Significant Figures

The number of significant figures refers to the number of digits reported for the value of a measured or calculated quantity. Significant figures indicate the precision of the value. Some students find that determining significant figures seems somewhat "distracting" from the important work of understanding chemistry, nothing could be further from the truth. Using the appropriate precision in your answers demonstrates that not only can you do a calculation properly but that you also understand the meaning and purpose of the answer.

Consider these two statements:

1) "Chemistry 1000 has 400 students".

2) "Chemistry 1000 has 442 students".

Both of these statements are true but demonstrate different precision and would be applicable for different situations. For example, the first statement has 1 significant figure and is meant to convey that Chemistry 1000 is a large class of between 350 and 450 students. This would be all the information necessary for comparisons with other class sizes. The second statement has three significant figures and suggests that there are exactly 442 students enrolled in the class. This level of precision would be important for ordering textbooks or determining class averages.

Determining Significant Figures

(a) **Magnitude:** The number of significant figures has nothing to do with the magnitude of the numbers. For example, in the numbers 0.2056, 2.056, 20.56, 205.6 and 2056, each has four significant figures.

(b) **Placeholders vs. measured values**:

1. Zeros that merely indicate the magnitude of the measurement are not significant. Thus the statement that a Faraday of electricity is 96,500 coulombs does not mean that there are five significant figures in this value. The last two zeros serve to indicate the magnitude of the term. Therefore this number has only three significant figures. The appearance of placeholder zeros often confuses people. This problem is usually avoided by using scientific notation. For example 96,500 coulombs can be expressed as 965×10^2 or 9.65×10^4. In this case we completely avoid any placeholder zeros and hopefully any confusion as well. If the last zero in a number is certain - for example, in 4650. (note the decimal after the 0) - this can also be indicated by the expression 4.650×10^3, in which there are four significant figures.

2. The zeros in the number 0.00342 are not significant since they merely denote the magnitude. If this is written 3.24×10^{-3} it becomes clear that there are only three significant figures.

3. Of course it is possible to measure something and arrive at a measured zero. For example, an object may be exactly 10 mm in length. In this case, if you want to convey that the zero is measured rather than a placeholder you may use scientific notation so that 10 mm becomes 1.0×10^{-1} mm. Alternatively, you may terminate the value with a decimal so that 10 mm where the zero represents a real measurement may be written as 10. mm. Additionally, any zeros purposely added where they are not needed as placeholders suggests that they are measured and thus significant figures. For example a mass of 3.50 g has three significant figures and suggests that you measured to the nearest 0.01 gram.

(c) **Multiplications and Division**: when multiplying or dividing measured quantities, give as many significant figures in the answer as there are in the measurement with the least number of significant figures.

(d) **Additions and Subtraction**: when adding of subtracting measured quantities, give the same number of decimal places in the answer as there are in the measurement with the least number of decimal places. Then count the number of significant figures in the answer.

(e) **Multiple Step Calculations**: For calculations involving multiple steps but which are completely multiplication or division, only limit the number of significant figures at the end of the calculation.

(f) **Mixed Operation Multiple Step Calculations**: For calculations involving multiple steps with both addition/subtraction and multiplication/division, follow the rules for the order of mathematical operations and determine the number of significant figures each time you switch between addition/subtraction and multiplication/division.

(g) **Logarithms (log) and natural logarithms (ln):** log and ln functions have two components, a mantissa (the numbers after the decimal) and a character (the numbers before the decimal). The character conveys the order of magnitude of a value and therefore is not considered to be a part of the significant figures of that value. Therefore only the number of figures after the decimal in a log or ln value should be counted as significant. So, when you take the antilog of 2.531 (that is raise 10 to the power 2.531) the answer must have only three significant figures as there are three digits after the decimal in 2.531. This is particularly important when we do calculations involving pH as pH is a logarithmic scale.

Exact Numbers

An exact number is a number that arises from counting something or a defined unit. They are considered to have infinites number of significant figures. For example, when counting eggs in a dozen there should be precisely 12 with no uncertainty. Therefore the answer 12 has an infinite number of significant figures. When using an exact number in a calculation, the number of significant figures in the answer is determined by the other numbers in the problem.