Physics 145: DATA ANALYSIS II

What's the point? You will study radioactive decay as a context for exploring the concepts, tools, and techniques of data analysis, including statistical error estimates, error propagation, non-linear curve fitting, and fitting uncertainties.

Equipment: Geiger counter and sample holder, weak sealed radioactive Cesium 137 sources, stack of aluminum and lead absorber plates.

Additional Required Reading: Carefully read the last section of the Data Analysis Reference guide on error propagation.

Introduction: This is a continuation of the previous lab, though it will be graded separately. You will need the gamma-ray absorption data that you collected previously, and hopefully saved. The first part of the lab is theoretical in nature, and requires that you demonstrate the ability to propagate estimated errors from measured quantities into the estimated errors of calculated quantities. In the second part, you will estimate the errors in your own raw data (time interval and counts) and propagate them into an error estimate for the count rate. In the last part, you will fit a non-linear curve to your data in order to obtain the absorption half-length and its uncertainty.

PROCEDURE

A. Gaussian error propagation

1) Reread the section of your reference materials on the error propagation formula.
2) Define total time $T = T_1 + T_2$ as the calculated sum of two measured times, T_1 and T_2. Use Gaussian error propagation to compute σ_T in terms of T_1, σ_{T_1}, T_2 and σ_{T_2}.
3) Define velocity $V = D/T$ as the calculated ratio of measured distance D over measured time T. Use Gaussian error propagation to compute σ_V in terms of D, σ_D, T and σ_T.
4) Define velocity $V = D/(T_1 + T_2)$ as the calculated ratio of measured distance D over the sum of measured times T_1 and T_2. Use Gaussian error propagation to compute σ_V in terms of D, σ_D, T_1, σ_{T_1}, T_2, and σ_{T_2}.

B. Estimate raw data errors, and apply Gaussian error propgation.

1) Add two new columns ("sigmaT", "sigmaN") to your dataanalysis.xls spreadsheet containing estimates of the errors in your raw data. For the number of counts, use what you know about Poisson statistics -- the error in N is sqrt(N). Use common sense to estimate the errors in the thickness and in the counting interval.
2) Because the total count rate is computed from two raw-data variables, N and T, you will need to propagate the raw-data errors, σ_N and σ_T, into an estimated error for R, which we will call σ_R. Place this computation into yet another column of your spreadsheet. Estimating errors in quantities that you didn't measure directly is tricky. Consult your TA as needed. Print a copy of the whole spreadsheet (without plots) into your lab notebook.
3) In your own words, explain the difference between error estimates for raw data and propagated error estimates for calculated quantities.

C. Perform a non-linear least-squares fit with error propagation

1) Create a three-column dataset in Logger Pro. Name the columns "Thickness", "Rate" and "sigmaR" and provide the correct units for each. Copy and paste the data from the corresponding columns in your Excel worksheet. Figure out how to use the column options to display the data as open circles with error bars.
2) Fit a model of the form $R(t) = a\,e^{-\ln(2)t/c} + b$ to your data. If your model was entered correctly, your fit should converge easily. If the error bars are properly calculated, the fitted curve will typically stay within the error bars of most of the individual data points. (a) Place the associated plot and fitting results (must show both the fitting parameters and their uncertainties) in your lab notebook. (b) Explain what physical quantity each fitting parameter represents. The grader will be looking for the half-length and its uncertainty obtained from the fit. Make sure that these two quanities are prominently displayed and interpreted in your report. (c) What is the percent error in the half life? Does it seem reasonable?
3) In what sense is this half-life value an improvement over the half-length value obtained in the previous lab? It is important that you understand that without an uncertainty estimate, any experimentally-determined value is essentially meaningless. Your conclusions should convey this understanding. Note that while Excel has basic curve-fitting capabilities, it cannot utilize the error estimates of the individual data values or estimate the uncertainty in a fitting parameter -- more of a toy than a serious analytical tool.