Collaboration vs Competition: A New Viewpoint for the Batteries

Traveling back to my hometown Kangra, Himachal Pradesh, right after the horrendous second wave of COVID-19, was a great relief. The clear sky, serene mountains, and cold breeze, all were gratifying to the mind and the body. The excitement of meeting my family, cousins, and friends, was always there throughout the joyous journey.

A few days later, I visited my uncle's home where Erica, my 13 years old cousin, was sitting in the drawing room. Her head was glued to the television screen. She was watching an episode of the popular "*The Tom and Jerry show*".

She saw me and excitedly said, "Look Di (*sister*), *Tom* and *Jerry* have teamed up against the *Spike*."

"Yes. Collaboration is the solution sometimes rather than competing." I replied.

She asked with curiosity, "What is a collaboration, Di?"

To which I replied, "Collaboration is the act of working together. Sometimes, accomplishing a task is easier and a lot quicker while working in a team than working alone towards it."

She asked, "Then which one is better? Is collaboration better than working independently?"

"Well, the answer should be yes if achieving the goal is the main priority instead of competing to achieve it first. Doing homework together, playing sports, and sharing work in the family, are among the few activities where you collaborate in your day-to-day routine. Be it in politics, business, arts, or science, 'collaboration' has become the norm, as, for most of the tasks involved in these fields, teamwork helps to achieve the goal easily. The participants of a team put their best into the task and address each other's limitations. Just like your *Tom* and *Jerry* did." I replied.

She laughed and said, "Right Di. I really enjoyed their partnership. Do you also like *Tom* and *Jerry*?"

I said "Yes. Of course. So much so that I have my own version of *Tom* and *Jerry* in my lab." I smiled.

She got confused and asked, "How come a science laboratory has a *Tom* and *Jerry*?"

I told her, "First, let me give you a brief background of what I do in my lab."

To which she replied, "Yes, yes, Di, tell."

I explained, “I basically work on the development of energy storage devices. An energy storage device stores electricity in chemical bonds that we can use later, for example, this battery in your TV remote. It consists of mainly three components, two electrodes, and an electrolyte. The chemical reactions happen at the electrodes while the electrolyte provides the passage for electrolyte ions to flow. The weight of all these components decides the quantity of energy that can be stored in a single cell or a battery. Heavy the components, heavier would be the battery and we don’t want our gadgets to be awfully heavy, right? Instead, we want them to be light in weight. This is possible if we use lightweight components or materials without compromising the working efficiency of a battery. What If I say the ‘air’ can be used as the lightest component of a battery? Isn’t it amazing?”

“Yes, it is if that is the case.” She replied with excitement.

I added, “Metal-air battery is one of these new types of batteries that use atmospheric air as one of the main component electrodes and hence, the weight of the battery reduces drastically without compromising with the energy storage capacity which is also termed as Energy density.”

“How many types of such batteries are there?” she asked.

“Well, to name a few, lithium-air, zinc-air, and iron-air are the most popular ones. As lithium is a highly reactive metal, it is difficult to handle the operation in an open atmosphere. The mobile phones and laptop batteries explosions are one of the consequences of using highly reactive and flammable materials used in Li-ion batteries. It will be amazing if we use environment-friendly, safer, and cheaper materials for batteries, right? This will make the overall use much safe and will also reduce the cost of the battery.

A zinc-air battery is one such amazing alternative that is cheaper and safer. Here, zinc metal acts as an anode and air as the cathode. When you discharge a battery, zinc metal oxidizes and releases electrons to the outer circuit which provides the energy. The oxidized zinc ions, then, converts to zinc oxide at the surface. While on the other side of the air electrode, the oxygen gas molecule (O_2), dissociates and combines with the hydrogen of a water molecule forming OH^- ions. This reaction keeps happening till both the electrodes or at least one of them reaches its limit to provide enough reactive species. During charging, when you apply external energy to the cell, reverse reactions happen at both of the electrodes. The zinc oxide, formed after discharge, converts back to metallic zinc while the OH^- ions formed convert back to oxygen gas. In simple words, at the air electrode, the O_2 is consumed during discharge while it is evolved during the charging process. Hence, the oxygen is always in circulation during the entire process." I explained (figure 1).

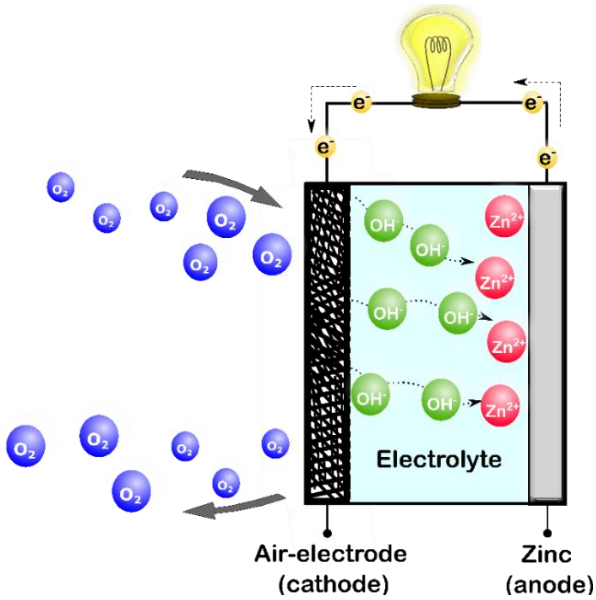

Figure 1. Schematic diagram of the working mechanism of a Zinc-air Battery

"Then, what is the issue? Why our batteries are not like these ones?" she asked pointing toward the battery in the TV remote.

"This is an important question, Erica. There are various issues related to these batteries. Zinc oxide, the byproduct of the discharge process, doesn't fully convert back to zinc on charging. Rather, it keeps accumulating at the electrode and eventually blocks the whole zinc surface. At this moment, the battery entirely fails as there are no exposed zinc sites left. So, what can be done? The electrolyte can play a major role in controlling the formation of zinc oxide. Conventionally, a highly concentrated potassium hydroxide (KOH) aqueous solution is considered the best electrolyte for alkaline zinc-air batteries. It has the best conductivity of ions (K^+ and OH^-) and the zinc oxide is highly soluble in it. So, it helps to control the passivation of the zinc electrode to an extent but not entirely.

Lithium (Li) is the smallest member of the family, just like *Jerry*, where potassium (K), *Tom*, belongs to. The hydroxide of lithium (LiOH), technically, can also be used in exchange for KOH. However, the problem with Li ions is their low conductivity. Lithium-ion (Li^+) is extremely small in size with a positive charge unlike the potassium-ion (K^+) which is relatively bigger. As a result, a Li-ion has a high tendency to attract and bind with a large number of water molecules in the electrolyte compared to the K ions. So, a Li-ion is associated with a more bulky complex than a K-ion in water. This hinders the overall conductivity of Li ions which eventually reduces the cell performance. Hence, LiOH alone is a poor choice of electrolyte.

However, Li ions come with different special powers. The positive charge is located at a very small Li-ion, so, is very intense compared to that in potassium ion. This high positive charge density at Li-ion helps to break the Zn-O bond which is a crucial step during the charging process. But what about the conductivity then?? Well, this is the moment when I thought that why can't my *Tom* and *Jerry* collaborate? The idea was to use a mixture of Li and K ions in the electrolyte. The K ions, as usual, help to improve the conductivity and provide better zinc oxide solubility. Li ions, on the other hand, help to mitigate the high energy requirement during the charging process and also delay the blocking of the zinc electrode. In this way, both the ions address each other's limitations and improve the battery performance with the strengths of both combined together. It was observed that the zinc-O_2 cell assembled with KOH alone, ran for 32 hours and the one assembled with LiOH, ran for 25 hours only. Interestingly, the cell functioned for 55 hours with the mixture of both the ions (Li and K) provided an equal concentration in each case. Also, the excess energy requirement during charging is also resolved using both the ions in the electrolyte.

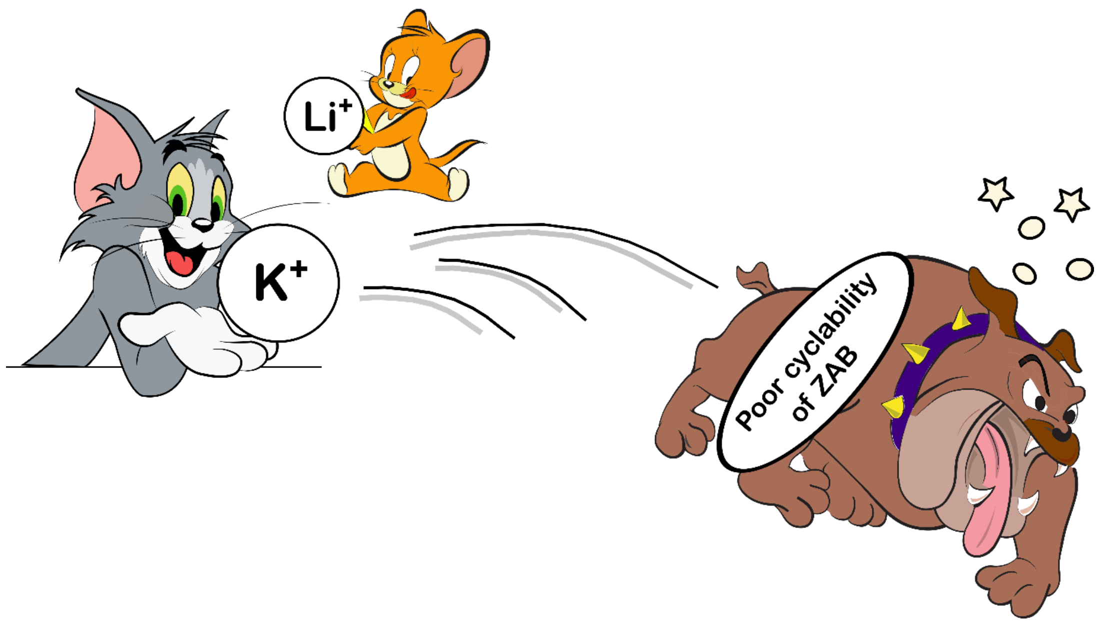

Figure 2. Tom and Jerry represent the K and Li ions, respectively, whereas the Spike represents the poor cyclability of zinc-air battery (ZAB). (*The individual cartoon images have been sourced from Pixabay and then modified into a single image*) https://pixabay.com/illustrations/tom-jerry-cartoon-art-mickey-mouse-5158824/.

Hence, collaboration can be an effective way to solve various issues that come across in our day-to-day life. We just need to think in the right direction". I replied (figure 2).

"This is very interesting, Di. Mummy always scolds me for watching cartoons. Now I will tell her about your work. Then she won't scold me." She laughed mischievously.

Declaration: *I hereby declare that the article is original and has not been previously published elsewhere.*