PRECISION AND STANDARD DEVIATION
A CLASS EXPERIMENT

PURPOSE:

1. To find the Mean Value for the "Molar Mass of a Diprotic Acid" based on the experimental values collected by the whole class
2. To become familiar with the concept of Precision
3. To be able to estimate validity of experimental data

PRINCIPLES:

Precision is the dispersion of, or closeness of the agreement between successive measurements of the same quantity.
The dispersion in a set of measurements is usually expressed in terms of the **standard deviation,** whose symbol is **"s"**

$$s = \left[\frac{\Sigma d_i^2}{N - 1} \right]^{1/2}$$

where:
- Σ **means the "the sum of"**
- $d_i = X_i - \bar{X}$ **= deviation**
- X_i **= a particular value of a measurement**
- X **= the mean value**
- N **= the number of measurements**

Measurements with high precision are narrowly dispersed, and these measurements have a smaller standard deviation than measurements with lower precision.
Unless the number of measurements of the same quantity is very large, the calculated value of the standard deviation is only an estimate of the true standard deviation. Nevertheless, even a limited set of measurements will allow an estimate of the dispersion in the measurement to be judged.

Example 1:

An Example in Calculating a Standard Deviation

Value of Measurement X_i	Deviation $d_i = (X_i - \bar{X})$	Squared Deviation d_i^2
10.11	- 0.01	0.0001
10.13	+ 0.01	0.0001
10.10	- 0.02	0.0004
10.12	0.00	0.0000
10.15	+ 0.03	0.0009
10.11	- 0.01	0.0001
10.12	0.00	0.0000
Sum = 70.84		Sum = 0.0016

$$\textbf{Mean} = (\bar{X}) = \frac{\Sigma X_i}{N} = \frac{70.84}{7} = 10.12$$

$$s = \left[\frac{0.0016}{7 - 1}\right]^{1/2} = 0.016$$

How is the formula used ?
The formula states:
Find the sum of the squares of the deviations, divide by one less than the total number of measurements, and take the square root of the result.
The example above illustrates the use of the formula: suppose we measure the length of an object seven times with a ruler.
The values of these measurements **(X_i)** are: 10.11 cm, 10.13 cm, 10.10 cm, 10.12 cm, 10.15 cm 10.11 cm, and 10.12 cm.
The calculation of the standard deviation of these results is shown in the table above.
When a quantity, such as the length of an object, is measured several times, it is customary to report the mean value of the measurements. The dispersion or precision of the measurements can be indicated, according to one custom, by writing ± the calculated of "**s**" after the mean.
Thus we would report: **10.12 ± 0.02 cm**
Note that the standard deviation of 0.016 was rounded to two decimals because there are only two figures to the right of the decimal point in the mean.
When we report **10.12 ± 0.02 cm** as the best value for the quantity, we are stating that the length of the object probably lies between:

10.12 + 0.02 cm = 10.14 cm

and

10.12 - 0.02 cm = 10.10 cm

The correct number of significant figures in a mean value will always be the number of certain digits plus one uncertain digit. In the example above we have shown that the length of the object probably lies between 10.10 cm and 10.14 cm, with a mean value of 10.12 cm.
Clearly, the first three digits in the mean value are certain, and uncertainty occurs in the fourth digit. The precision of these measurements justifies the use of four significant figures in the mean value.

Example 2

It will instructive to consider one further example.
Suppose we measure the mass of an object six times and find values of:

13.34 g **13.08 g** **13. 58 g** **13.42 g** **13.29 g** **13.45 g**

As you could verify by calculations, the **mean value** is: **13.36 g**
and the **standard deviation** is: **0.17 g**

The mass of the object probably lies somewhere between: **13.19 and 13.53**
In this case the first uncertain digit is the third digit.
The precision of these measurements is poor and therefore will justify only three significant figures even though four digits were obtained in each measurement.
If the measuring device(s) used to obtain the data justify four significant figures in the value of the mean, one must admit than one or several of the measurements are in error and should be discarded. Then, the mean should be recalculated (using the remaining measurement) until an answer could be given in four significant figures.
Logic suggests that the first measurement to be discarded is the one with the highest deviation.
If after recalculating the new mean, an answer could be given in four significant figures, no further steps are necessary.
If not, a second analysis of the deviations and a possible second discard of an odd measurement is in order.
It must be noted however, that at least more than half of the measurements must be included in the calculation of the mean, or otherwise the value reported is meaningless. If this is not possible, it must be concluded that the experimental data collected is so poor (lacks precision) that the whole set of measurements must be repeated and a new set of data collected.

PROCEDURE:

Report the Mean Value for the Molar Mass of a Diprotic Acid to four significant figures based on the experimental data collected from the whole class. Include the standard deviation in your answer

Molar Mass of Unknown Diprotic Acid: [± **g/mol**]

The Molar Mass probably lies between: [ ] **and** [ ]

Note:

All students in the class will earn the same number of points which is based on the closeness of the reported mean value to the theoretical value (% Error).
Therefore, it is sufficient to turn in one answer only.
You are not required to show your calculations.

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REPORT FORM

NAME: ___________________________

Molarity of standardized NaOH solution : _________________ M

Weigh out accurately between 0.15 g and 0.30 g of weak diprotic acid (H_2A)

	1st Titration (g)	2nd Titration (g)	3rd Titration (g)	4th Titration (g)	5th Titration (g)
Initial mass of H_2A + Vial					
Final mass of H_2A + Vial					
Mass of H_2A used					

	1st Titration (mL)	2nd Titration (mL)	3rd Titration (mL)	4th Titration (mL)	5th Titration (mL)
Final Buret reading:					
Initial Buret reading:					
mL of NaOH used:					
L of NaOH used:					
Moles of NaOH used					

Balanced Chemical Equation for the reaction occurring between the weak diprotic acid (H_2A) and sodium hydroxide:
(Please include state designations)

Balanced Net Ionic Equation for the reaction occurring between the weak diprotic acid (H_2A) and sodium hydroxide:
(Please include state designations)

	1st Titration (g)	2nd Titration (g)	3rd Titration (g)	4th Titration (g)	5th Titration (g)
Moles of H_2A used:					
Mass of H_2A used (g):					
Molar Mass of H_2A (g/mol)					

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	1st Titration (g)	2nd Titration (g)	3rd Titration (g)	4th Titration (g)	5th Titration (g)
Molar Mass of H_2A (g/mol)					
Average Molar Mass of H_2A (g/mol)					
Deviation, $\mid d_i \mid$					
Mean Deviation, d					
Relative Mean Deviation, RMD					