Batteries for portable use

A common question from people starting out with portable operating is what type of battery is best? As with many things there is no single answer and what is best depends on many different factors. This article aims to explore some of the options with a view to allowing people to make an informed decision. However, a word of warning, battery technology is evolving so this article will become out of date but it's good for now – mid 2015.

The "best" battery will depend on how you are intending to use it. The most appropriate battery to carry for mountain-top portable may well be different to one that you might take for use in a remote cottage with no electricity. Equally, the best battery to power a 100 Watt radio during a contest will be different to that used to power a low-power radio on a trip to a local park.

Most amateur radio equipment needs a DC voltage of 12-14 Volts for optimum performance. Some transceivers designed specifically for portable use may accept a wider range of voltages (especially lower voltages). An example is the popular FT-817 which is specified from 8-16 Volts. In such cases voltages can be kept low for optimum efficiency.

Battery capacity

Batteries are usually described as having a capacity of a certain number of milliampere-hours or amp-hours. These capacity rating are often measured under artificial conditions that may not reflect the capacity under normal usage. For example a 7Ah lead-acid gel cell will be unlikely to provide 7 Amps for an hour but it will probably provide 70mA for 100 hours.

You can calculate the approximate capacity of battery that you will need by looking at the current drawn by your equipment when receiving or transmitting. For example, let's say you want to use a FT-857 running 100 Watts for 4 hours on a special event station. The specification indicates that it will draw 1 Amp on receive and 22 Amps on transmit. Let's assume that you will spend 25% of the time (1 hour) on transmit and the remaining 3 hours on receive.

For the receiving (RX) time you will need a capacity of 3 x 1 Ah = 3 Ah.

The capacity for transmitting (TX) is slightly more complicated. The specification refers to the peak current drawn. This might be a good estimate for FM but for modes such as SSB or CW it will be an over estimate. For our example we can assume that SSB will be use and we will use a de-rating factor of 70% (note: this is just a guess). Our 22 Amps peak falls to 22 x (1 - 0.7) = 6.6 Amp average. 6.6 Amps for an hour is 6.6 x 1 = 6.6 Ah.

Now we can work out our nominal battery capacity by adding the RX and TX figures up:

3 + 6.6 = 9.6 Ah

Of course we made a few assumptions (guesses!) along the way so a reasonable battery capacity might be 15 Ah to give us a bit of a margin.

Battery technologies - overview

Batteries are often classified as being made up of either primary cells (non-rechargeable) or secondary cells (rechargeable). While this article will look mainly at secondary cell batteries, primary cells still have their place as I will discuss later.

Lead Acid [ref. 1]

Years ago the main secondary cell technology was the wet lead acid battery. These had to be regularly maintained and topped up with distilled water. They have largely been replaced by sealed gel and absorbed glass-mat lead acid batteries. Up to around 15 years ago, these were the battery of choice for many types of portable operating. They are rugged and reliable if looked after properly. Most portable equipment, with its nominal "12 Volt" (or 13.8 Volt) rating was designed with this sort of battery in mind. A fully charged lead acid battery of six cells will have a terminal Voltage of about 12.8 Volts. Lead acid batteries can be left to trickle charge which has made them a popular choice for many types of standby power. Beware though as batteries that have been on trickle charge for years can often appear on the amateur market as new or nearly-new but may have greatly reduced capacity.

Excessive charging of lead acid batteries can cause the build up of hydrogen gas with a risk of explosion.

Lithium Polymer [ref. 2]

Lithium Polymer (LiPO) batteries are a relatively new technology. They are probably the most common battery type in consumer electronics devices. More accurately called Lithium-Ion batteries they consist of a malleable metallic pouch containing a gel or liquid electrolyte. While generally safe and reliable, they can fail due to misuse. In such cases they can catch fire. Proper handling of these batteries will mitigate most risk however. They have a fully charged terminal voltage of 3.7 Volts which can make them tricky to use with some equipment as 3 cells give a nominal terminal voltage of 11.1 Volts while four give a voltage 14.8 Volts; either a bit too high or a bit too low for many radios[1].

LiPO batteries can easily be damaged by over-discharging them. Under no circumstances should the voltage of any cell be allowed to drop below about 3.1 Volts. Low-voltage alarms are readily available from various sources.

[1] Note on LiPO batteries: 4 cell LiPO batteries have a terminal voltage of nearly 15 Volts. This is too much for many radios. The terminal voltage can be reduced by putting two diodes in series with the battery. The diodes need to be suitable for the maximum current that will be drawn by the radio. As they will turn some of the energy in the battery into heat, they effectively reduce the available useful energy capacity of the battery. The diodes will get hot if used to drop the voltage when running high-duty cycle modes (such as FM) at 100 Watts. Once the terminal Voltage of the battery has reduced a little, the diodes can be removed.

Lithium Iron Phosphate [ref. 3]

Another new battery technology, LiFePO4 batteries are similar in many ways to LiPO batteries. They have some advantages over LiPO batteries though:

- a slightly lower cell voltage of 3.2 Volts makes them ideal for use with 12 volt radio systems.
- their chemistry makes them less prone to fire hazards
- they can withstand more charge/discharge cycles without loss of capacity.

Nickel Cadmium [ref. 4]

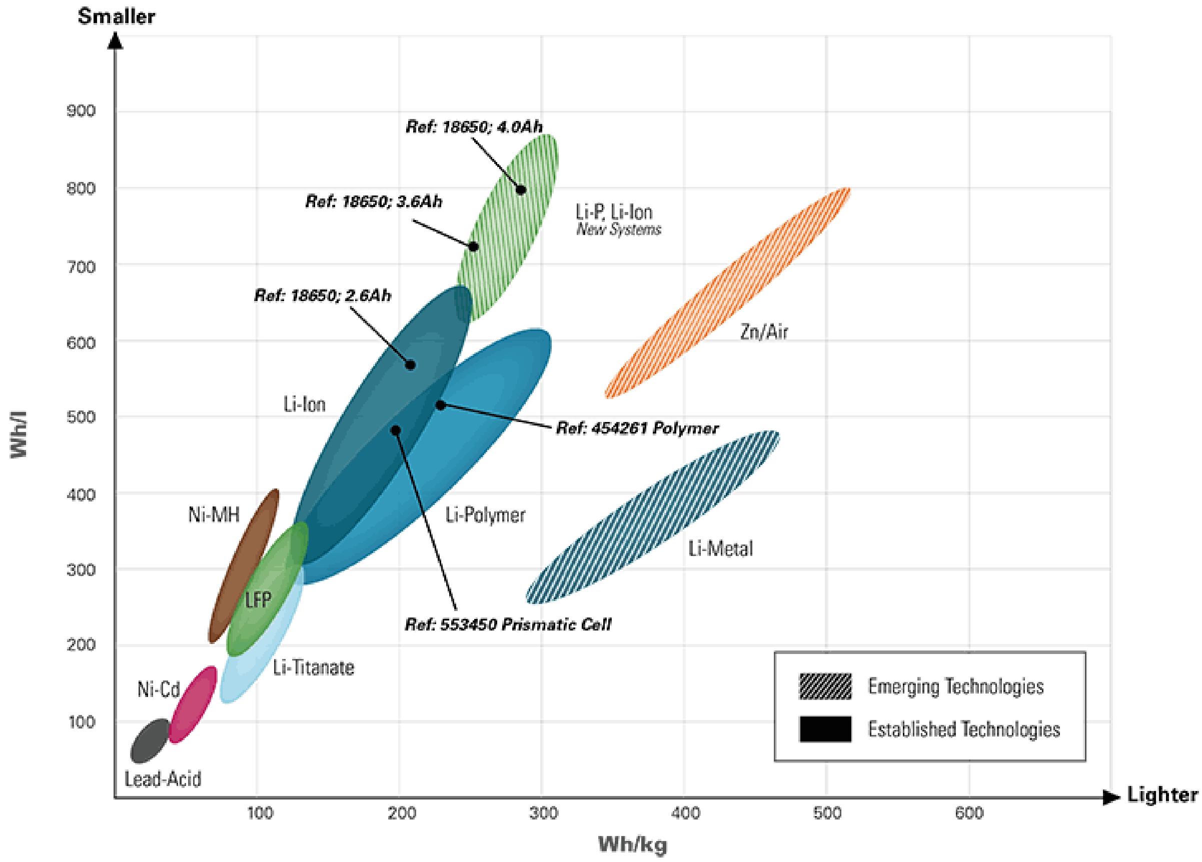
NiCad batteries are still found in some amateur radio equipment but they are getting less common. A combination of poor capacity, relatively high internal resistance and limited recharge cycles makes them not worth considering in most cases. Their nominal cell voltage is 1.2 Volts.

Nickel Metal Hydride [ref. 5]

With a much higher energy density than NiCad cells and simple charging arrangements, NiMH batteries are common. They tend to be most useful in lower current applications (a few amps) and make a good replacement for primary AA and AAA sized cells. Their nominal cell voltage is 1.2 Volts.

How to decide?

Having looked briefly at the main contenders, the next question is surely how to decide which one to use. We will look at some characteristics of the main types to compare them.



Source: ref. 6

The graph above compares a number of different battery chemistries. In essence the further towards the upper right-hand side of the graph the chemistry type is the smaller and lighter will be a battery for a given capacity. The graph makes it clear why Apple does not supply iPads with lead-acid batteries!

Some real figures (see table below) help to make the comparison clear. The gravimetric energy density (highlighted) shows the relative merits of the different cell chemistries. Note that LiFePO4 is not listed but is similar to LiPO.

Comparison of the characteristics of the six most commonly used rechargeable battery systems in terms of energy density, cycle life, exercise requirements and cost. The figures are based on average ratings of commercially available batteries at the time of publication.

	NiCd	NiMH	Lead Acid	Li-ion	Li-ion polymer	Reusable Alkaline
Gravimetric Energy Density(Wh/kg)	45-80	60-120	30-50	110-160	100-130	80 (initial)
Internal Resistance (includes peripheral circuits) in mΩ	100 to 200[1] 6V pack	200 to 300[1] 6V pack	<100[1] 12V pack	150 to 250[1] 7.2V pack	200 to 300[1] 7.2V pack	200 to 2000[1] 6V pack
Cycle Life (to 80% of initial capacity)	1500[2]	300 to 500[2,3]	200 to 300[2]	500 to 1000[3]	300 to 500	50[3] (to 50%)

	NiCd	NiMH	Lead Acid	Li-ion	Li-ion polymer	Reusable Alkaline
Fast Charge Time	1h typical	2-4h	8-16h	2-4h	2-4h	2-3h
Overcharge Tolerance	moderate	low	high	very low	low	moderate
Self-discharge / Month (room temperature)	20%[4]	30%[4]	5%	10%[5]	~10%[5]	0.3%
Cell Voltage(nominal)	1.25V[6]	1.25V[6]	2V	3.6V	3.6V	1.5V
Load Current						
- peak	20C	5C	5C[7]	>2C	>2C	0.5C
- best result	1C	0.5C or lower	0.2C	1C or lower	1C or lower	0.2C or lower
Operating Temperature(discharge only)	-40 to 60℃	-20 to 60℃	-20 to 60℃	-20 to 60℃	0 to 60℃	0 to 65℃
Maintenance Requirement	30 to 60 days	60 to 90 days	3 to 6 months[9]	not req.	not req.	not req.
Typical Battery Cost (US$, reference only)	$50 (7.2V)	$60 (7.2V)	$25 (6V)	$100 (7.2V)	$100 (7.2V)	$5 (9V)
Cost per Cycle(US$)[11]	$0.04	$0.12	$0.10	$0.14	$0.29	$0.10-0.50
Commercial use since	1950	1990	1970	1991	1999	1992

Figure 1: Characteristics of commonly used rechargeable batteries

1. Internal resistance of a battery pack varies with cell rating, type of protection circuit and number of cells. Protection circuit of Li-ion and Li-polymer adds about 100mΩ.
2. Cycle life is based on battery receiving regular maintenance. Failing to apply periodic full discharge cycles may reduce the cycle life by a factor of three.
3. Cycle life is based on the depth of discharge. Shallow discharges provide more cycles than deep discharges.
4. The discharge is highest immediately after charge, then tapers off. The NiCd capacity decreases 10% in the first 24h, then declines to about 10% every 30 days thereafter. Self-discharge increases with higher temperature.
5. Internal protection circuits typically consume 3% of the stored energy per month.
6. 1.25V is the open cell voltage. 1.2V is the commonly used value. There is no difference between the cells; it is simply a method of rating.
7. Capable of high current pulses.
8. Applies to discharge only; charge temperature range is more confined.
9. Maintenance may be in the form of 'equalizing' or 'topping' charge.
10. Cost of battery for commercially available portable devices.
11. Derived from the battery price divided by cycle life. Does not include the cost of electricity and chargers.

Source: ref. 7

The table above shows that while lead acid batteries are cheap, their low energy density makes them a poor choice for applications where the weight and size of a battery will be important. The lithium chemistries stand out for their high energy densities – but at a cost.

The tables below offer a simplified comparison of the various battery chemistries.

Characteristics comparison table

Battery Type	lead acid	LiPO	LiFePO	NiCad	NiMH
Energy density	✶	✶✶✶✶	✶✶✶✶	✶✶	✶✶✶
Cost (lowest)	✶✶✶✶	✶✶✶	✶✶	✶✶✶	✶✶
Recharge cycles	✶✶	✶✶✶	✶✶✶✶	✶✶✶✶	✶✶✶✶
Nearest to 12.8 Volts	✶✶✶✶	✶	✶✶✶✶	✶✶✶	✶✶✶✶
Perceived safety	✶✶✶✶	✶✶	✶✶✶	✶✶✶✶	✶✶✶✶

Application suitability

Battery Type	lead acid	LiPO	LiFePO	NiCad	NiMH
SOTA/backpacking	✶✶	✶✶✶✶	✶✶✶✶	✶✶	✶✶✶
Operating from RV/motorhome	✶✶✶✶	✶✶✶	✶✶✶✶	✶✶	✶
Special event station – off grid	✶✶✶✶	✶✶✶	✶✶✶	✶	✶

Charging batteries

With lead-acid batteries charging is very simple. A car-battery charger will do the job nicely. Lithium batteries are much more critical and do require the use of a proper charger. Don't be tempted to substitute chargers. If the battery that you are charging has much more capacity than, say a laptop battery it's a good idea to keep an eye on it while it charges. LiPO batteries will start to deform (blow up like a balloon) if they are over charged. This is non-reversible and a deformed battery is hazardous and must be treated accordingly.

Special flame-proof safety pouches are available for storing lithium batteries while they are being charged. The use of a balanced charger will reduce the possibility of one cell within a battery pack being overcharged. Some sources recommend charging higher capacity batteries outside although this may not be necessary (or practical) for many people.

Carrying batteries on aircraft [ref. 8]

Different airlines have different policies, and of course, policies can change. In respect of batteries airlines classify them according to their power capacity – not their milliampere hour rating. To calculate the power capacity of your battery, multiply the current by the nominal terminal Voltage. for example let's calculate the power capacity of a 7000 mAh 4 cell (4S) lipo battery.

7000 mA = 7 Amps. The nominal terminal voltage of a 4 cell LiPO is 14.8 Volts

Power capacity is P= V x I

14.8 x 7 = 104 Wh.

It is prudent to check what conditions your airline requires for the carriage of batteries. In any event making sure that the connections of the battery cannot short out under any circumstances is a necessary precaution. It can be helpful to print out your airline's requirements to take with you to the airport. Bear in mind that if the airport security staff really do not want you to take a battery through into the airport, it is often in your best interests to acquiesce (annoying though that may be). Don't be too worried though as radio amateurs travel with batteries of various sorts every day of the year and very few encounter any problems.

Storing batteries [ref. 9]

Portable batteries get used from time-to-time but mostly they spend their lives in storage. Different manufacturers offer advice on getting the best life out of their stored batteries. As a general rule, never store batteries without some charge in them. Always store batteries in a cool place (below 15 degrees C is good). Do not store batteries where they may be frozen.

LiPO batteries are best stored with a partial charge of between 40 and 50 % or 3.82 Volts per cell. Check the battery terminal voltage periodically to ensure that the battery is retaining some charge – all batteries will self-discharge over time.

While there is little clear information, it appears LiFePO4 batteries are also best stored with a partial charge of between 40 and 50 % or 3.25 Volts per cell. Check the battery terminal voltage periodically to ensure that the battery is retaining some charge – all batteries will self-discharge over time.

12 Volt Lead-acid batteries should be stored charged and recharged if the terminal voltage falls below 12.42 Volts.

Marking Batteries

It is a good idea to mark rechargeable batteries with their date of purchase and a unique identifier. this makes it easy to differentiate between them and is especially useful if a battery of cells starts to lose capacity.

Primary cells – non-rechargeable batteries

Non-rechargeable alkaline batteries remain a useful option for low power portable operating. AA size cells have a reasonable energy density and are available in most parts of the world. They have a great advantage in being supplied fully charged and ready-to-roll. So if you are travelling overseas, a battery case for your radio suitable for taking AA cells is a useful fallback. You don't need to take the batteries as you can buy them at your destination.

Battery connections [ref. 10]

Batteries come with a variety of connectors (or none). Many radio amateurs have standardised their systems to use Andersen Powerpole connectors. There is a standard way of using these connectors which will allow your batteries and equipment to work with other people's set-ups. If you want to change the connectors on a high capacity battery it must be done carefully – one lead at a time. Do not simply try to cut the existing connector off as in doing so you will short out the battery. It is sometimes safer to make up a special adapter lead with Powerpoles on one end and a suitable connector for the battery on the other end.

Never be tempted to connect a radio to a battery using reversible connections such as 4mm banana plugs of crocodile clips. Many radios have been damaged because of these methods.

Batteries can safely be connected in parallel to increase the current capability of a system. If doing this the batteries should be of the same chemistry, the same capacity and same voltage. Using Powerpole connectors with a simple distribution board makes this easy.

Disposing of batteries

If a battery has a reduced capacity or is damaged you will need to dispose of it. Batteries of any type must not be simple thrown away with general rubbish. Ideally they should be discharged, wrapped individually and returned to a recycling facility. Some internet sources suggest immersing spent lithium batteries in a bucket of salt water although this is not suggested by any of the more authoritative sources.

References

1. https://en.wikipedia.org/wiki/Lead%E2%80%93acid_battery
2. https://en.wikipedia.org/wiki/Lithium_polymer_battery
3. https://en.wikipedia.org/wiki/Lithium_iron_phosphate_battery
4. https://en.wikipedia.org/wiki/Nickel%E2%80%93cadmium_battery
5. https://en.wikipedia.org/wiki/Nickel%E2%80%93metal_hydride_battery
6. http://www.iccnexergy.com/battery-systems/battery-energy-density-comparison/
7. http://batteryuniversity.com/learn/article/whats_the_best_battery
8. http://www.iata.org/whatwedo/cargo/dgr/Documents/lithium-battery-guidance-document-2015-en.pdf
9. http://batteryuniversity.com/learn/article/how_to_store_batteries
10. http://www.arrl.org/files/file/Public%20Service/TrainingModules/Technical/Anderson%20powerpole.pdf

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