

# SIGNIFICANT FIGURES

## SUMMARY CHECKLISTS

### 1. Check-list for the percent deviation calculation

- The Chem21lab computer program tells you what values to use in the subtraction to get the value for the computer-graded calculation.
- For the sig fig question that follows: The number of sig figs in the percent deviation is **ALWAYS** the number of sig figs in the percent deviation.
- If the value is zero to the correct number of sig figs in the subtraction, then the percent deviation is zero.

### 2. Checklist for the standard deviation calculation

- Start with the standard deviation.
  - For a leading digit of “1” the standard deviation will have 2 sf.
  - Otherwise, the standard deviation has only 1 sf.
- Then look at the mean.
  - The **MAXIMUM** possible number of sig figs in an average is the number of sig figs in the data.
  - The **MAXIMUM** possible number of sig figs in a slope is determined from  $\Delta y/\Delta x$ .
  - The **MAXIMUM** possible number of sig figs in an intercept will have as many places after the decimal point as the y-data.
  - The sig figs may be limited further by the decimal position of the least significant digit as determined from the st dev.

## Significant figures

The rules for significant figures can be summarized as follows:

1. To determine the number of significant figures:
  - All nonzero digits are significant. (1.234 has 4 sig figs)
  - Zeroes between nonzero digits are significant. (1.02 has 3 sig figs)
  - Zeroes to the left of the first nonzero digits are not significant. (0.012 has 2 sig figs)
  - Zeroes to the right of a decimal point in a number are significant. (0.120 has 3 sig figs)
  - When a number ends in zeroes that are not to the right of a decimal point, the zeroes are not necessarily significant. (120 may have 2 or 3 sig figs)
    - To avoid ambiguity, use scientific notation. ( $1.2 \times 10^2$  or  $1.20 \times 10^2$ )
2. If a value ends exactly in a 5 and needs to be rounded, round up. So for example 122.5 would round to 123. However, 122.499 would round to 122. (**NOTE: This is a change from last semester due to the requirements of the Chem21labs assignments.**)
3. For addition or subtraction, round the result to the leftmost decimal place. It may help to put values in scientific notation to the same power of 10. For example:  $40.123 + 20.34 = 60.46$ . Or,  $4.25 \times 10^5 + 3.23 \times 10^3 = 4.25 \times 10^5 + 0.0323 \times 10^5 = 4.28 \times 10^5$ .
4. For multiplication or division, round the result to the smallest number of significant figures. For example:  $1.23 \times 2.0 = 2.5$ , not 2.46.

5. Some numbers are exact because they are known with complete certainty. Exact numbers never limit the number of significant figures. For example: there are exactly 60 seconds in 1 minute. Therefore, 325 seconds =  $325/60 = 5.42$  minutes.
6. For logarithms, retain in the mantissa (the number to the right of the decimal point in the logarithm) the same number of digits as there are in the number whose logarithm you are taking. Examples:  $\log(12.8)=1.107$ . The mantissa is .107 and has 3 digits because 12.8 has 3 sig figs)  
 $\log(10.5)=1.021$ . The mantissa is .021 and has 3 digits because 10.5 has 3 sig figs).  
 NOTE: It is the number of digits, not the number of sig figs in the mantissa
7. For exponents, the number of sig figs is the same as the number of digits in the mantissa. For example  $10^{1.23} = 17$  or  $1.7 \times 10^1$ . This has 2 sig figs because there are 2 digits in the mantissa (.23).
8. For multiple calculations, compute the number of significant digits to retain in the same order as the operations. When parentheses are used, do the operations inside the parentheses first. To avoid round off errors, keep extra digits until the final step.
9. When determining the mean and standard deviation based on repeated measurements
  - o The mean cannot be more accurate than the original measurements. For example, when averaging measurements with 3 digits after the decimal point the mean should have a maximum of 3 digits after the decimal point.
  - o The standard deviation provides a measurement of experimental uncertainty and should almost always be rounded to one significant figure. The only exception is when the uncertainty (if written in scientific notation) has a leading digit of 1 when a second digit should be kept. For example if the average of 4 masses is 1.2345g and the standard deviation is 0.323g, the uncertainty in the tenths place makes the following digits meaningless. The uncertainty should be written as  $\pm 0.3$ . The number of significant figures in the value of the mean is determined using the rules of addition and subtraction. It should be written as  $(1.2 \pm 0.3)$ g.
  - o The exception is when the uncertainty (if written in scientific notation) has a leading digit of 1 when a second digit should be kept. For example  $(1.234 \pm 0.172)$ g should be written as  $(1.23 \pm 0.17)$ g.
  - o In the event that the uncertainty is in a digit that is not significant, report it as such. For example you might report a value as  $123.5 \pm 0.02$  if the data limited you to 4 significant figures but the uncertainty was in a smaller digit.
10. Percent deviation (sometimes called percent error) is defined as  $100 \left( \frac{\text{actual} - \text{theoretical}}{\text{theoretical}} \right)$ . The number of significant digits is determined from the subtraction. For example, if a theoretical value is 4.567 and the actual value is 4.24, the numerator only has 2 significant digits so the percent yield can only have 2 significant digits.
11. Percent yield is defined as  $100 \left( \frac{\text{actual yield}}{\text{theoretical yield}} \right)$ . Examples of percent yield calculations are given in chapter 2 of your textbook.

You will often perform calculations using two or more values that both have associated uncertainties. The propagation of errors is a topic that is beyond the scope of this course. If you plan to continue in experimental science, you should take a course in statistics.

### **To determine the number of significant figures in the slope and intercept**

1. **SLOPE:** First, determine the **maximum** number of significant figures in the slope. Use the two data points that are furthest apart to calculate  $\frac{\Delta y}{\Delta x}$ . For example, in the following data set which describes the volume of a gas as a function of its temperature, the **maximum** number of significant figures for

the slope is 4 because  $\frac{\Delta y}{\Delta x} = \frac{26.54-5.36}{400.6-273.6} = \frac{21.18}{127.0} = 0.1669 \text{ L K}^{-1}$ . This method does **not** give you the value of the slope. It only gives you the maximum number of significant figures.

Table 1 – Example data set

Temperature (K)	Volume (L)
273.6	5.36
298.6	8.35
315.0	12.00
343.4	16.90
358.9	18.89
400.6	26.54

The actual value of the slope can be found by the LINEST function in Excel. Using LINEST on this data gives:

Table 2 – LINEST for example data set

	Slope	y-intercept
	0.16909	-41.3874
Standard deviation	0.005069	1.694302

Although the maximum number of significant figures for the slope is 4 for this data set, in this case it is further limited by the standard deviation. Since the standard deviation can only have one significant figure (unless the first digit is a 1), the standard deviation for the slope in this case is 0.005. Since this standard deviation is accurate to the thousandths place, the slope can only be accurate to the thousandths place at the most. Therefore, the slope for this data set is **0.169 ± 0.005 L K<sup>-1</sup>**.

If the standard deviation is very small such that it is in a digit that is not significant, you should not add additional digits to your slope. For example, if the standard deviation in the above example was two orders of magnitude smaller, you would report it as **0.1691 ± 0.00005 L K<sup>-1</sup>**. Note that here the slope has its maximum number of significant digits based on the data, even though the standard deviation is in the next place.

- Y-INTERCEPT:** To determine the maximum number of significant figures for the y-intercept, look at the y-values in the data set. The y-intercept cannot have a higher level of accuracy than the values in the data set. For example, in this data, the volumes are accurate to the hundredths place. This means that the y-intercept is also only accurate to the hundredths place at most, which is 41.39 L.

However, like the slope, the y-intercept can be further limited by its standard deviation. The y-intercept cannot be more accurate than its standard deviation. Thus, the standard deviation is 1.7. This number is accurate to the tenths place, which means that the y-intercept can only be accurate to the tenths place at the most. The correct y-intercept is therefore **-41.4 ± 1.7 L**.