Calculating charge and discharge rate for each battery made

The charge and discharge rate is determined for each battery depending on the mass of active material in each battery. In this lab we are making 80:15:5 electrodes, e.g. 80% of the mass comes from cathode material on phage, 15% super P carbon, and 5% PTFE (teflon) binder. Of the 80%, only about 70% of that is actually active material, since the mass of phage is inert and only serves as a template on which to make the active material for this lab we will disregard this since we haven't measured thermogravimetric analysis on each electrode to determine what the amount of inactive material is (**note if you added silver, gold or C-nanotubes you should subtract an additional 5% from the active material [if this were new research, you would have to determine the exact amount of mass of active material using various analytical techniques]**). The first thing to know is the mass of the electrode which you will measure after preparing the electrode, as an example: we have a 2 mg electrode.

$$2\ mg\ X\ 0.8\ X\ 0.7 = 1.12\ mg\ active\ material$$

We will be charging the battery at a rate of 1C, this means that it will fully discharge in one hour from a fully charged state and it will fully charge in one hour from a fully discharged state. As an example we will use Co_3O_4; it has a capacity of 881 mAh/g. If we had a gram, and wanted to discharge it in one hour, we would put a negative current of 881 mA, with an electrode mass of 1.6 mg:

$$1.12\ mg\ X\ \frac{1\ g}{1000\ mg} X \frac{445.96\ mAh}{1\ g} X \frac{1}{1\ hr} = 0.499\ mA$$

Whenever an electrode is discharged, the instrument applies a negative current, when it is being charged, the instrument applies a positive current.

The meaning of C

For charging a sample in one hour, or discharging in one hour, we will apply a positive or negative current that is equivalent to the capacity of the material. It means that we will charge a battery to full capacity in one hour. Typically this doesn't work! A battery performs best if it is charged and discharged slowly (especially relevant for charging). If a battery is charged too quickly, then it will be hindered from reaching full capacity. The reason for this is that upon charging and discharging, there is reduction/oxidation going on both at the anode and cathode, this means there is literally a structural transition happening. If a battery is charged too quickly not all of the material will release Li^+ or will not undergo the proper structural transition.

In this lab we will be charging the batteries at 1C, so it should take one hour to charge each battery and it should take one hour to discharge each battery. What you will find is that the battery actually took less than one hour to charge, and less than one hour to discharge. We know the theoretical capacity, now you will have to determine the actual capacity. This is done by multiplying the charge rate (current in mA) by the corrected time (time of the actual step in hours) and dividing by the actual mass (grams). The data file from the Galvanostat will be in the form of a .csv (comma separated variable or excel file). Here are the step by step instructions for getting your data in a usable format using Excel a brief description of what is happening in red.

1. Open data (.CSV) file
2. Select column B and format column (click on the B highlights all of column B) right click/format cells and select **General** in the number tab. This changes the time data format so that it is in decimal form for number of days, it must be converted to hours.
3. In cell K5 type "time_hr" and in cell K6 type "=b6*24" and drag that down to make all of the K cells use that formula. This makes a new time wave that converts the time from days to hours.
4. Now make a new worksheet Alt/i/w this makes a new worksheet so that you can separate the charge and discharge curves in order to calculate the capacities.
5. On the new worksheet you will want to label cells a1-j1 as something specific for your experiment I would label them:

voltC	AmpC	timeC	corrtimeC	capC	voltD	AmpD	timeD	corrtimeD	capD

6. The C and D stands for charge and discharge you can do it in any order you want, technically the discharge step occurred first in the run. From the first worksheet copy the volt current and time cells for the charge cycle, go to the next worksheet and in the correct cells paste special (right click/paste special) and have it paste values (otherwise it will paste the formula for time_hr).
7. In the corrtimeC cells type "=c2-c$2". This makes a corrected time that always subtracts the initial time.
8. In the capC cells type "=((b2*1000)*d2)/mass of active material in grams. This will calculate the capacity of the charge step.
9. Repeat for the discharge step.

Now plot the voltage vs. capacity with capacity on the X axis. You can plot both the charge and discharge curves on the same graph using whatever graphing program you want.

This calculated capacity is the actual capacity of your battery at a charge rate of 1C. How does it compare to the theoretical capacity? How does it compare to the different additives (silver nanowires, gold nanowires, carbon nanotubes, gold particles...)?