WORKSHOP 2:
STATISTICAL UNCERTAINTY

Recall that radioactive decay is a *random* process, so in a given minute, identical amounts of a given sample could undergo slightly different amounts of decay. The average value of many trials, therefore, is a good way to report how many counts per minute one can expect to get from a typical sample. In last week's lab, the class data was pooled to arrive at *average values* for the number of counts per minute emitted by each radioisotope.

The average value by itself, however, does not provide any information about how much fluctuation there was from trial to trial. For example, suppose your class data looked like this for the counts per minute recorded from a particular sample:

Trial #	cpm
1	1034
2	1033
3	1035
4	1034

Now suppose another lab's data looked like this:

Trial #	cpm
1	1950
2	460
3	1000
4	726

In both sets of data, the average value is 1034 cpm. What is different between the two data sets? Which set of data reflects statistical consistency? Which demonstrates large statistical fluctuation? About which average value are you more "certain"?

The standard deviation is a measure of how widely spread out the data are around the average value. Your lab instructor will explain the mathematical expression for standard deviation (σ):

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} \left(x_i - \bar{x}\right)^2}{N - 1}}$$

The standard deviation is the root-mean-square deviation from the average (mean) value.

- For each individual value, x_i, subtract the average value, $\bar{x}$
- Square that result so that you are not working with negative numbers
- Find the average of the squared deviations (variance)
- Take the square root of this number

Note: It turns out that for small samples of random processes like radioactivity, it is more accurate to use $\sigma = \sqrt{\bar{x}}$. However, these two ways of calculating σ yield almost identical results for most cases. Therefore, we will simply be using stdev calculated by Excel for our radioactivity calculations.

PART A: Question for thought: Which set of data would you expect to have a higher standard deviation – the height of every person in the United States, or the height of every NBA player? Would the average values of these two data sets be the same?

PART B: A guessing game: What percent of marbles in the container are red?

Split up into four groups. Each group should place 10 red marbles and 40 non-red marbles in an opaque container. The goal is to see how accurate and precise different statistical experiments are at determining what percent of marbles in the container are red.

Depending on the group, you will use one of the four following methods to do this. **Before you do the experiment:** What is different between the various groups' experiments? Which group do you think will have the closest guess? Which group do you think will have the smallest standard deviation in their guess?

Group 1) Randomly take out exactly 5 marbles. Determine what percent of them are red, and record this percentage. Replace and mix these marbles. Repeat this 4 times. Calculate the average percentage from the 4 trials and find the standard deviation in the percentage.

Group 2) Randomly take out exactly 20 marbles. Determine what percent of them are red, and record this percentage. Replace and mix these marbles. Repeat this 4 times. Calculate the average percentage from the 4 trials and find the standard deviation in the percentage.

Group 3) Randomly take out exactly 5 marbles. Determine what percent of them are red, and record this percentage. Replace and mix these marbles. Repeat this 10 times. Calculate the average percentage from the 10 trials and find the standard deviation in the percentage.

Group 4) Randomly take out exactly 20 marbles. Determine what percent of them are red, and record this percentage. Replace and mix these marbles. Repeat this 10 times. Calculate the average percentage from the 10 trials and find the standard deviation in the percentage.

As a class, make a table and discuss the results in light of your hypotheses.

What do the results say about the effect of sample size and the number of times you repeat an experiment on how uncertain you are about the average value?

Based on this experiment, name two things you could do to the nuclear chemistry lab to improve your estimates of the average counts per minute (hint: one of these has to do with how long you wait to record your measurement)

PART C: Report uncertainty. When uncertainty is known (standard deviation is one way to determine uncertainty), throw out the standard significant figure rules and use these instead:

1) Report uncertainty (σ) rounded to one significant figure
2) Round your value to the same digit (i.e. 54.3 ± 0.2; both are rounded to the tenths place)

Questions for discussion:

1) Why is uncertainty rounded to one sig fig?
2) Why do we round the average value to the same precision (i.e. the same decimal place) as the uncertainty?