Campus Academic Resource Program

Understanding Significant Figures

This handout will:

- Explain the term "significant figures" and explain its importance
- Explain how to determine what digits are considered significant
- Review rules for rounding numbers with the concept of significant figures in mind
- Analyze the application of significant figures in arithmetic calculations
- Describe why significant figures are important in measuring devices
- Provide various problems in order to assess comprehension of significant figures

Definition of the term significant figures

Significant figures are digits that are recorded from a measurement or calculation. Figures or numbers are considered significant because they are known with some degree of reliability. The importance and the idea behind **significant figures** is to make sure that the amount of **precision**[1] from a measurement or calculation is not being over-represented. This is done in order to make sure that the results are not more precise than the measurements observed or the calculations given.

Which digits are considered significant?

When reading what digits are significant, the following question is ultimately being asked:
"Which digits give information about how **precise** a measurement or a calculation is?"
In general, the answer to this question is that all digits are significant, except zeroes that are being used as placeholders. The examples in the table below will visualize these concepts.
Following are three rules that should be kept in mind whenever counting the amount of significant figures:

- Nonzero digits are significant.
- Zeroes between significant digits are significant.
- A final zero or trailing zeroes in the decimal portion are significant.

[1] Precision is the closeness of a measurement to other measurements of the same phenomenon in a series of experiments. This can also be referred to as reproducibility.

Examples are provided below in order to show how these rules apply:

Number	Amount of Significant Figures
365.34	• There are 5 significant figures because all nonzero digits are significant.
365 000	• There are only 3 significant figures because the zeroes at the end are trailing zeroes.
360.00	• There are a total of 5 significant figures because the decimal point makes the trailing zeroes significant.
3.650×10^{-5}	• There are 4 significant figures because the trailing zero is considered significant due to the decimal point.
365 034	• There are 6 significant figures because zeroes between significant digits are significant.
000 365	• There are 3 significant figures because leading zeroes are not significant.
0.0036500	• There are 5 significant figures because the three zeroes before the number 3 are leading zeroes while the zeroes after the number "5" are trailing zeroes

Rounding numbers and significant figures

Rounding numbers play a role especially when dealing with calculations such as addition, subtraction, multiplication, and division. In general, when rounding a number to a certain degree of significant figures, the rules are as follows:

- If the number 0, 1, 2, 3, or 4 follows the specified amount of significant figures, the digit to the left of the specified amount of significant figures is kept and not rounded up.
- If the number 5, 6, 7, 8, or 9 follows the specified amount of significant figures, the digit to the left of the specified amount of significant figures is replaced by rounding it up by one number.

Here are a few examples:

Round to two significant figures $37.5\ ℃$	$38\ ℃$
Round to three significant figures 5.487×10^{-5} calories	5.49×10^{-5} calories
Round to four significant figures 0.023583 mL	0.02358 mL
Round to five significant figures 45.3406 g	45.341 g

Significant Figures in Arithmetic Calculations

Rounding numbers and keeping track of the amount of significant figures are particularly important in calculations so that the amount of significant figures stays the same. It is very important to not claim more significant figures (or more certainty) in the answer than the original data. The general rule for rounding is that:

- The least certain measurement sets the limit on certainty (significant figures) for the entire calculation.
- The final answer is written with the determined amount of significant figure based on the least certain measurement.

Example:

Suppose a student wants to find the density[2] of a piece of metal. He measures the weight of the unknown metal using a balance and it read 43.2587 g. He also measures its volume using a graduated cylinder and he finds that it is 5.5 mL. After dividing the mass by the volume, he determined that the density is $7.825\overline{218}$ g/mL. According to the general rule, we have to use the least certain measurement, in this case the volume, in order to determine the amount of certainty we can have. Since the volume only has two significant figures, the density should only have two significant figures which results to 7.8 g/mL.

In addition to the general rule, there is also specific rules for the different kinds of arithmetic operations.

[2] Density is calculated by dividing the mass and the volume. $D = \text{mass/volume}$

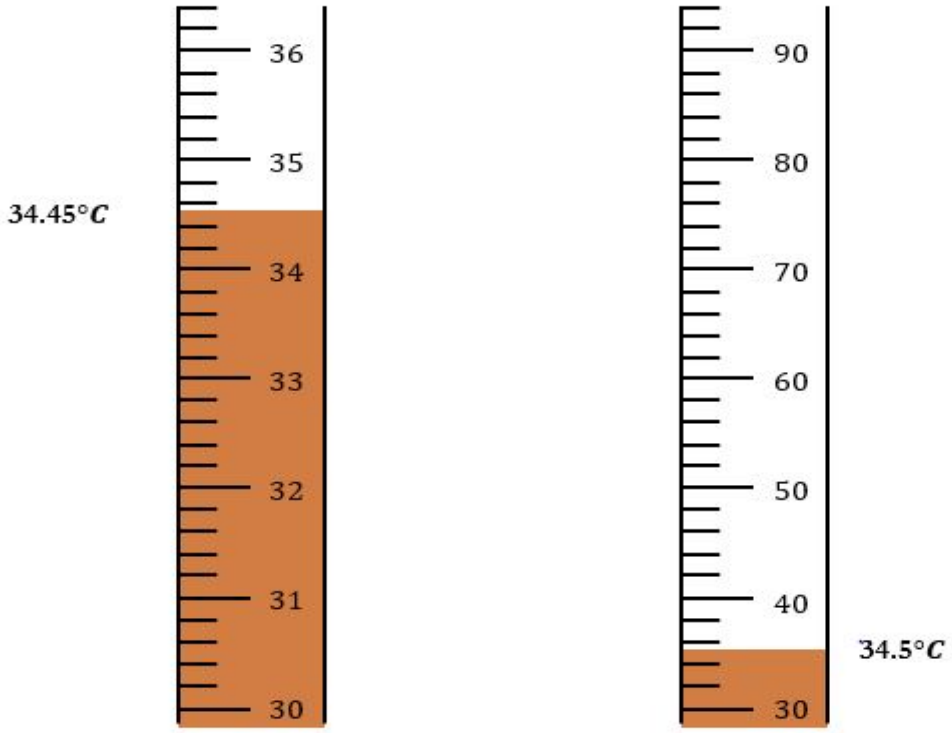
- For multiplication and division, the answer should contain just as much significant figures as in the value with the least amount of significant figures.
- For addition and subtraction, the answer has the same number of decimal places as there are in the measurement with the fewest decimal places.

Here are a few problems that show each of the arithmetic operations:

$9.2\ \text{cm} \times 10.8\ \text{cm} \times 0.5346\ \text{cm}$	$53\ \text{cm}^3$
$96.5\ \text{mL} + 23.56\ \text{mL}$	$120.1\ \text{mL}$
$3.5\ \text{moles} \div 0.636\ \text{liters}$	$5.5\ \text{Molarity}$[3]
$97.8\ °\text{F} - 73.4°\text{F}$	$24.4°\text{F}$

Importance of Significant Figures in Measuring Devices

In order to display the differences in the amount of significant figures in measuring devices, the following illustration of two thermometers will be analyzed:



[3] Molarity is a unit for concentration and is calculated using $M = \text{moles/liters}$

Both of the thermometers show the same temperature, but take note that each thermometer is on different scale. The one on the left shows a scale with every number while the one on the right shows a scale with every ten numbers. Additionally, the two thermometers show different amounts of significant figures. One more digit can be assumed with the given measurement.

The thermometer on the left is graduated to the tenths place and it reads 34.45℃. On the other hand, the thermometer on the right is graduated to the ones place and it reads 34.5℃.

Reading the correct amount of significant figures in a measurement is critical. This is because of the concept of *accuracy*[4]. When measuring calculations, it is important to read the correct significant figures because it allows for a measurement to come very close to what the actual measurement is. Students or scientists should try to yield the most accurate result.

[4] Accuracy refers to how close a measurement is to the actual value.

Exercises:

Determine the amount of significant figures in each of the examples provided.

a.) 87.34 ____ significant figures

b.) $000\ 756$ ____ significant figures

c.) $0.000\ 043\ 573$ ____ significant figures

d.) 8.505×10^{-5} ____ significant figures

Round the following numbers with the specified amount of significant figures.

e.) Round 0.29773 to two significant figures.

f.) Round 870.46 to three significant figures.

g.) Round 464.3436 to four significant figures.

h.) Round 36.207488 to five significant figures.

Solve the following problems.

i.) $42.272 + 237.8 =$

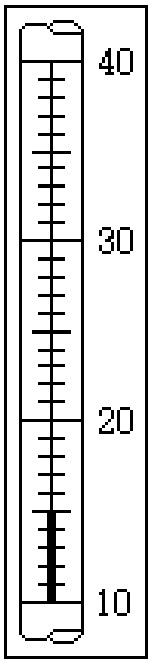
j.) $804.09 - 77.065 =$

k.) $3062 \times 0.67 =$

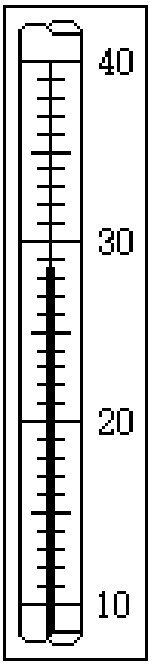
l.) $673 \div 78.9 =$

Answers: a) 4 b) 3 c) 5 d) 4 e) 0.30 f) 870. g) 464.3 h) 36.207 i) 280.1 j) 727.03 k) 2100 l) 8.53

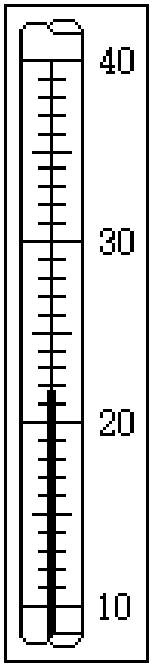
Determine the temperature with correct accuracy.



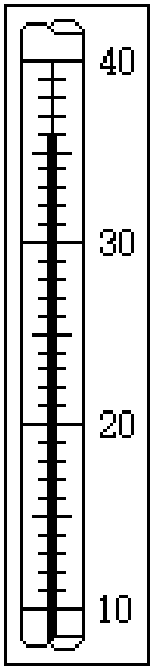
1) _____ °C



2) _____ °C



3) _____ °C



4) _____ °C

Answers: 1) 15°C 2) 28.5°C 3) 21.8°C 4) 30°C

Appendix

"ChemTeam: Measurement Underlies Sig Figs." *ChemTeam: Measurement Underlies Sig Figs*. Chem Team, n.d. Web. 20 Nov. 2015.

Tutorial on the Use of Significant Figures, Page 3. University of South Carolina, n.d. Web. 13 Nov. 2015.

Significant Figures. Khan Academy. N.p., 20 April 2011. Web. 28 October 2015.

Silberberg, Martin S., and Elizabeth Bent. Weberg. Chemistry: The Molecular Nature of Matter and Change. 5th ed. Boston: McGraw-Hill, 2009. Print.