Basic Math Review
For Radon Professionals

Math for radon exams is nothing more than addition, subtraction, multiplication and division. The exam is about radon measurement, not a math exam so your focus should be on the purposes, protocols and other aspects in terms of study. To help anyone with math concerns we have prepared a brief study review for you here. Some math basics are at the end of this document if that is helpful.
Explaining all the factors associated with this will take class time but you can familiarize yourself with the issue and math by reading this. We will work examples in class too.

There are two simple formulas in the radon measurement class that you should understand.

The first one is called the Equilibrium Ratio Equation.

Radon undergoes radioactive decay and produces what are called radon decay products, radon progeny, or radon daughters (different names for the same substances). Radon is measured in units called picoCuries per liter (pCi/L) and radon decay products (RDPs) are measured in units called Working Levels (WL). **The fundamental relationship is that the complete decay of 100 picocuries per liter (pCi/L) of radon will produce 1 Working Level (WL) of radon decay products(RDP). Likewise, 50 pCi/L of radon will produce 0.5 WL of RDPs, and so on. Therefore, we can always find the maximum possible RDP concentration (in WL) by dividing the radon concentration by 100.** These decay products have characteristics that cause some of them to attach to physical objects such that the RDPs are no longer circulating in the air and are thus not measurable or breathable. This process is called “plating out.” Inside buildings, common sites for “plate out” of RDPs would include walls, floors, ceilings, furniture or even clothing of persons in the space. **The equilibrium ratio is simply the percentage of all the RDPs which have formed, which are still circulating in the air (i.e., those which have <u>not</u> “plated out.”)** If all of the RDPs which have formed were still airborne (no “plate out”), the equilibrium ratio would be 1 (or 100%). However, equilibrium ratios vary with time, ventilation, and location, and ratios of 0.3 to 0.7 (or 30% to 70%) are commonly observed. To calculate the equilibrium ratio, it is necessary to know both the radon concentration <u>and</u> the RDP concentration in the same place at the same time. Then, the ER equation is used with the proper values put in place for WL and pCi/L.

We could write the equilibrium ratio formula in words:

The equilibrium ratio equals the actual measured RDP concentration divided by the maximum possible RDP concentration at that radon concentration; or as a formula

$$ER = \frac{\text{measured WL}}{\text{maximum possible WL (which is measured pCi/L / 100)}}$$

or, more simply

$$ER = \frac{WL}{pCi/L / 100}$$

Some mathematicians think it is easier to multiply the WL by 100 than it is to divide the pCi/L by 100, but you still get the same answer either way. Using the re-arranged formula, we get:

The basic Equilibrium Ratio formula is $ER = \frac{WL \times 100}{pCi/L}$

This equation allows one to determine a specific equilibrium ratio if you have both measurements.

Let's try an example: The radon in a house is 10 pCi/L. Simultaneously, it is found that the radon decay products in the house are 0.02 WL.

$$ER = \frac{WL \text{ X } 100.}{pCi/L}$$

Plug in values:

$$ER = \frac{0.02 \text{ X } 100}{10} = 0.2 \text{ (or 20\%)}$$

Here is another example: Simultaneous measurements of radon and radon decay products indicate 4.0 pCi/L* and .02 WL* respectively (* = U.S. EPA's Threshold for Action). What is the equilibrium ratio?

$$ER = \frac{WL \text{ X } 100.}{pCi/L}$$

Plug in values:

$$ER = \frac{0.02 \text{ X } 100}{4} = 0.5 \text{ (or 50\%)}$$

This formula can also be used to convert from picoCuries/Liter to Working Levels, or vice versa.

- When you need to calculate the ER, use
  $$ER = \frac{WL \times 100}{pCi/L}$$
- When you need to calculate the WL, use
  $$WL = \frac{ER \times pCi/L}{100}$$
- When you need to calculate the radon, use
  $$pCi/L = \frac{WL \times 100}{ER}$$

Most of the time all that is available is a radon measurement and not decay product measurements. In this situation we have to assume an equilibrium ratio in order to convert from pCi/L to WL. A commonly assumed equilibrium ratio is 0.5 (or 50%). The US EPA has used this assumption in developing their radon program. Simply stated, the 50% equilibrium factor assumption means that for a given amount of radon, it is assumed that half of the decay products produced are plated out (non-hazardous) and the other half are available for inhalation (hazardous).

Let's try an example: The radon in a house is 10 pCi/L. Assuming a typical equilibrium ratio of .5 (50%) what is the WL concentration?
When you need to calculate the WL, use

$$WL = \frac{ER \times pCi/L}{100}$$

Plug in values:

$$WL = \frac{.5 \times 10}{100} = \frac{5}{100} = 0.05 \text{ WL}$$

Let's try an example: The WL concentration in a house is .06 pCi/L. Assuming a typical equilibrium ratio of .5 (50%) what is the radon concentration?
When you need to calculate the radon, use

$$pCi/L = \frac{WL \times 100}{ER}$$

Plug in values:

$$pCi/L = \frac{.06 \times 100}{.5} = \frac{6}{.5} = 12 \text{ pCi/L}$$

The second formula we need to know is called the Relative Percent Difference

One action a measurement professional can take to assure quality is to conduct duplicate measurements. This is the side by side use of two identical devices under the same conditions in order to compare the results and see how close together, or precise they are.
We would like these side by side measurements to be close together, ideally the same, but they usually do not produce exactly the same results.
The precision error, or the degree of disagreement between duplicates, can be composed of many factors. These include the error caused by the random nature of counting radioactive decay, slight differences between detector construction (for example, small differences in the amount of carbon in activated carbon detectors), and differences in handling of detectors (for example, differences in accuracy of the weighing process, and variations of analysis among detectors). Based on many measurements and experience, we can expect a typical distribution range among these duplicate measurements. The specific difference of one pair of results can be described using a statistic called the Relative Percent Difference. It can be calculated by using the difference between the two results and the average of the two results as follows:

Calculating the Relative Percent Difference (RPD) provides a measure of precision:
Here is the formula:

$$\text{RPD} = \frac{\text{(*Difference between Result 1 - Result 2)}}{\text{**Average of both results}} \times \text{***}100$$

*Difference = higher Result 1 – lower Result 2

$$\text{**Average} = \frac{\text{Result 1 + Result 2}}{2}$$

***We multiply the answer times 100 to turn the RPD into a whole number with a decimal point.

<u>Here is an example:</u> The results from two identical test devices exposed for the same day period are 4.6 pCi/L and 4.1 pCi/L. What is the Relative Percent Difference?

Difference = 4.6 - 4.1 = 0.5 pCi/L,

$$\text{Average} = \frac{(4.1 + 4.6)}{2} = \frac{8.7}{2} = 4.4 \text{ pCi/L (rounded up from 4.35)}$$

$$\text{RPD} = \frac{0.5 \text{ pCl/L}}{4.4 \text{ pCi/L}} = .113$$

If we want a whole number expression of this we can multiply .113 x 100 to get 11.3%
So the RPD for this pair of results is 11.3%

<u>Here is another example;</u> The results from two identical test devices exposed for the same day period are 16.6 pCi/L and 14.2 pCi/L. What is the Relative Percent Difference?

Difference = 16.6 - 14.2 = 2.4 pCi/L,

Average = $\frac{(16.6 + 14.2)}{2} = \frac{30.8}{2} = 15.4$ pCi/L

RPD = $\frac{2.4 \text{ pCl/L}}{15.4 \text{ pCi/L}} = .156$

If we want a whole number expression of this we can multiply .156 x 100 to get 15.6%
So the RPD for this pair of results is 15.6%

<u>Here is another example;</u> The results from two identical test devices exposed for the same day period are 1.6 pCi/L and 3.6 pCi/L. What is the Relative Percent Difference?

Difference = 3.6 – 1.6 = 2.0 pCi/L,

Average = $\frac{(3.6 + 1.6)}{2} = \frac{5.2}{2} = 2.6$ pCi/L

RPD = $\frac{2.0 \text{ pCl/L}}{2.6 \text{ pCi/L}} = .769$

If we want a whole number expression of this we can multiply .769 x 100 to get 76.9%
So the RPD for this pair of results is 76.9%

Basic Math Review

In many cases, you will be given two of three numbers and asked to calculate the unknown variable. For many of us, we had pimples and braces the last time someone asked us to calculate a value for X, so here's some middle school math to take us back to those days.

An equation is a combination of numbers and mathematical symbols separated into left and right sides. The two sides are separated by an equal sign, which, not surprisingly, means that both sides are equal!

$$\text{LEFT} = \text{RIGHT}$$

$$2 + 3 = 5$$

Normally we use "X" to symbolize the unknown value. Let's try to set up a few equations using "X" as our unknown.

1.) Two plus a number (unknown) equals five

$$X + 2 = 5$$

2.) Five times a number equals 25

$5 * X = 25$ [(*) means multiply by and (/) means divided by]

5X means X is multiplied by 5

3.) Two more than (addition) some number equals five

$$X + 2 = 5$$

4.) Five less than (subtraction) some number equals ten.

$$X - 5 = 10$$

5.) Two more than five times a number equals twelve

$$5X + 2 = 12$$

To find the value of the unknown variable X, we must now isolate it on one side of the equation. When isolating X, we must live by a rule: Whatever we do to one side of the equation must be done to the other side as well.

For example, let's solve the equation: $X + 2 = 5$

To isolate X, we must subtract 2 from the left side; and therefore, we must subtract 2 from the right side as well.

$$X + 2 - 2 = 5 - 2$$
$$X = 3$$

Now let's solve: $X - 5 = 10$

To isolate X, we must add 5 to the left side, and therefore, we must add 5 to the right side as well.

$$X - 5 + 5 = 10 + 5$$

$$X = 15$$

Now let's solve: $5X = 25$

In this case, to isolate X on the left side, we must divide by 5; and therefore, we must divide by 5 on the right side as well.

$$5X / 5 = 25 / 5$$

$$X = 5$$

We can verify this solution by replacing the unknown value in the equation with the number 5 (which was our answer).

$$5X = 25$$

$$X = 5$$

$$5 (5) = 25$$

Here's a slightly more complicated equation: $5X + 5 = 15$

First we will subtract 5 from both sides of the equation.

$$5X + 5 - 5 = 15 - 5$$

$$5X = 10$$

Next we will divide both sides by 5.

$$5X (/5) = 10 (/5)$$

$$X = 2$$

Let's try another one.

Solve: $12 = \frac{X + 2}{4}$

First we must multiply both sides by 4.

$$12 (*4) = \frac{X + 2}{4} (*4)$$

$$48 = X + 2$$

Next subtract 2 from both sides.

$$48 - 2 = X + 2 - 2$$

$$46 = X$$

$$X = 46$$