PRECISION AND ACCURACY

Precision & deviation are measures of the closeness of the experimental values to each other, & is an indication of systematic error. It is possible to get wrong answers that are very close together when the cause of the problem is consistently repeated.

Accuracy & error are measures of the closeness of the experimental value to the best known value, or the assumed true value. The best-known value may change as better techniques are used. Accuracy is an indication of random error.

Precision

Absolute Deviation, |d|: is the absolute difference between either two values, A and B, or a value and an average value, X: |d| = |A − B| or |X − A|
Can |d| be negative? What are the units of |d|?

Relative Deviation, rd: is |d| divided by a value, often the average value.
    Percent Relative Deviation, % rd:

$$rd = \frac{|d|}{A} \quad or \quad rd = \frac{|d|}{B} \quad or \quad rd = \frac{|d|}{\overline{X}}$$

Relative Deviation in Parts per

$$ppt\ rd = \left(\frac{|d|}{A}\right) \times 10^3 \quad or \quad ppt\ rd = \left(\frac{|d|}{B}\right) \times 10^3 \quad or \quad ppt\ rd = \left(\frac{|d|}{\overline{X}}\right) \times 10^3$$

Thousand, ppt rd:

Can % rd be negative? What are the units of % rd?

Percent Relative Average Deviation from the Mean, % rad: Although the length of this term is long and can be overwhelming, if you take it a word at a time, you'll see you already know how to do it. You will calculate the deviation of each measurement from the mean (x-|d|), average them, making the average relative (dividing by the average) and convert to percent (multiplying by 100). For example consider the data: 24.51, 24.53, 23.99, 24.28 and 24.37.

$$\overline{x} = \frac{24.51 + 24.53 + 23.99 + 24.28 + 24.37}{5} = \frac{121.68\dot{:}0}{5} = 24.33\dot{:}6$$

$$\overline{d} = \frac{\left(|24.33\dot{:}6 - 24.51|\right) + \left(|24.33\dot{:}6 - 24.53|\right) + \left(|24.33\dot{:}6 - 23.99|\right) + \left(|24.33\dot{:}6 - 24.28|\right) + \left(|24.33\dot{:}6 - 24.37|\right)}{5}$$

$$= \frac{0.17\dot{:}4 + 0.19\dot{:}4 + 0.34\dot{:}6 + 0.05\dot{:}6 + 0.03\dot{:}4}{5} = 0.16\dot{:}1$$

$$\%\ rad = \left(\frac{\overline{d}}{\overline{x}}\right)100\% = \left(\frac{0.16\dot{:}1}{24.33\dot{:}6}\right)100\% = 0.66\dot{:}2\ \% = 0.66\ \%$$

Accuracy

Absolute Error, ae: is the absolute difference between an experimental value, A, and the correct value, C: ae = |A - C| Notice that ae is very similar to |d|, but where |d| compares a value to another or an average (thus judging the difference between them, indicating precision), ae compares a value to the correct value, indicating accuracy. Can ae be negative? What are the units of ae?

Percent Relative Error, % re: is the ae divided by the correct value and multiplied by 100 %.

$$\%\ re = \left(\frac{ae}{C}\right) \times 100\% \quad Can\ \%\ re\ be\ negative?\ What\ are\ the\ units\ of\ \%\ re?$$

PRECISION AND ACCURACY-WORKSHEET

Complete the following, remembering to watch SF's.

1) An experiment in chemistry lab was performed to determine standard molar volume of a gas. The experimental value obtained was 22.42 L/mol.

   a) Determine the absolute error for this experiment using 22.414 L/mol as the accepted value.

   b) Determine the percent relative error for this experiment.

2) A student prepared and standardized a solution of potassium permanganate in CHEM 185. The 3 values she obtained were: 0.01965$\overset{.}{.}$5 M, 0.01966$\overset{.}{.}$7 M & 0.01962$\overset{.}{.}$9 M

   a) Determine the average concentration of these solutions.

   b) Determine the average absolute deviation from the mean.

   c) Determine the relative average deviation in ppt.

3) Several students experimentally determined the percent by mass of oxygen in calcium oxide. The percents were found to be: 56.08 %, 56.04 %, 55.95 %, 56.00 % and 56.23 %.

   a) Determine the mean value for the student values.

   b) Determine the average absolute deviation from the mean.

   c) Determine the percent relative average deviation from the mean.

   d) Knowing that the accepted percent by mass oxygen in calcium oxide is 53.54$\overset{.}{.}$3 %, determine the percent relative error.

4) Your answer to an experiment is 26.65% Sb. The correct answer is 26.93% Sb. Find the % re.

5) Two experimentally determined values for the molarity of a solution are 0.09872 M and 0.09794 M. What is the ppt rd?

6) Find the % rad from the mean for the following results: 3.25 % V, 3.28 % V, and 3.20 % V.

LINEAR SCALES

It is necessary to know how to read a scale when using an instrument that has a scale, such as a graduated cylinder. Follow the following key steps **every** time you read a scale:

1. Note the **direction** in which the values on the scale increase.

2. Determine the value of the **increment** of the scale. An increment is the space between adjacent lines.
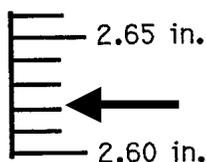
— 2.65 in. ← — 2.60 in.	Count the 5 increments between the labeled lines shown in the scale to the left.	How many increments are there between the labeled lines in the scale to the right? (ten)

— 230°F
←
— 235°F

To determine the value of the increment, subtract the two labeled values, and divide by the number of increments between the labeled lines. For example, the scale above and to the left has 5 increments between 2.60 and 2.65 in. Its increment is therefore determined by:

$$\frac{2.65 \text{ in} - 2.60 \text{ in}}{5} = 0.01 \text{ in}$$

What is the increment of the scale above and to the right?   (0.5 °F)

The purpose of determining the increment is to decide what digits we report that we have confidence in. In the scale, above and to the left, we know that the length is at least 2.62 but less than 2.63. When we report measured values, we report all of the digits we are confident in, **and** the first digit we have to estimate.

3. To **estimate the last digit**, we need to first think about what family the scale belongs to. There are three we will consider; the 10 family, the 5 family or the 2 family.
   A. The **10 family** consist of scales that have increments of 10×10^n, that is to say, increments with 1 in them such as 100,10, 1, 0.1 etc. For the 10 family, mentally divide the increment into 10 spaces and estimate which one of increments the reading is closest to.

      For example, in the scale above and to the left, it has an increment in the 10 family (0.010) so I would imagine dividing the increment into 10 spaces. I then estimate that the arrow is pointing just above the last labeled line, or the first imagined space. I would therefore report this reading as 2.621 in.

   B. The **5 family** consist of scales that have increments of 5×10^n, that is to say, increments with 5 in them such as 500, 50, 5, 0.5 etc. For the 5 family, mentally divide the increment into 5 spaces and estimate which one of these the reading is closest to. What is the value at the arrow on the scale, above and to the right?
                                                                        (231.7 °F)
   C. The **2 family** consist of scales that have increments of 2×10^n, that is to say, increments with 2 in them such as 200, 20, 2, 0.2 etc. For the 2 family, mentally divide the increment into 2 spaces & estimate which one of these the reading is closest to.

Realize that this last place is an estimate, and your ability to accurately determine it will depend on the spacing of the increments (lines farther apart are easier to read than those close together are) and the thickness of the scale lines. Your ability to read these scales will improve with practice. You may not estimate the last place the same as the student next to you, but you should be within one or two on the estimated digit (if you are both doing it correctly.)

You should **only** report **one** estimated digit. Do not forget zeroes. If the reading looks like it falls exactly on a line, then your estimated digit will be 0.

Notice that with the 10 family, the estimated digit is the one in the next decimal place. Look at the following examples and think about the correct possible values and why the wrong ones are not correct:

Increment	Possible Value	Wrong Value	Wrong Value
1 pound	13.2 pounds	13 pounds	13.22 pounds
10 years	133 years	133.1 years	130 years
0.01 g	23.416 g	23.42 g	23.422 g

For the 5 and 2 family, the decimal place of the estimated value is the same as the decimal place of the increment. If the increment is 0.2, you will report the value to the nearest 0.1. If the increment is 500, you will report the value to the nearest_____(100) Look at the following examples and think about the correct possible values and why the wrong ones are not correct:

Increment	Possible Value	Wrong Value	Wrong Value
5 pound	37 pounds	37.3 pounds	40 pounds
2 years	133 years	133.1 years	130 years
0.02 g	23.49 g	23.5 g	23.490 g

4. We assume that the **absolute uncertainty (au)** in a measured reading from a scale is some part of the increment, meaning that it is always **smaller** than the increment. The au is assumed to be the size of the imagined space in an increment of the scale and thus is ±1 in the last reported digit. By reporting that the arrow on the previous scale (left) was 2.621 in we are saying it is 2.621 ± 0.001 in which means it could be 2.620, 2.621 or 2.622 in.

5. All measured digits in a value are considered to be **significant figures (SF's).** SF's, thus are all digits you are certain of **and** the first estimated or uncertain digit. If you are reporting a value that needs zeroes as place holder, remember to use a dashed line to separate the significant digits from the non-significant ones.

6. If the answer lies on a labeled line, you need to determine the absolute uncertainty (thus the increment and family) to know how many zeroes to include.

 For example, the scale to the left has an a.u. of 0.01 (do you agree?) so the measurement should be reported as 0.30.