Uncertainty in Measurements & Calculations

A Directed Learning Activity for Hartnell College Chemistry 1

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Student Learning Objective

This tutorial will help you to:
Determine how uncertainty in measurements (data) is reflected in results (calculations)
Getting Started

- This set of Power Point slides will lead you through a series of short lessons and quizzes on the topics covered by this Directed Learning Activity tutorial.

- Move through the slideshow at your own pace. There are several hyperlinks you can click on to take you to additional information, take quizzes, get answers to quizzes, and to skip to other lessons.

- You can end this slide show at any time by hitting the “ESC” key on your computer keyboard.
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What You Should Already Know

- The difference between a “number” and a “value”
- The difference between “accuracy” and “precision”
- The difference between “exact” and “measured” values

If you are a little unsure of these terms, click here for a quick review before continuing. If you need more help, please review your textbook.
Measurements & Uncertainty

In your everyday life, when you use a thermometer to take someone’s temperature or use a bathroom scale to take your weight in the morning, you are using a *measuring device or instrument*.

You do the same when making *quantitative* observations in a scientific laboratory - you are taking a measurement with a measuring device or instrument to determine *how much* of something there is in your sample. Such measured values are typically called “*data*.”
Let’s use this picture of a graduated cylinder as an example of using a scientific measuring device.

We can see from the picture that the larger markings are labeled every 10 milliliters (mL). In between the larger labeled markings are short marks every 1 mL.

So you know for certain that the volume of liquid in this graduated cylinder is somewhere between 34 and 36 mL – in fact, it is pretty close to 35 mL.
The uncertainty inherent in any measuring device will depend on the accuracy of the markings on that particular piece of equipment. But the general scientific procedure is to estimate one decimal place past the digits you know for certain. By using the same procedure each time, you know how accurately you know a measured value, and which digit is uncertain because it is estimated.

So in this example, you would be allowed to estimate one decimal place past what is actually known for certain – in this case, to the tenths of a mL. So, depending on how you see the level of the liquid, the volume might be reported as “35.0 mL”. But remember, there is an amount of uncertainty in that last digit (the zero), since you are estimating that digit.
Counting Significant Figures

**Significant figures** are numbers used to record scientific data and report the results of calculations. What is special about significant figures is that in a decimal number, only the last integer is presumed to be estimated. In other words, the number of significant figures allows you to communicate how certain the value is that is being reported.

There are several rules on how we count significant figures – these are presented with examples on the next few slides. These slides are followed by several problems that you can use to test your understanding of this topic.
Nonzero Integers

- A **nonzero integer** is any digit from 1 through 9
- Any nonzero integer always counts as a significant figure.

Example a: 1234.56789 has 9 significant figures

Example b: 23,456 has 5 significant figures

Example c: 6.022x10^{23} has 4 significant figures
Quiz on Nonzero Integers

Examine each of the following numbers or values and determine how many significant figures there are in each. Click here to check your answers.

- 17.3 mL
- 33.
- 54,677 kilograms
- 1.223

Click here to skip to next lesson
Answers: Quiz on Nonzero Integers

Significant Figures

- 17.3 mL: 3
- 33.: 2
- 54,677 kilograms: 5
- 1.223: 4

If you missed any of these, you can click here to review this lesson.

Click here for the next lesson
Zeros

There are three kinds of zeros with different rules for counting as significant figures:

- **Leading zeros** (zeros to the left of nonzero digits) never count as significant figures.
  
  Example: 0.0025 has 2 significant figures

- **Captive zeros** (zeros between nonzero digits) always count as significant figures.
  
  Example: 1.008 has 4 significant figures.
More on Zeros

- **Trailing zeros** (zeros to the right of nonzero digits) only count as significant figures if the number contains a decimal point.

  - Example: 100 has 1 significant figure
  - Example: 1.00 has 3 significant figures
  - Example: 100. has 3 significant figures

[Click for quiz on this lesson] [Skip to next lesson]
Quiz on Zeros

How many significant figures does each of the following have? Click here to check your answers.

- 103
- 1.035
- 0.0010
- $1.00 \times 10^2$
### Answers: Quiz on Zeros

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<td>103</td>
<td>3 Captive</td>
</tr>
<tr>
<td>1.035</td>
<td>4 Captive</td>
</tr>
<tr>
<td>0.0010</td>
<td>2 Leading &amp; trailing</td>
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<tr>
<td>1.00\times10^2</td>
<td>3 Trailing</td>
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If you missed any of these, you can click [here](#) to review this lesson.

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Exact Numbers

- **Exact numbers** are considered to have an infinite number of significant figures. There are two kinds of exact numbers:
  - **Counted numbers**
    - Example: 3 apples or 8 molecules are considered to have an infinite number of significant figures
  - **Defined numbers**
    - Example: 1 kilogram = 1000 grams have infinite numbers of significant figures

Go to quiz
Quiz on Significant Figures

Decide which of the following are measured numbers and which are exact. Click here to check your answers.

- 14.3 inches
- 4 balls
- 16 gallons
- 1 egg

Skip to next lesson
Answers: Significant Figures

- 14.3 inches  Measured
- 4 balls       Exact
- 16 gallons   Measured
- 1 egg        Exact

If you missed any of these, you can click [here](#) to review this lesson.

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Rounding Off Significant Figures

Different rules apply for multiplication & division, than for addition & subtraction

1. **After calculating a number using multiplication or division**, you must round off the answer to the correct number of significant figures.
   - a. Determine whether each value is exact, and ignore exact values in counting significant figures.
   - b. Determine the number of significant figures for each value that is measured.
   - c. Round off the answer (considering rule 3 below) to the same number of significant figures as the measured value with the fewest number of significant figures.

Example: $1.83 \text{ cm} \times \frac{1 \text{ in.}}{2.54 \text{ cm}} = 0.72047244 \text{ in.} = 0.720 \text{ in.}$
2. After calculating a number using addition or subtraction, you must round off the answer to the correct number of decimal places.

- a. Determine whether each value is exact, and ignore exact values.

- b. Determine the number of decimal places for each value that is not exact.

- c. Round off the answer (considering rule 3 below) to the same number of decimal places as the measured value with the fewest decimal places. Remember that this rule is different than the rule for multiplication and division.

Example: \[ 43.6 \text{ g} + 132.31 \text{ g} = 175.9 \text{ g} \]
Rounding (3)

3. The following two rules always apply when you are rounding off:

- a. When the first digit of those to be dropped is less than 5, leave the preceding digit unchanged.
  
  Example: the number 56.748 rounded off to the nearest 0.1 becomes 56.7.

- b. If the first digit of those to be dropped is 5 or greater, raise the preceding digit by 1.

  Example: the number 2.146 rounded off to the nearest 0.01 becomes 2.15.
Quiz 1 on Rounding

Solve these problems:

a. 12.01 cm + 17.3 cm + 0.11 cm = ?

b. 133 g – 2.2 g = ?

Click here to check your answers.
Answers: Rounding Quiz 1

a. \(12.01 \text{ cm} + 17.3 \text{ cm} + 0.11 \text{ cm} = 29.4 \text{ cm}\)
   Explanation: not 29.42 because the 2 is in the hundredths column of the sum is farther to the right than the 3 of 17.3 and so it cannot be significant. It is dropped because it is less than 5.

a. \(133 \text{ g} - 2.2 \text{ g} = 131 \text{ g}\)
   Explanation: not 130.8 for the same reason as above, but the number being dropped (8) is larger than 5, so the number is rounded up to 131.

If you missed any questions, click here to review this lesson.

Click for more quiz questions
Quiz 2 on Rounding

Solve these problems:

a. 12.7 \times 11.2 = ?

b. 108 \div 7.2 = ?

Check your answers here.

Click here for more quiz questions.
Answers: Rounding Quiz 2

a. \(12.7 \times 11.2 = 142\)
   Explanation: there are 3 significant figures in each of the numbers being multiplied, therefore the answer can only have 3 significant figures.

b. \(108 \div 7.2 = 15\)
   Explanation: the fewest number of significant figures in the two numbers being divided is 2, therefore the answer can only have 2 significant figures.

If you missed any questions, click here to review this lesson.
Quiz 3 on Rounding

a. \((1.0042 - 0.0034) \times 1.23 = ?\)

b. \((1.0042)(0.0034) \div 1.23 = ?\)

c. \((1.0042)(-0.0034)(1.23) = ?\)

Click [here](#) to check your answers.

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Answers: Rounding Quiz 3

a. \((1.0042 - 0.0034) \times 1.23 = 1.23\)
   
   Explanation: When 0.0034 is subtracted from 1.0042, a number with 5 significant figures results. When this number is multiplied by 1.23, which only has 3 significant figures, the answer must have 3 significant figures.

b. \((1.0042)(0.0034) \div 1.23 = 4.2 \times 10^{-3}\)

b. \((1.0042)(-0.0034)(1.23) = -2.8 \times 10^{-3}\)
   
   Explanation: In both these cases, the number with the least number of significant figures has 2, so the answer can only have 2 significant figures.
Congratulations!

You have successfully completed this Directed Learning Activity tutorial. We hope that this has helped you to better understand this topic.

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A Quick Review of Terms

- **Numbers** are the integers 1 through 9 and zero
- **Values** are an integer plus a unit of measure, such as “1 gram” or “1 liter” or “1 mile per hour”
- **Accuracy** means how close your value is to the actual value of a measurement
- **Precision** means how close your values are to each other, without considering what the “right” answer is
- **Exact values or numbers** are those that are counted or are definitions
- **Measured values** are ones that you determine by using a measuring device, such as a balance or meter stick

Return to "Terms You Should Know"
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