# Significant Figures in Measurement and Calculations

A successful chemistry student habitually labels all numbers, because the unit is important. Also of great importance is the number itself. Any number used in a calculation should contain only figures that are considered reliable; otherwise, time and effort are wasted. Figures that are considered reliable are called *significant figures*. Chemical calculations involve numbers representing actual measurements. In a measurement, significant figures in a number consist of:

<p align="center">Figures (digits) definitely known + One estimated figure (digit)</p>

In class you will hear this expressed as "all of the digits known for certain plus one that is a guess."

Recording Measurements

When one reads an instrument (ruler, thermometer, graduate, buret, barometer, balance), he expresses the reading as one which is reasonably reliable. For example, in the accompanying illustration, note the
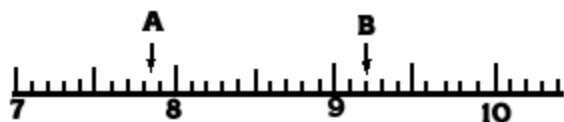
reading marked *A*. This reading is definitely beyond the 7 cm mark and also beyond the 0.8 cm mark. We read the 7.8 with certainty. We further *estimate* that the reading is five-tenths the distance from the 7.8 mark to the 7.9 mark. So, we estimate the length as 0.05 cm more than 7.8 cm. All of these have meaning and are therefore significant. We express the reading as 7.85 cm, accurate to three significant figures. All of these figures, *7.85*, can be used in calculations. In reading B we see that 9.2 cm is definitely known. We can include one estimated digit in our reading, and we estimate the next digit to be zero. Our reading is reported as 9.20 cm. It is accurate to three significant figures.

Rules for Zeros

If a zero represents a measured quantity, it is a significant figure. If it merely locates the decimal point, it is not a significant figure.

Zero Within a Number. In reading the measurement 9.04 cm, the zero represents a measured quantity, just as 9 and 4, and is, therefore, a significant number. <u>A zero between any of the other digits in a number is a significant figure</u>.

Zero at the Front of a Number. In reading the measurement 0.46 cm, the zero does not represent a measured quantity, but merely locates the decimal point. It is not a significant figure. Also, in the measurement 0.07 kg, the zeros are used merely to locate the decimal point and are, therefore, not significant. <u>Zeros at the first (left) of a number are not significant figures</u>.

Zero at the End of a Number. In reading the measurement 11.30 cm, the zero is an estimate and represents a measured quantity. It is therefore significant. Another way to look at this: The zero is not needed as a placeholder, and yet it was included by the person recording the measurement. It must have been recorded as a part of the measurement, making it significant. <u>Zeros to the right of the decimal point, and at the end of the number, are significant figures</u>.

Zeros at the End of a Whole Number. Zeros at the end of a whole number may or may not be significant. If a distance is reported as 1600 feet, one assumes two sig figs. Reporting measurements in scientific notation removes all doubt, since all numbers written in scientific notation are considered significant.

1 600 feet	1.6×10^3 feet	Two significant figures
1 600 feet	1.60×10^3 feet	Three significant figures
1 600 feet	1.600×10^3 feet	Four significant figures

Sample Problem #1: Underline the significant figures in the following numbers.

(a) 0.0420 cm   answer = 0.0<u>420</u> cm   (e) 2 403 ft.   answer = <u>2 403</u> ft.
(b) 5.320 in.   answer = <u>5.320</u> in.   (f) 80.5300 m   answer = <u>80.5300</u> m
(c) 10 lb.   answer = <u>10</u> lb.   (g) 200. g   answer = <u>200</u> g
(d) 0.020 ml   answer = 0.0<u>20</u> ml   (h) 2.4×10^3 kg   answer = <u>2.4</u> $\times 10^3$ kg

Rounding Off Numbers

In reporting a numerical answer, one needs to know how to "round off" a number to include the correct number of significant figures. Even in a series of operations leading to the final answer, one must "round off" numbers. The rules are well accepted rules:

1. If the figure to be dropped is less than 5, simply eliminate it.
2. If the figure to be dropped is greater than 5, eliminate it and raise the preceding figure by 1.
3. If the figure is 5, followed by nonzero digits, raise the preceding figure by 1
4. If the figure is 5, not followed by nonzero digit(s), and preceded by an odd digit, raise the preceding digit by one
5. If the figure is 5, not followed by nonzero digit(s), and the preceding significant digit is even, the preceding digit remains unchanged

Sample Problem #2: Round off the following to three significant figures.

(a) 3.478 m answer = 3.48 m (c) 5.333 g answer = 5.33 g
(b) 4.8055 cm answer = 4.81 cm (d) 7.999 in. answer = 8.00 in.

Multiplication

In multiplying two numbers, when you wish to determine the number of significant figures you should have in your answer (the product), you should inspect the numbers multiplied and find which has the least number of significant figures. This is the number of significant figures you should have in your answer (the product). Thus the answer to 0.024 x 1244 would be rounded off to contain two significant figures since the factor with the lesser number of significant figures (0.024) has only *two* such figures.

Sample Problem #3: Find the area of a rectangle 2.1 cm by 3.24 cm.

Solution: Area = 2.1 cm x 3.24 cm = 6.804 cm^2

We note that 2.1 contains two significant figures, while 3.24 contains three significant figures. Our product should contain no more than *two* significant figures. Therefore, our answer would be recorded as 6.8 cm^2

Sample Problem #4: Find the volume of a rectangular solid 10.2 cm x 8.24 cm x 1.8 cm

Solution: Volume = 10.2 cm x 8.24 cm x 1.8 cm = 151.2864 cm^3

We observe that the factor having the least number of significant figures is 1.8 cm. It contains two significant figures. Therefore, the answer is rounded off to 150 cm^3.

Division

In dividing two numbers, the answer (quotient) should contain the same number of significant figures as are contained in the number (divisor or dividend) with the least number of significant figures. Thus the answer to 528 ÷ 0.14 would be rounded off to contain *two* significant figures. The answer to 0.340 ÷ 3242 would be rounded off to contain three significant figures.

Sample Problem #5: Calculate 20.45 ÷ 2.4

Solution: 20.45 ÷ 2.4 = 8.52083

We note that the 2.4 has fewer significant figures than the 20.45. It has only *two* significant figures. Therefore, our answer should have no more than two significant figures and should be reported as 8.5.

Addition and Subtraction

In adding (or subtracting), set down the numbers, being sure to keep like decimal places under each other, and add (or subtract). Next, note which column contains the first estimated figure. This column determines the last decimal place of the answer. After the answer is obtained, it should be rounded off in this column. In other words, round to the least number of decimal places in you data.

Sample Problem #6: Add 42.56 g + 39.460 g + 4.1g

Solution:

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          42.56 g
          39.460 g
           4.1 g
Sum =     86.120 g
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Since the number 4.1 only extends to the first decimal place, the answer must be rounded to the first decimal place, yielding the answer 86.1 g.

Average Readings

The average of a number of successive readings will have the same number of decimal places that are in their sum.

Sample Problem #7: A graduated cylinder was weighed three times and the recorded weighings were 12.523 g, 12.497 g, 12.515 g. Calculate the average weight.

Solution:

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          12.523 g
          12.497 g
          12.515 g
          37.535 g
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In order to find the average, the sum is divided by 3 to give an answer of 12.51167. Since each number extends to three decimal places, the final answer is rounded to three decimal places, yielding a final answer of 12.512 g. Notice that the divisor of 3 does not effect the rounding of the final answer. This is because 3 is an exact number - known to an infinite number of decimal places.