

In practice, the full battery capacity could never be realized, as there is a significant mass contribution from nonreactive components such as binders & conducting particles, separators & electrolytes and current collectors and substrates, as well as packaging. Additionally, the chemical reactions cannot be carried out to completion; either due to unavailability of reactive components, inaccessibility of active materials or poor reactivity at the electrode/electrolyte interface. The capacity is strongly dependent upon the load and can decrease rapidly at high drain rates as defined by the magnitude of current drawn, due to increased overpotential losses and ohmic losses which can exacerbate the problems with completion of the reaction. At higher drain rates denoting high operating currents, a battery will be discharged faster.

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1.2.4

Shelf - Life

A cell may be subject to self discharge in addition to discharge during operation. Self - discharge is caused by parasitic reactions, such as corrosion, that occur even when the cell is not in use. Thus, the chemical energy may slowly decrease with time. Further energy loss may arise as a result of discharge during which insulating products may form or the electrolyte may be consumed. Therefore, shelf – life is limited by factors related to both nonuse and normal usage.

1.2.5

Discharge

Discharge Curve/Cycle Life

The discharge curve is a plot of the voltage against the percentage of the capacity

discharged. A flat discharge curve is desirable as this means that the voltage remains constant as the battery is used up. Some discharge curves are illustrated

in Figure 1.9 , where the potential is plotted against time as the battery is discharged through a fixed load. In the ideal mode, the cell potential remains steady with time until the capacity is fully exhausted at the same steady rate and then it falls off to a low level. Some of the primary lithium cells display this type of nearly ideal flat discharge characteristics. In most other real batteries, the voltage may slope down gently with time as in primary alkaline cells or do so in two or more stages during discharge as in Leclanche cells.

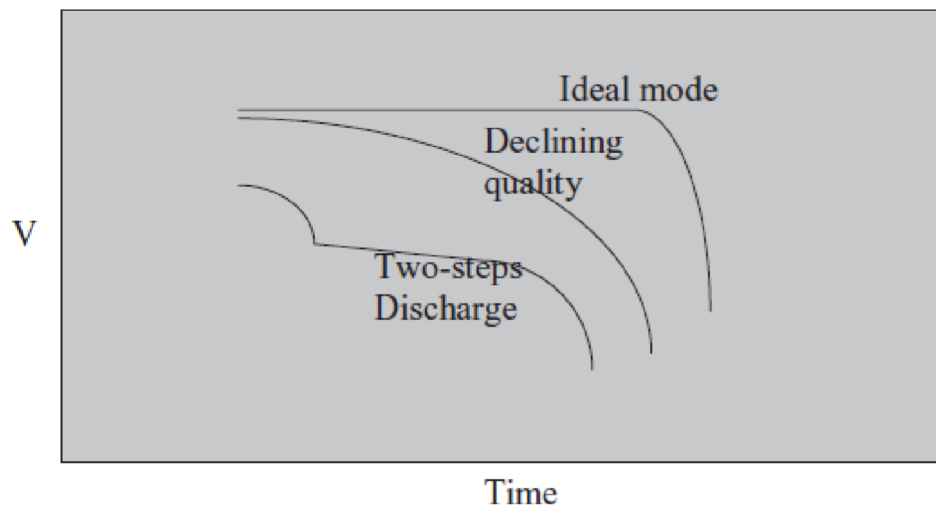


Figure 1.9 Change of voltage with time behavior in different cells [2].

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Specific Energy Density

The specific energy density, Wh/kg, is the energy that can be derived per unit mass of the cell (or sometimes per unit mass of the active electrode material). It is the product of the specific capacity and the operating voltage in one full discharge cycle. Both the current and the voltage may vary within a discharge cycle and, therefore, the specific energy, E , derived is calculated by integrating the product of the current and the voltage over time

$$(E = \int V \cdot I \, dt) \quad (1.35)$$

The discharge time is related to the maximum and minimum voltage thresholds and is dependent upon the state of availability of the active materials and/or the avoidance of an irreversible state for a rechargeable battery. An active component may be less available due to side reactions, such as

,i) zinc reacting with the electrolyte in alkaline or silver oxide – zinc batteries)

,ii) dendrite formation in rechargeable batteries)

iii) formation of passivation layers on the active components. Since batteries are used mainly as energy storage devices, the amount of energy (Wh) per unit mass (kg) is the most important property quoted for a battery. It must be noted that the quoted values only apply for the typical rates at which a particular type of battery is discharged. The specific energy density values vary between 45 and 300 Wh/kg for primary batteries and 30 and 240 Wh/kg for secondary (rechargeable) batteries

Power Density

The power density is the power that can be derived per unit mass of the cell

(W/kg). At higher drains, signifying higher currents relating to higher power)

densities, the specific energy tends to fall off rapidly, hence, decreasing the capacity. This trade - off between power and energy density is best expressed in a Ragone plot, an idealized version of which is given in Figure 1.10 . It is obvious that a certain battery has a range of values for specific energy and power, rather than a battery having a specific value of energy and power. In order to derive the maximum amount of energy, the current or the power drain must be at the lowest practical level. For a given cell chemistry, increasing the surface area of the electrodes can increase the cell's current at a given current density and, thus, deliver more power. The most efficient way to deliver a higher power density is to increase the effective surface area of an electrode while keeping the nominal area constant. It is important to consider any increase in parasitic reactions that may be enhanced due to the increase in the effective surface area. For example, in systems where corrosion is a concern, simply increasing the surface area may enhance the corrosion reactions while depleting the active material. Under these circumstances, the cell capacity will decrease along with the shelf – life

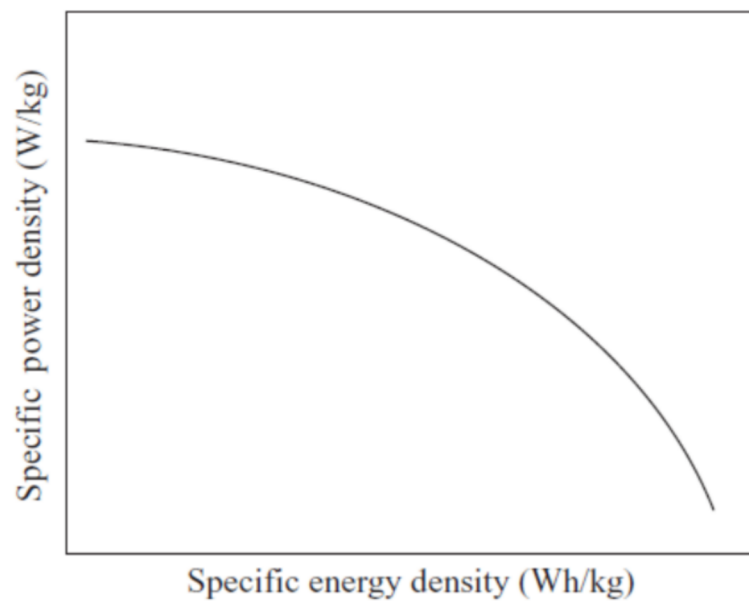


Figure 1.10 Ideal Ragone plot.