Chapter I

You don't have to look too deeply to see how chemistry affects your life.

Every breath you take, every meal you eat, everything has something to do with the interaction of chemicals! And I know for a fact that you know how chemicals affect your life every time you finish a large meal (or go too long without a meal!)

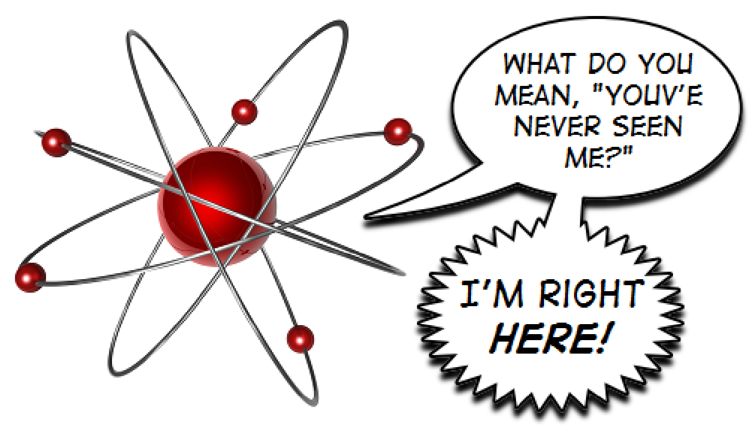
But you need to know something that many people do not understand – even though we will be spending a lot of time studying the tiniest pieces of matter within this book...

Nobody on the planet has ever actually seen an atom before!

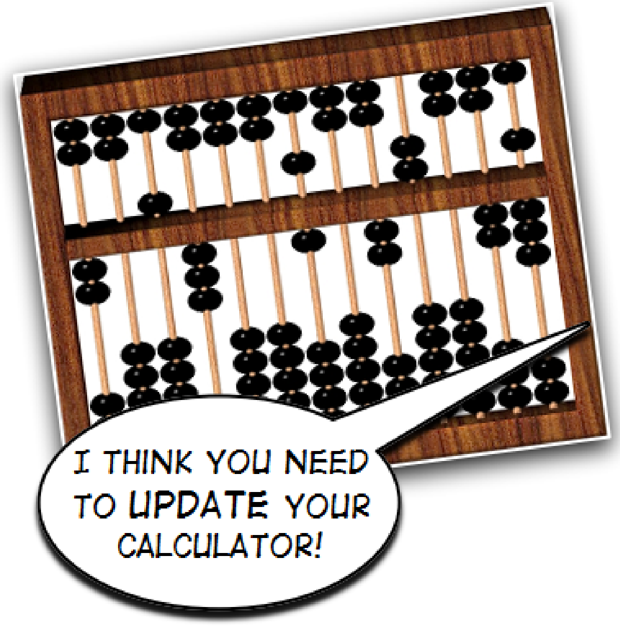
This does not mean that scientists have been making all of this stuff up over the years. Thousands of experiments have been run in order to create the best models for our understanding of chemistry. Remember - the study of chemistry is the study of very small particles! Much like the scientists who have created these chemistry models, you too will be successful in measuring very tiny pieces of matter to incredibly precise details! The nature of how we measure or quantify these particles is the topic of study this first week.

Since the study of chemistry has to do with measuring many different things about incredibly tiny pieces of matter, a new way of writing down massively large or small numbers had to be developed. Let's get real here, who really wants to write out that there are 3,011,500,000,000,000 molecules of sugar* in every cup?

* I'm really not joking here. This is pretty close to the actual number!



So a short cut was needed to make all of these large numbers a little easier to manage. This short cut is known as **scientific notation**. The rules of this method are very easy to follow as long as you can multiply or divide any number by 10.



Instead of writing out the number 100, you would write 10^2. The "2" that is hovering on top of the 10 represents the multiplication of the number 10 by itself. The number 1000 would be written as 10^3; 10,000 would be 10^4, and so on. The following chart can be used to follow how these exponents work:

100 = 10 x 10 = $\mathbf{10^2}$ = **one hundred**
1,000 = 10 x 10 x 10 = $\mathbf{10^3}$ = **one thousand**
10,000 = 10 x 10 x 10 x 10 = $\mathbf{10^4}$ = **ten thousand**
1,000,000 = 10 x 10 x 10 x 10 x 10 x 10 = $\mathbf{10^6}$ = **one million**
1,000,000,000 = 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 = $\mathbf{10^9}$ = **one billion**

This chart only tells us how to make our number larger. We can use this same procedure <u>in reverse</u> to determine how small an object can be as well. For example:

1/10 = $\mathbf{10^{-1}}$ = **one tenth**
1/100 = 1/10 x 10 = $\mathbf{10^{-2}}$ = **one hundredth**
1/1,000 = 1/10 x 10 x 10 = $\mathbf{10^{-3}}$ = **one thousandth**
1/10,000 = 1/10 x 10 x 10 x 10 = $\mathbf{10^{-4}}$ = **one ten thousandth**
1/1,000,000 = 1/10 x 10 x 10 = $\mathbf{10^{-6}}$ = **one millionth**
1/1,000,000,000 = 1/10 x 10 x 10 = $\mathbf{10^{-9}}$ = **one billionth**

So how do all of these short cuts help us? Well, instead of writing out the number 2,500 when you are doing your calculations, you can write it as
$2.5 \times 10 \times 10 \times 10 = 2{,}500$

Or, you can make it REALLY easy on yourself and use scientific notation to write it as 2.5×10^3.

In scientific notation, the first number you wrote down (the 2.5) is known as the **coefficient** and the 10^3 is called the **exponent**. There is one little rule with coefficients:

The coefficient must always be a number between 1.0 and 9.9

This may seem to be more work that it is really worth. And you may be right when we are using small numbers like 2,500. However, it is very possible that you will have to work with much larger numbers like the one you read about a little while ago - 3,011,500,000,000,000. This is where scientific notation comes in handy. Let's use this short cut once again:

Question #1:

$$3{,}011{,}500{,}000{,}000{,}000 = 3.0115 \times 10^{15}$$

How can you figure out how many times you have to divide this large number by 10 to get 3.0115×10^{15}?

After a few practice problems, you will probably become very good at solving this problem. Until then, you can use a little device to help you count the number of 10's you'll need for your answer.

Simply count the number of loops you draw from the beginning decimal to where it will create a coefficient between 1.0 and 9.9.

The same is true if you have a very small number and you need to put it into scientific notation. For example, take a look at the following example:

$$0.0112556 = 1.12556 \times 10^{-2}$$

In order to convert 0.0112556 into scientific notation, you need to multiply this number by 100 to get a coefficient between 1.0 and 9.9. This can be represented with the following pic:

Another way to determine how to convert a large or small number into scientific notation is to remember this simple rule:

If the coefficient needs to get smaller during a conversion, the exponent will need to get bigger, and vice versa!

For example, let's assume we need to convert the following number into scientific notation:

$$3{,}011{,}500{,}000{,}000{,}000$$

This number will need to get smaller, right? So if this number gets smaller, its exponent will need to get larger. Therefore...

$$3{,}011{,}500{,}000{,}000{,}000 = 3.0115 \times 10^{15}$$

If you have a small number like this one... 0.016115

...and you need to convert it into scientific notation, it will have to become LARGER in order to be a proper coefficient. Therefore...

$$0.016115 = 1.6115 \times 10^{-2}$$

Question #2:
So how do you know where you should place the final decimal?
That is easy! Your coefficient should always be between 1 and 9.999...

Question #3:
Why are we doing this again?
Okay, I will be honest with you. Crunching numbers and practicing scientific notation problems may not be the most exciting thing to do. However, this skill is very important not only to chemists, but to mathematicians, and engineers too!

Chemists need the best data possible when running experiments on such tiny pieces of matter. The ability to accurately AND precisely identify very large or small numbers is extremely important. You may be thinking that accuracy and precision is the same thing. But they're not!

Precision is how close a series of measurements are to each other.

Accuracy is how close a measured value is to the real value of the object.

You can see how these two terms work in the kitchen:

Imagine baking three batches of cookies. Everything is going fine until you get distracted with phone calls, TV, etc. and end up burning all three sheets of cookies.

This is an example of being precise but not accurate (they all look like charcoal, but that's not what you were hoping for!)

So you cook three more sheets of cookies and make certain to set a timer this time. The bell goes off and you pull out the cookies only to find that the sheet on the bottom of the oven burned all of the cookies but the sheets on top of the oven were still gooey. Your oven does not heat evenly!

This is an example of being NEITHER precise nor accurate.

You decide to give it one more try. The timer is set and you have the brilliant idea to rotate your cookie sheets within the oven as they are cooking. When the time is up, you pull out your cookies and find all of them to be cooked perfectly!

This is an example of being BOTH accurate and precise. All of the cookies have been cooked precisely the same as each other AND the accuracy of how long they were to be cooked was perfect!

This week, you need to practice how to place large and small numbers into scientific notation. I know there are a lot of problems to do. But practice makes perfect. Actually, **perfect** practice makes perfect. Good luck and get ready for next week because we are going to see how to take these huge numbers and apply a little mathematics to them. Stay tuned....

Scientific notation practice (Part I)

Convert the following to scientific notation:

1) 45,700 ______________________________
2) 0.009 ______________________________
3) 23 ______________________________
4) 0.9 ______________________________
5) 24,212,000 ______________________________
6) 0.000665 ______________________________
7) 21.9 ______________________________
8) 0.00332 ______________________________
9) 321 ______________________________
10) 0.119 ______________________________
11) 1492 ______________________________
12) 0.2713 ______________________________
13) 314159 ______________________________
14) 6022 ______________________________
15) 0.12011 ______________________________

Convert the following numbers in scientific notation to expanded form:

16) 3.825×10^{3} ______________________________

17) 6.3×10^{4} ______________________________

18) 2.3×10^{-2} ______________________________

19) 4.44×10^{-6} ______________________________

20) 7.121×10^{9} ______________________________

21) 1.2×10^{-1} ______________________________

22) 1.8×10^{2} ______________________________

23) 8.1×10^{-4} ______________________________

24) 6.7×10^{5} ______________________________

25) 3.4×10^{7} ______________________________

If you did okay with these first problems, let's see how you do with a few more...

Scientific notation practice (Part II)

Put these numbers into scientific notation.

26) 0.000034 ______________________________

27) 65000 ______________________________

28) 36000×10^{10} ______________________________

29) 549 ______________________________

30) 0.0000403×10^{12} ______________________________

31) 0.00000000082 ______________________________

32) 0.000000000205 ______________________________

33) 21.8×10^{-4} ______________________________

34) 0.00973×10^{8} ______________________________

35) 0.0000070 ______________________________

36) 3,621.471 ______________________________

37) 3,752.6 ______________________________

38) 456.83 ______________________________

39) 215 ______________________________

40) 0.0428 ______________________________

41) 0.00005673 ______________________________

42) 0.00000000900 ______________________________

43) 0.000039256 ______________________________

44) 0.000000010 ______________________________

45) 0.0037004 ______________________________

46) 0.002 ______________________________

47) 0.0080×10^{-3} ______________________________

48) 36000×10^{-10} ______________________________

49) 0.156 ______________________________

50) 0.045×10^{-3} ______________________________