Significant Figures Handout

There are three rules on determining how many significant figures are in a number:

1. Non-zero digits are always significant.
2. Any zeros between two significant digits are significant.
3. A final zero or trailing zeros in the decimal portion <u>ONLY</u> are significant.

Focus on these rules and learn them well. They will be used extensively throughout the remainder of this course. You would be well advised to do as many problems as needed to nail the concept of significant figures down tight and then do some more, just to be sure.

Please remember that, in science, all numbers are based upon measurements (except for a very few that are defined). Since all measurements are uncertain, we must only use those numbers that are meaningful. A common ruler cannot measure something to be 22.4072643 cm long. Not all of the digits have meaning (significance) and, therefore, should not be written down. In science, only the numbers that have significance (derived from measurement) are written.

If you're not convinced significant figures are important, you may want to read this <u>Significant Figure Fable</u> at the end of this handout.

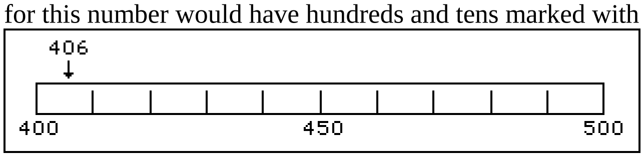
Rule 1: Non-zero digits are always significant.

Hopefully, this rule seems rather obvious. If you measure something and the device you use (ruler, thermometer, triple-beam balance, etc.) returns a number to you, then you have made a measurement decision and that ACT of measuring gives significance to that particular numeral (or digit) in the overall value you obtain.

Hence a number like 26.38 would have four significant figures and 7.94 would have three. The problem comes with numbers like 0.00980 or 28.09.

Rule 2: Any zeros between two significant digits are significant.

Suppose you had a number like 406. By the first rule, the 4 and the 6 are significant. However, to make a measurement decision on the 4 (in the hundred's place) and the 6 (in the unit's place), you HAD to have made a decision on the ten's place. The measurement scale for this number would have hundreds and tens marked with an estimation made in the unit's place. Like this:



Rule 3: A final zero or trailing zeros in the decimal portion <u>ONLY</u> are significant.

This rule causes the most difficulty with ChemTeam students. Here are two examples of this rule with the zeros this rule affects in boldface:

0.005**00**
0.0304**0**

Here are two more examples where the significant zeros are in boldface:

2.3**0** x 10^{-5}
4.5**00** x 10^{12}

What Zeros are Not Discussed Above

Zero Type #1: Space holding zeros on numbers less than one.

Here are the first two numbers from just above with the digits that are NOT significant in boldface:

0.**00**500
0.**0**3040

These zeros serve only as space holders. They are there to put the decimal point in its correct location. They DO NOT involve measurement decisions. Upon writing the numbers in scientific notation (5.00×10^{-3} and 3.040×10^{-2}), the non-significant zeros disappear.

Zero Type #2: the zero to the left of the decimal point on numbers less than one.

When a number like 0.00500 is written, the very first zero (to the left of the decimal point) is put there by convention. Its sole function is to communicate unambiguously that the decimal point is a deciaml point. If the number were written like this, .00500, there is a possibility that the decimal point might be mistaken for a period. Many students omit that zero. They should not.

Zero Type #3: trailing zeros in a whole number.

200 is considered to have only ONE significant figure while 25,000 has two.

This is based on the way each number is written. When whole number are written as above, the zeros, BY DEFINITION, did not require a measurement decision, thus they are not significant.

However, it is entirely possible that 200 really does have two or three significnt figures. If it does, it will be written in a different manner than 200.

Typically, scientific notation is used for this purpose. If 200 has two significant figures, then 2.0×10^2 is used. If it has three, then 2.00×10^2 is used. If it had four, then 200.0 is sufficient. See rule #2 above.

How will you know how many significant figures are in a number like 200? In a problem like below, divorced of all scientific context, you will be told. If you were doing an experiment, the context of the experiment and its measuring devices would tell you how many significant figures to report to people who read the report of your work.

Zero Type #4: leading zeros in a whole number.

00250 has two significant figures. 005.00×10^{-4} has three.

Exact Numbers

Exact numbers, such as the number of people in a room, have an infinite number of significant figures. Exact numbers are counting up how many of something are present, they are not measurements made with instruments. Another example of this are defined numbers, such as 1 foot = 12 inches. There are exactly 12 inches in one foot. Therefore, if a number is exact, it DOES NOT affect the accuracy of a calculation nor the precision of the expression. Some more examples:

There are 100 years in a century.

2 molecules of hydrogen react with 1 molecule of oxygen to form 2 molecules of water.

There are 500 sheets of paper in one ream.

Interestingly, the speed of light is now a defined quantity. By definition, the value is 299,792,458 meters per second.

Are Significant Figures Important? A Fable

A student once needed a cube of metal which had to have a mass of 83 grams. He knew the density of this metal was 8.67 g/mL, which told him the cube's volume. Believing significant figures were invented just to make life difficult for chemistry students and had no practical use in the real world, he calculated the volume of the cube as 9.573 mL. He thus determined that the edge of the cube had to be 2.097 cm. He took his plans to the machine shop where his friend had the same type of work done the previous year. The shop foreman said, "Yes, we can make this according to your specifications - but it will be expensive."

"That's OK," replied the student. "It's important." He knew his friend has paid $35, and he had been given $50 out of the school's research budget to get the job done.

He returned the next day, expecting the job to be done. "Sorry," said the foreman. "We're still working on it. Try next week." Finally the day came, and our friend got his cube. It looked very, very smooth and shiny and beautiful in its velvet case. Seeing it, our hero had a premonition of disaster and became a bit nervous. But he summoned up enough courage to ask for the bill. "$500, and cheap at the price. We had a terrific job getting it right -- had to make three before we got one right."

"But--but--my friend paid only $35 for the same thing!"

"No. He wanted a cube 2.1 cm on an edge, and your specifications called for 2.097. We had yours roughed out to 2.1 that very afternoon, but it was the precision grinding and lapping to get it down to 2.097 which took so long and cost the big money. The first one we made was 2.089 on one edge when we got finshed, so we had to scrap it. The second was closer, but still not what you specified. That's why the three tries."

"Oh!

Practice Problems

Identify the number of significant figures:

1) 3.0800

2) 0.00418

3) 7.09×10^{-5}

4) 91,600

5) 0.003005

6) 3.200×10^{9}

7) 250

8) 780,000,000

9) 0.0101

10) 0.00800

Answers

1) 3.0800 - five significant figures. All the rules are illustrated by this problem. Rule one - the 3 and the 8. Rule Two - the zero between the 3 and 8. Rule three - the two trailing zeros after the 8.

2) 0.00418 - three significant figures: the 4, the 1, and the 8. This is a typical type of problem where the student errs by giving five significant figures as the answer.

3) 7.09×10^{-5} - three significant figures. When a number is written in scientific notation, only significant figures are placed into the numerical portion. If this number were taken out of scientific notation, it would be 0.0000709.

4) 91,600 - three significant figures. The last two zeros are not considered to be significant (at least normally). Suppose you had information that showed the zero in the tens place to be significant. How would you show it to be different from the zero in the ones place, which is not significant? The answer is scientific notation. Here is how it would be written: 9.160×10^4. This CLEARLY indicates the presence of four significant figures.

5) 0.003005- four significant figures. No matter how many zeros there are between two significant figures, all the zeros are to be considered significant. A number like 70.000001 would have 8 significant figures.

6) 3.200×10^9 - four significant figures. Notice the use of scientific notation to indicate that there are two zeros which should be significant. If this number were to be written without scientific notation (3,200,000,000) the significance of those two zeros would be lost and you would - wrongly - say that there were only two significant figures.

7) 2

8) 2

9) 3

10) 3