

Significant Figures – Chem 1A

Determining the number of significant figures in a measurement:

1. All nonzero digits are significant.
Example: 4.79 has three significant figures.
2. Zeros in the middle of a number are significant.
Example: 1.049 has four significant figures.
3. Leading zeros (at the very beginning of the number) are not significant.
0.032 has two significant figures. It may be written as 3.2×10^{-2} .
0.0000411 has three significant figures. (It is also 4.11×10^{-5} .)
4. Zeros at the end of a number are significant **if** the number contains a decimal point.
1.30 has three significant figures.
4.00 has three significant figures.
350. has three significant figures. (The decimal point at the end is the indication that the zero is significant.)
5. Zeros at the end of a number that does not contain a decimal point may or may not be significant (it is unclear). When in doubt, assume they are not significant.
The number 2500 could have been measured to the nearest ± 100 or to the nearest ± 10 or to the nearest ± 1 . Since it is not indicated, you are forced to assume the worst case: the greatest uncertainty.
2500 has two significant figures. (2.5×10^3)
140 has two significant figures. (1.4×10^2)

Determining the number of significant figures in a calculation:

A calculation can't be more precise than the least precise measurement used to do the calculation. (The least precise measurement limits the precision of the result.)

Multiplication and Division:

1. The number of significant figures in the result should be the same as that in the number with the least significant figures.
 $3.42 \div 1.3 = 2.630769\dots$ rounds to 2.6 (two significant figures).
 $43.1 \times 9.227 = 397.6837$ rounds to 398 (three sig figs).

Addition and Subtraction:

2. The number of decimal places in the result should be the same as in the number with the fewest decimal places.

$$\begin{array}{r} 4.381 \\ +131.4 \\ \hline 135.781 \\ \text{rounds to 135.8} \\ \text{(one decimal place)} \end{array}$$

$$\begin{array}{r} 31.5563 \\ - 1.410 \\ \hline 30.1463 \\ \text{rounds to 30.146} \\ \text{(three decimal places)} \end{array}$$

Notice that when adding and subtracting, if you were to round to the lowest number of significant figures, you would get the wrong answer.

If you are adding or subtracting numbers that don't contain decimal places, you must instead look at the uncertainty in each measurement. The answer should have the same uncertainty as in the number with the **greatest** uncertainty.

$$\begin{array}{r} 550 \quad (\pm 10) \\ 1000 \quad (\pm 1000) \\ + \quad 36 \quad (\pm 1) \\ \hline 1586 \quad (\pm 1000) \end{array}$$

the answer rounds to 2000, or 2×10^3 .
(One significant figure)

Exact Numbers:

Exact numbers are those obtained by counting or by definition. They have an infinite number of significant figures. They do not limit the number of significant figures used in a calculation.

Examples:

27 students in a room (27 was obtained by counting. It is therefore not a measurement, and does not have any uncertainty.)

1 m = 1000 mm (This is a definition within the metric system. It is not the result of a measurement.)

Note that numbers without decimal places are not necessarily exact numbers! If you encounter the number 27, do not assume that it is exact unless it came from counting or a definition. If it is a measurement, it has two significant figures. (It was measured to the nearest ± 1 .) If you are unsure, assume that it is not exact.

Rounding:

If the first number to be removed is:

- a) less than 5, then drop it (and all remaining numbers).
- b) 5 or above, then increase the last digit by 1.
- c) exactly 5, then the last number remaining should end in an even digit.

Examples:

| <u>Unrounded number</u> | <u>Rounded to 4 significant figures</u> |
|-------------------------|-----------------------------------------|
| 12.3845 | 12.38 |
| 12.2683 | 12.27 |
| 12.3651 | 12.37 |
| 12.3650 | 12.36 |
| 12.3750 | 12.38 |

When doing multistep calculations, don't round off the answer until the end of the calculation. Keep the number in your calculator. (If for some reason you cannot keep it in your calculator, keep 1 or 2 extra digits, and then round at the end.) If you round off prematurely, you may introduce rounding error.

Note: When you round off numbers, be very careful that you do not change the magnitude of a number! (This is a very common mistake for beginning students.)

For example: $38 \times 122 = 4636$

38 has two significant figures. 122 has three significant figures. When these measurements are multiplied, the result should have two significant figures. Therefore, the result should be rounded to 4600, or 4.6×10^3 .

Many students make the mistake of rounding it to 46! It's true that 46 has two significant figures, but 46 is a dramatically different number than 4600! Please do not make this mistake.

It helps if you think of these numbers as if they were money. Imagine someone owes you \$4636, but they don't have exact change and you don't either. You decide to round off the number. Would you be happy getting only \$46? Would you be happy getting only \$460?

Most people understand the difference between \$46 and \$4600. We use money regularly so it makes sense to us. Beginning chemistry students often don't really think about the size of the answers that they calculate for chemistry problems.

I'd like to encourage you to **think about whether your answer makes sense** any time you do a calculation. If you spend a little time thinking about the size of your answer and what it means, you can often catch mistakes! Doing this will help you get a better grade in this class.

Optional Background Information

Why does error propagate in this way? What are the reasons behind these significant figure rules that you are memorizing? Let's look at some examples.

Multiplication and Division

If you multiply 1.41×6.328 , the unrounded result is 8.92248. According to the rules of significant figures, you should round this result to three significant figures, so it should be rounded to 8.92. Why is this?

Explanation: 1.41 has an implied uncertainty of ± 0.01 . Let's change it by 0.01 to 1.42, and re-do the calculation. $1.42 \times 6.328 = 8.98576$, which should round to 8.99. This changes our result, but it changes it in the uncertain digit.

Now let's instead change the other number. 6.328 has an uncertainty of ± 0.001 . Let's change it to 6.329, and redo the original calculation. $1.41 \times 6.329 = 8.92389$, which should round to 8.92. It doesn't change the result at all within the number of significant figures we are supposed to use.

In the first case, the numbers begin to differ in the third digit. In the second case, they begin to differ in the fourth digit.

The uncertainty in the first number outweighs the uncertainty in the second one. Incrementing both numbers by one in their uncertain digit : $1.42 \times 6.329 = 8.98718$. This begins to differ from our original result of 8.92248 in the third digit. It should therefore be rounded to three digits, and it is understood that the last digit contains some uncertainty.

Addition and Subtraction

If you add $1.41 + 16.328$, the result is 17.738. It should be rounded to 17.74 according to the significant figure rules. Why is this?

Explanation: Incrementing the first number by one in the last significant digit gives $1.42 + 16.328 = 17.748$, which rounds to 17.75. It begins to differ from the original result in the second decimal place.

Incrementing the second number by one in the last significant digit:

$1.41 + 16.329 = 17.739$, which rounds to 17.74. It begins to differ from the original result of 17.738 in the third decimal place.

Incrementing both of the numbers by one in the last significant digit:

$1.42 + 16.329 = 17.749$, which rounds to 17.75. It begins to differ from the original result of 17.738 in the second decimal place.

The uncertainty of the number with the fewest decimal places is the largest. It has the most effect on the uncertainty of the result. Its uncertainty outweighs the other uncertainties.