode. A cathode is the positive end of the battery and the anode is the negative end and is made of copper foil with graphite coated on it. The objective of this study was to test the effect of different discharges on lithium-ion batteries to test their longevity. My hypothesis is if the lithium-ion battery is discharged fully then it will have a longer longevity as compared to partially discharging the battery. This was researched by having 4 AA lithium-ion batteries labeled control, partial discharge, full discharge, and 80%-20% so I can tell them apart. Once the batteries are at their designated charge I will then run them through a motor. The motor was connected to a voltmeter that I would collect data from every 10 minutes. My data confirms that a battery discharged fully had a greater longevity as compared to the battery discharging it partially.

**Introduction:** Lithium-ion batteries are found in commonly used devices such as your phone and in laptops. These batteries are a top pick because of their high energy density and low weight. (faraday.ac.uk/2021/04) The struggle with lithium-ion batteries is that they are more expensive than other types of rechargeable batteries. A consumer of a rechargeable AA Lithium-ion battery can expect to pay 3 times as much as you would pay for a nickel cadmium rechargeable battery. When a battery reaches the end of its useful life around 93% of those batteries end up in landfills and in the garbage. If the batteries are not disposed properly in landfills they can make their way to contaminate water supplies and ecosystems. ("The Environmental Impact of Lithium Batteries." 12 Nov. 2020, *Institute for Energy Research*) For these reasons it is important to understand factors that may affect your battery's life and help you save money and protect the environment.

Like many batteries, lithium-ion batteries work by an electrochemical cell. In that cell there is an anode and a cathode. A cathode is the positive end of the battery and is a piece of aluminum foil with a type of lithium compound on top of it. The anode is the negative end and is made of copper foil with graphite coated on it. In between the anode and cathode is a very thin plastic membrane with a liquid electrolyte. The liquid electrolyte contains lots of Lithium ions ( $\text{Li}^+$ ). When the battery is being charged you are pumping electrons from the cathode to the anode and the lithium-ions are traveling to the anode through the electrolyte. (Battery 101, 30 Oct. 2023.) The figure one two and three below shows a battery being fully charged, fully discharged, and partially discharged.

Figure 1 - Fully Charged

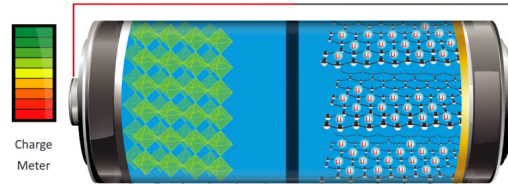


Figure 2 - Fully Discharged

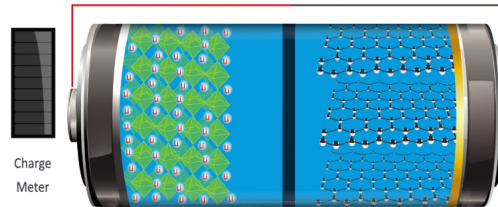
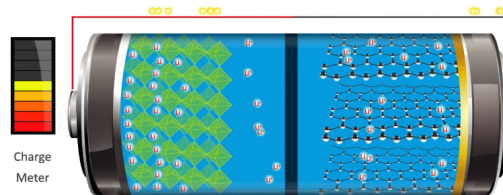


Figure 3 - Partially Discharged



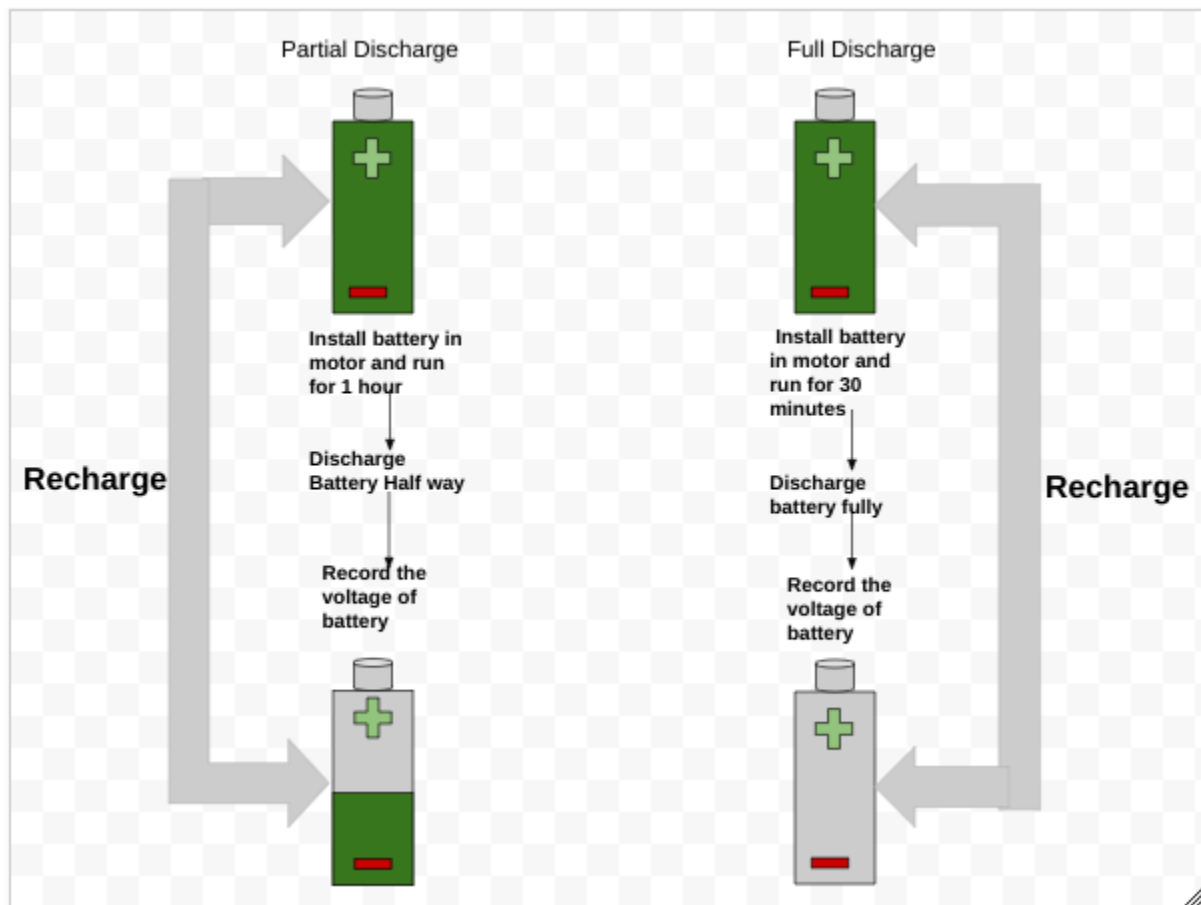
(“How Lithium-Ion Batteries Work.” *Energy.gov*)

While using partial discharge, your battery can last longer and only uses a portion of your battery's capacity before recharging. Unlike full discharge where your battery is fully drained before recharging. Lithium-ion batteries undergo degradation. Degradation happens when a battery worsens and becomes weaker. Fully discharging batteries can increase the degradation.

This can happen from a change in temperature, the current, and a level of which a battery is charged and discharged. Avoid letting the battery get too cold or hot to preserve the longevity. If the temperature is majorly above or below 77 degrees, then your battery's life is shortened. You also want to make sure the average you should charge your battery to is 80% or less. The discharge should not go below 20% either (*CleanTechnica*, 3 Aug. 2021). Knowing what factors can increase degradation and how different discharge levels can affect the lifespan of your electronic devices make sure your battery lives the longest. ([faraday.ac.uk/2021/04](http://faraday.ac.uk/2021/04))

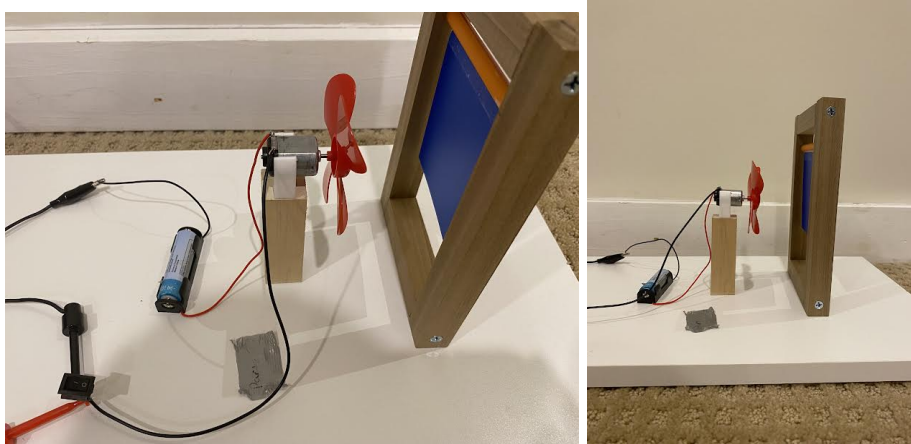
**Hypothesis:** My hypothesis is that if the lithium-ion battery is discharged fully then it will have a longer longevity as compared to partially discharging the battery.

**Methods:**



I had 3 AA lithium-ion batteries labeled control, partial discharge, and full discharge so I was able to tell them apart. I charged the partial and the full battery up all the way to 100%. The "Control" battery did not get used until the very end to test the discharge. Once the batteries were at their designated charge I ran them through a motor.

### **Photo 1- Project Setup**



**The battery was hooked up to the motor connected to a fan so I could drain the battery. The fan was blowing a piece of plastic also so I could have a visual of how the battery was running.**

I placed each battery into the same motor so it would not add any difference to the data. I only ran the partial discharge battery for 50 minutes so that it will only have half charge left. The full discharge lithium-ion battery was left in the motor for 105 minutes so the battery is empty. The motor will discharge each of the batteries. The "partial discharge" was discharged halfway, the "full discharge" was fully discharged then recharged. I repeated this process 10 times.

## Photo 2- Recharging The Battery



**Both batteries were recharged in this which took around 50-60 minutes to recharge. The recharger is designed to work with AA lithium-ion batteries**

Once I repeated this 10 times then I fully charged them all and put them all in a motor at different times. I collected data from each battery on how long they lasted in the motor. I also collected the voltage with a voltmeter. The voltmeter will be connected to the positive and negative ends of the battery. I made sure to keep the temperature the same throughout all the batteries because if I don't then it would have made inaccurate data.

## **Results:**

### **Data Table 1- Initial Partial Discharge**

<b>Battery ID</b>	<b>Date</b>	<b>Trial</b>	<b>Time</b>	<b>Volt</b>	<b>Amp</b>
Partial discharge	<b>1/1/2024</b>	Initial Discharge	<b>0</b>	<b>1.52</b>	<b>1.15</b>
Partial discharge	1/1/2024	Initial Discharge	10	1.37	1.16
Partial discharge	1/1/2024	Initial Discharge	20	1.39	1.09
Partial discharge	1/1/2024	Initial Discharge	30	1.38	1.06
Partial discharge	1/1/2024	Initial Discharge	40	1.39	0.94
Partial discharge	1/1/2024	Initial Discharge	50	1.38	1.16
Partial discharge	1/1/2024	Initial Discharge	60	1.38	1.09
Partial discharge	1/1/2024	Initial Discharge	70	1.38	1.08
Partial discharge	1/1/2024	Initial Discharge	80	1.35	1.2
Partial discharge	1/1/2024	Initial Discharge	90	1.35	1.2
Partial discharge	1/1/2024	Initial Discharge	100	0	0

This was the first initial partial discharge battery so I could find its captivity. I had to drain the battery all the way to zero so I could see if one battery had any advantage or disadvantage.

### **Data Table 2- Initial Full Discharge**

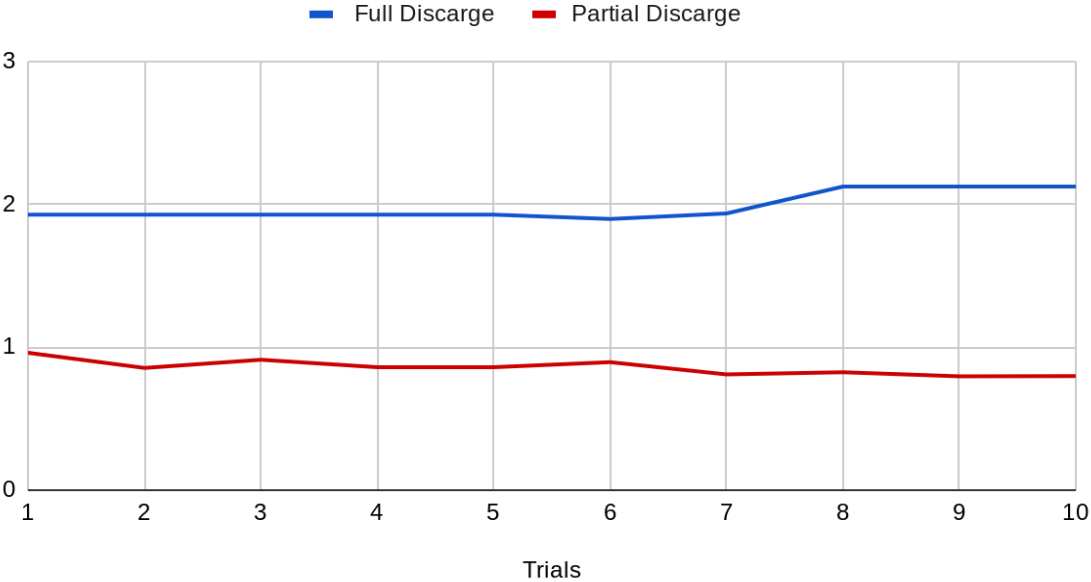
<b>Battery ID</b>	<b>Date</b>	<b>Trial</b>	<b>Time</b>	<b>Volt</b>	<b>Amp</b>
Full Discharge	<b>1/1/2024</b>	Initial Discharge	<b>0</b>	<b>1.507</b>	<b>1.31</b>
Full Discharge	1/1/2024	Initial Discharge	10	1.502	1.16
Full Discharge	1/1/2024	Initial Discharge	20	1.504	1.24
Full Discharge	1/1/2024	Initial Discharge	30	1.503	1.07

Full Discharge	1/1/2024	Initial Discharge	40	1.502	1.07
Full Discharge	1/1/2024	Initial Discharge	50	1.5	1.14
Full Discharge	1/1/2024	Initial Discharge	60	1.499	1.2
Full Discharge	1/1/2024	Initial Discharge	70	1.504	1.19
Full Discharge	1/1/2024	Initial Discharge	80	1.502	1.1
Full Discharge	1/1/2024	Initial Discharge	90	1.5	1.18
Full Discharge	1/1/2024	Initial Discharge	100	1.501	1.21

The data in this graph is from the first initial full discharge battery so I could also find its captivity. The battery was also drained all the way to zero so I could see if one battery had any advantage or disadvantage.

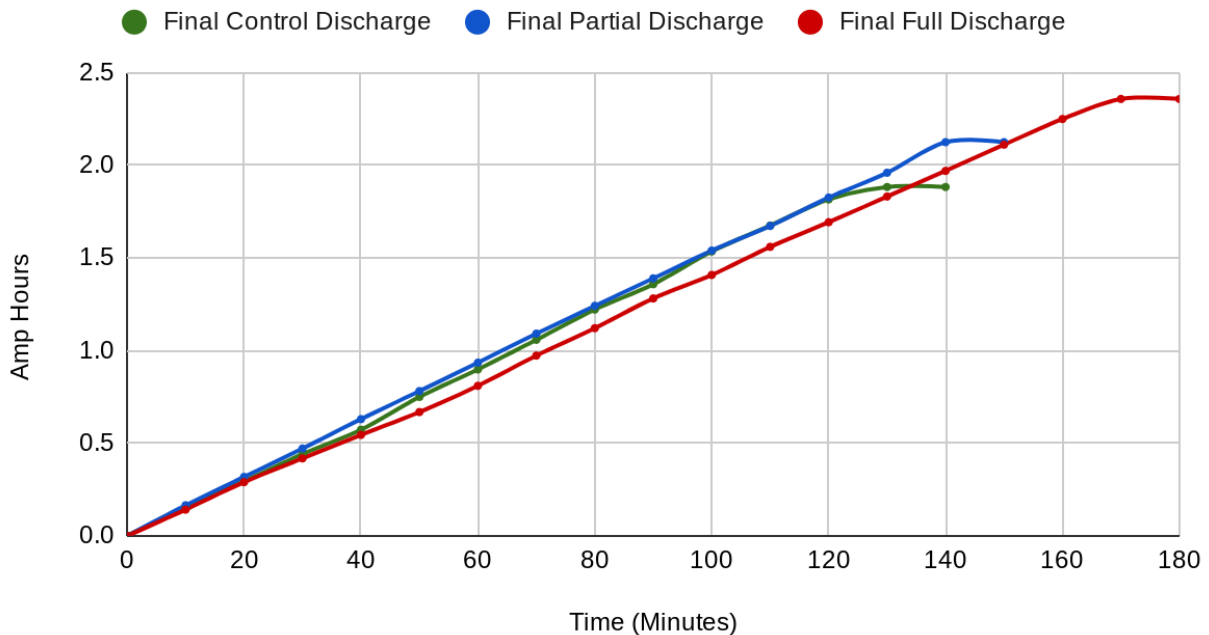
**Graph 1-**

Amps. Collected Per Trial



This graph shows the amount of amp hours collected from each of the 10 battery trials and how the amount of amp hours collected stayed very constant.

## Final Discharge Of The Three Lithium Batteries



This graph shows the amount of amp hours collected every ten minutes between the three batteries. The control was used because this was the very final test.

**Discussion:** The batteries on the first 2 data tables had to be emptied to zero so I could see that they were all the same incase one started or heald out for a longer period of time. Both the initial partial and full discharge batteries took 100 minutes to drain. The trails emptied out around the same time because they have a similar longevity to each other on the first test. Also as shown on graph 1 the reason the partial discharge had a lower amp hours throughout the trials is because the battery only ran for 50 minutes. The 50 minutes was not long enough of time for it to make more amp hours to the same level of the full discharge. The reason the full discharge battery lasted the longest was because the battery went through a complete cycle which helps the battery maintain its capacity. Full Discharging the battery was able prevent the buildup of chemicals

such as electrodes and electrolyte that cause the battery to degrade. When the battery was being partially discharged it did not go through a complete cycle so it did not maintain the capacity. It leads to an overall decrease in the capacity over time as shown on graph 1.

**Limitations:** One limitation was how long it took to run the batteries to zero. I had not realized it would take over 100 minutes for the batteries to die. In addition it also took 1 hour to charge the batteries back to full charge so it. I was not expecting it to take so long , and it put me behind on collecting data. Another limitation was not knowing when the batteries were at a certain percentage because the voltage stayed very constant the whole time it was running. The final limitation I had was that sometimes the wires that I melted together would come apart causing me to fix it, interrupting the data I was collecting.

**Future Studies:** The next logical step I would take would be to use a better motor that works more efficiently. The motor could possibly be something that connects to a computer and runs it to act more like a phone. It would also be a great step to study efficiency of rechargeable lithium-ion batteries on how much energy they give out Vs. how much they get back from recharging.

**Sources:**

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