

Exploring Radioactive Decay in Excel: An Interactive Visual Thinking Tool

[Scott A. Sinex](#)

Prince George's Community College

Abstract

An interactive Excel spreadsheet investigation of radioactive decay kinetics and associated measurement error is presented for use in general chemistry. Students are engaged in numerous higher-order thinking and science process skills as they work through the activity.

Keywords

Excel spreadsheet
discovery learning
radioactive decay kinetics
random and systematic error

Introduction

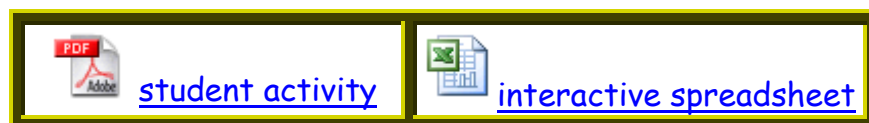
Radioactive decay is a general chemistry topic, usually covered late in the second semester, and a typical example used to illustrate exponential behavior in mathematics textbooks. Developing an interactive discovery-based activity for examining aspects of radioactive decay was accomplished using the graphical and numerical data display capabilities of Excel. The basics of developing interactive computational Excel spreadsheets including an [Excel tutorial](#) are discussed in Sinex (2004). Further Excel application support is also provided as links later in this article (Sinex, 2005a). Discovery learning is in line with national reform efforts (Siebert and McIntosh, 2001).

The tool consists of a series of questions that allow students to discover a number of aspects of radioactive decay while examining an interactive multi-layered Excel spreadsheet. There are five learning objectives to be addressed: (1) introduce the basics of radioactive decay kinetics including determining half-life; (2) examine the growth of the stable daughter nuclide produced from the parent nuclide; (3) examine the behavior of an unstable or radioactive daughter nuclide (behavior of consecutive reactions) including total radioactivity; (4) investigate the counting error of the parent activity, its effects and correction, and; (5) investigate background radiation and its effect and correction on the measurement. Numerous higher-order thinking questions are posed throughout the activity along with the

application of science process skills. The interactive dynamic nature of the technology employed enhances the discovery learning of both chemical and mathematical concepts in freshman chemistry for non-majors. Recently, Lim (2003) has outlined some advantages of using spreadsheets in chemistry, where in quantum chemistry the symbolic mathematics is purposely hidden due to its more complicated nature.

This activity is done having covered chemical kinetics earlier in the semester and with an introduction to radioactive decay via the [penny](#) or [M&M flipping activity](#) to uncover the exponential nature of decay and define half-life. The statistical nature of the process is discovered and the appropriate mathematical relationships can be derived. Students have used Excel as a data handling, graphing, and analyzing tool in their general chemistry experience and we provide support documentation (Sinex and Gage, 2001). Experience with Excel is not really necessary to use this spreadsheet; although students should be introduced to using an interactive spreadsheet. A large percentage of our students come into general chemistry with Excel experience; however, it generally does not involve plotting scientific data.

Here are the links to the files:



Interactive Excel Spreadsheet

The approach of questioning drives the student to discover concepts as they explore the interactive spreadsheet. Students are going to perform numerical experiments and address many "what if" scenarios; hence, they are engaging in science process while learning. The questions are keyed to the tabs (lower left of screen) on the Excel spreadsheet as shown below in Figure 1.

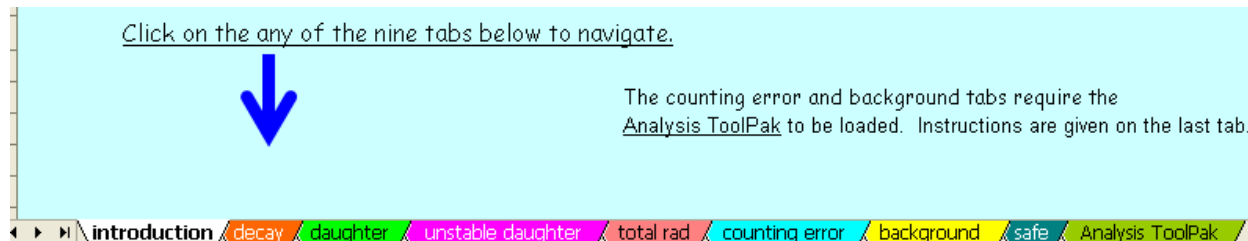


Figure 1 - Tabs of multilayered Excel Workbook

A number of adjustable variables, where values are typed in (shown as yellow cells) or adjusted with sliders (scroll bars as referred to in Excel on the [Forms toolbar](#)), are included on each worksheet. As they are adjusted, the graphs and data in columns respond and regressions are re-evaluated as well. [Comment cells](#), indicated by a small red triangle in the upper right corner of the cell, are included to offer explanation. A number of these features are illustrated on the screen shot (Figure 2) from the counting error tab worksheet given below.

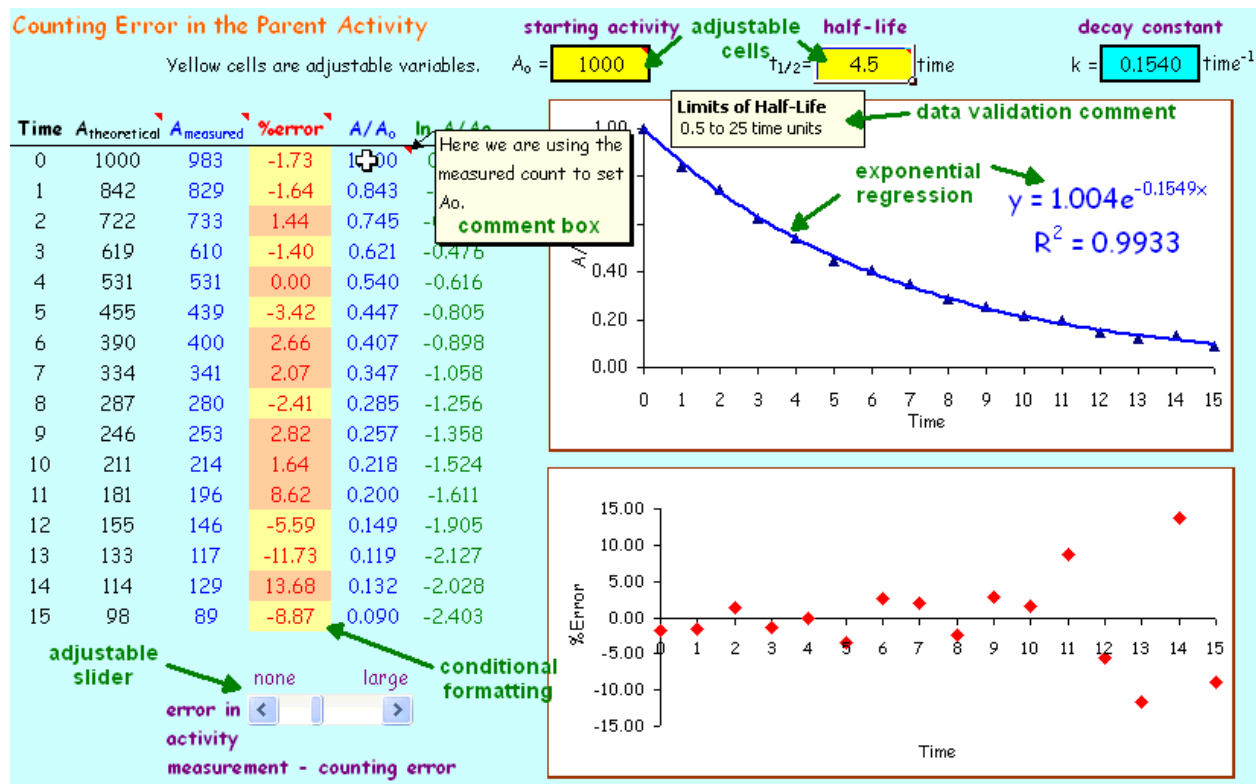


Figure 2 - Screen shot of Counting Error Tab

For novices to these interactive spreadsheets or simulations, it is generally recommended to adjust the variables in a systematic way (low to medium to high or vice versa) and to explore the full range of the variable. Excel's [data validation](#) feature is used in some cases to set specific limits on variables. [Conditional formatting](#) is used to enhance patterns (cell background color changes) in numerical data such as the random error and safe worksheets. Each worksheet has the [Protect Sheet...](#) selected under the Tools to prevent students from accidentally modifying formulas. This can be turned off by selecting Unprotect Sheet... to allow modification or generation of other plots. Password protection and the ability to hide formulas are also available options.

The unstable daughter situation allows the introduction of consecutive reactions ($A \rightarrow B \rightarrow C$). From the graphical display students can discover that the slower step (longer half-life) controls the overall rate. Use of the total radioactivity or the sum of the parent plus radioactive daughter makes this easy to follow as illustrated in Figure 3.

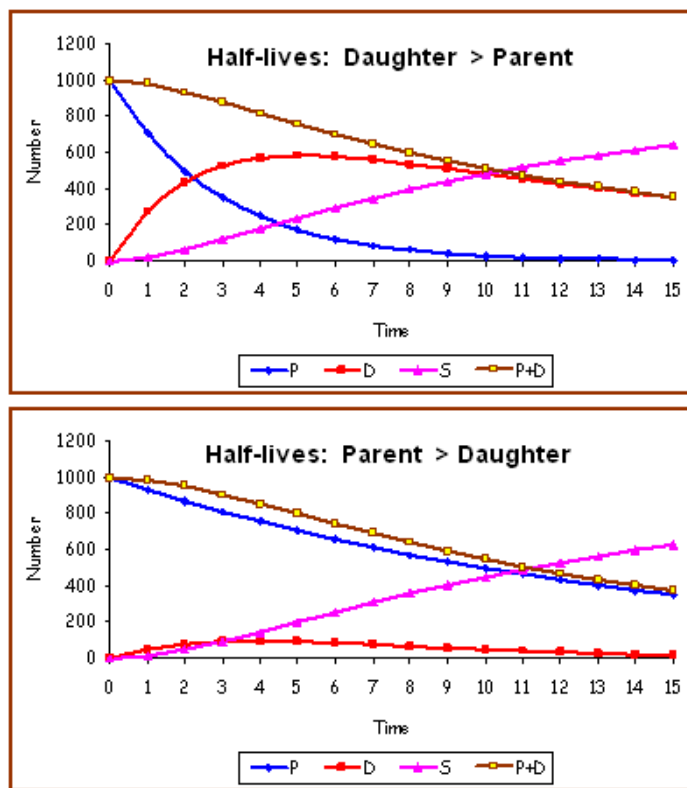


Figure 3 - Unstable Daughter Plots

The investigation of counting error and background uses adjustable random noise added to the data via the [RANDBETWEEN function](#) available in the [Analysis ToolPak](#) of Excel (loading instructions included on spreadsheet, see the last tab). The equation given below illustrates how adding error to the activity, A_{measured} , was accomplished:

$$A_{\text{measured}} = A_{\text{theoretical}} + x[\text{RANDBETWEEN}(-10,10)]$$

The RANDBETWEEN function is set to generate random numbers between -10 to 10 in this case. The "x" variable is then tied to an adjustable slider that can be adjusted from zero to some upper limit. $A_{\text{theoretical}}$ is simply based on exponential decay, $A_0 e^{-kt}$. Hence, the noise can be removed (set $x = 0$) or increased to examine

its consequence. If your students are not used to dealing with scatter and its effects in data analysis, see Sinex (2005b). The %Error graph in Figure 2 shows how relative error grows larger at later times. Students can discover that increasing initial activity, A_0 , can reduce the random counting error.

Student Feedback and Assessment

A survey of 23 students that used this activity in spring 2005 showed that 74% had no difficulty in usage and 65% thought it helped them understand the concepts, due to its interactive and/or visual nature. The graphs were indicated as the most common (43%) valuable aspect. The background and counting errors proved to be the most difficult (35%) as this was totally new material not discussed in class. One student commented "I learned through my own actions and got to manipulate my own data. I felt more like an active learner," while another suggested to "do without the Excel." When the students were asked to have the option of the interactive activity or lecture, 57% wanted their instructor to just lecture. However, research such as Oliver-Hoyo and others (2004) has shown otherwise.

Assessment is accomplished by having students analyze a set of data (which can be easily modified from semester-to-semester or even student-to-student) to evaluate the half-life of a radioactive isotope and examine experimental error. Figure 4 illustrates the scoring (out of 25 points) for the assessment, labeled as project, and a follow-up set of similar questions with different data on the final

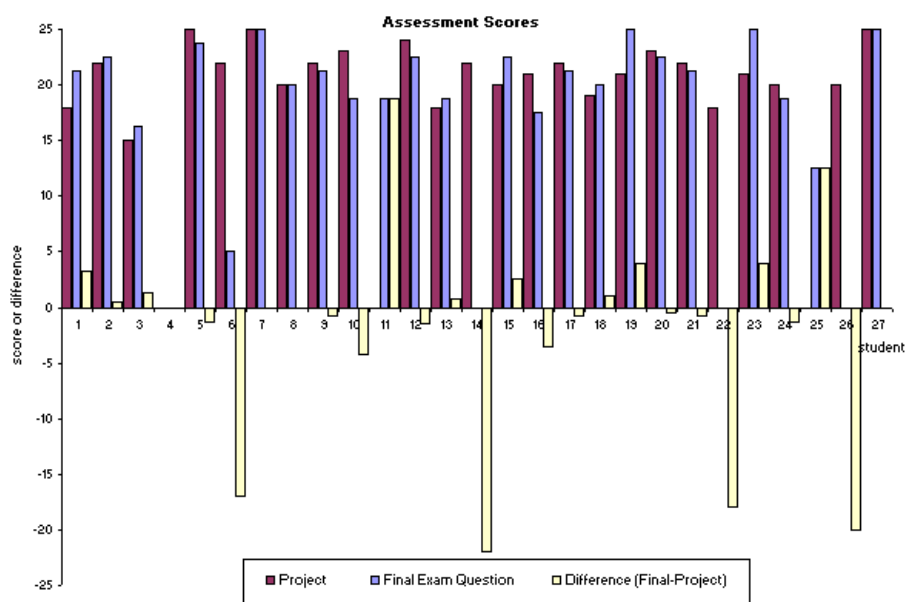


Figure 4 - Assessment Scores Comparison

exam. The project is an out-of-class assignment and may be worked on in groups with each student submitting results. Of the 24 students that completed both, 42% showed an increase or achieved maximum points, while 17% (four large negative differences) showed that learning should be stressed in cooperative learning activities.

Discussion

As students work through this learner-centered activity, discussion of chemical concepts is included at a number of points and the connections to the mathematics are emphasized as well. We deal with the daughter nuclide and the "conservation of nuclides" to remind students of the product in the decay reaction. The unstable daughter is an introduction to consecutive reactions and useful for discussion of decay series, such as ^{238}U , or radioactive generators in nuclear medicine. The discussion also distinguishes between random and systematic errors. Error is introduced earlier as part of the laboratory to this course; see Sinex (2005c) for further discussion. Counting error is random in nature. This random variation in the counts becomes a serious problem when the total counts are small numbers at later times. Larger percent errors can greatly influence the exponential regression results. Background radiation induces a systematic error, which has the largest effect at low activities and has a major influence on the resulting exponential regression if left uncorrected. They also research information on background radiation with proper citation of their sources. An instructor can generate a new set of data for assessment using the background tab worksheet and adjusting the half-life, starting activity, counting error, and background level. Data generated by the instructor can be copied from Excel and pasted into a Word document as a table for students to analyze.

The advantages of the interactive Excel spreadsheet in general chemistry are numerous and include the following:

- readily available off-the-shelf software;
- students have previous experience with Excel;
- disguises the mathematical computations to allow easier integration of the mathematical aspects with less anxiety;
- provides visual display of graphs with multiple variables plotted along with numerical data and symbolic relationships;
- emphasizes data modeling with analysis and interpolation;
- strengthens the connection between science and mathematics;

- interactivity allows comparison and exploration of variables (a poor man's simulation package) through numerical experimentation;
- easily modified, and;
- enhances discovery-based learning through "what if" scenarios.

Other topics explored by students in Excel include a [review of mathematical functions](#) for modeling, [investigating the gaseous state of matter](#), [velocity distribution for gases](#), [acid distribution diagrams](#) (monoprotic, diprotic, and triprotic acids), [chemical kinetics](#), [consecutive and competing reactions](#), and [Beer's Law](#) ([Beer's Law activity](#)).

Students are exposed to the topic of radioactive decay via a hands-on minds-on investigation using available technology that enhances the graphical and numerical nature of the kinetic behavior. The nature of radioactive decay and its measurement error are explored through a mathematical modeling approach, which is in itself good science process. With the proper mode of questioning, a little simulation can generate a wealth of reasoning by students. The dynamic nature of interactive spreadsheet brings the mathematics "alive" for students, as novice learners do not readily see this in mathematical equations. This approach works to strengthen the "rule of four," through which mathematics educators (AMATYC, 2005; NCTM, 2000) are trying to emphasize and relate graphical, numerical, symbolic, and verbal descriptions. In the end, the technology helps students develop an understanding of concepts involving radioactive decay (Sherman and Kurshan, 2004).

References

AMATYC (2005) [Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College](#). American Mathematical Association of Two Year Colleges (online).

<<http://http://amatyc.org/Crossroads/CROSSROADS>> Accessed 17 November 2005.

Lim, K. (2003) [Using Spreadsheets in Chemical Education to Avoid Symbolic Mathematics](#), *Using Computers in Chemical Education Newsletter*, Spring 2003. Accessed 17 November 2005.

NCTM (2000). *Principles and Standards for School Mathematics*. National Council of Teachers of Mathematics (NCTM), Reston, VA.

Oliver-Hoyo, M.T., Allen, D., Hunt, W.F., Hutson, J., and Pitts, A. (2004) Effects of an Active Learning Environment: Teaching Innovations at a Research I Institution, *Journal of Chemical Education* 81 (3): 441-448.

Sherman, T., and Kurshan, B. (2004). Teaching for Understanding. *Learning and Leading with Technology* 32 (4): 6-11.

Siebert, E.D. and McIntosh, W.J. (2001) *College Pathways to the Science Education Standards*, National Science Teachers Association (NSTA) Press, Arlington, VA.

Sinex, S.A. (2004) [An Interactive Higher-Order Thinking Tool](#), *TechLearning Educator's Outlook*. Accessed 17 November 2005.

Sinex, S.A. (2005a) [Developer's Guide to Excelets: Dynamic and Interactive Visualization with "Javaless" Applets or Interactive Excel Spreadsheets](#). Accessed 17 November 2005.

Sinex, S.A. (2005b) [Exploring the Goodness of Fit in Linear Models](#), *Journal of Online Mathematics and Its Applications* 5. Accessed 17 November 2005.

Sinex, S.A. (2005) [Investigating Types of Errors](#), *Spreadsheets in Education* 2 (1) 115-124. Accessed 17 November 2005.

Sinex, S.A. and Gage, B.A. (2001) [Using Excel for Handling, Graphing, and Analyzing Scientific Data: A Resource for Science and Mathematics Students](#). Accessed 17 November 2005.

Return to [Using Computers in Chemical Education Newsletter - Fall 2005](#)