# Experiment 5
# Measurements - Volume

**Jay C. McLaughlin**
**Colorado Northwestern Community College**

Name:



Date:

## Key Objectives

1. Understand the difference between Accuracy and Precision.
2. Calculate average and standard deviation
3. Measure volume using a variety of techniques

## Discussion

The volume of a substance refers to the space it occupies. In chemistry labs liquids are most frequently measured by volume, though the may occasionally be measured by mass if the density is known.

Most liquids form a meniscus due to different attractive forces between the liquid and the liquid (cohesive) and the liquid and the container (adhesive). The formation of a meniscus is most apparent in narrow tubes. For water the menisus curves upwards (is concave) as the attractive forces between the water and the glass is larger than that between the water and other water molecules. For mercury it is the opposite, the meniscus curves downwards (concave) as mercury is more attracted to mercury than glass.

Volume measurements are commonly made by reading the point on the graduated scale that coincides with the bottom of the curved surface called the **meniscus** of the liquid as shown in Figure 15.2. A discussion of why a meniscus is formed can be found in Hein Ch. 13.5 (p. 305), Chang Ch. 11.3 (p. 443) or McMurry Ch. 10.4 (p. 391).

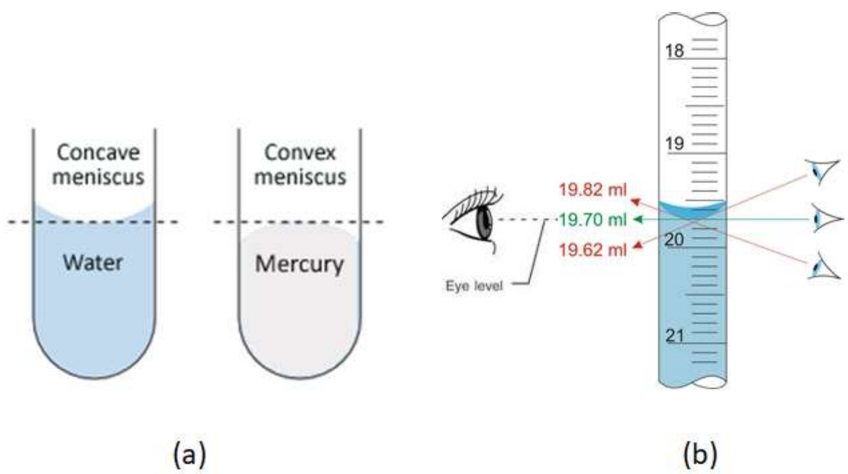


Figure 5.1: (a) Two types of meniscus, (b) When measuring the volume of liquids always look at eye level and for water read the bottom of the meniscus. credit: (a) `http://water.usgs.gov/edu/meniscus.html` (b) E. Generalic, `https://glossary.periodni.com/glossary.php?en=meniscus`

Several methods for measuring liquid volumes are described below. Measurements in this laboratory will most often be done with graduated cylinders and pipets.

**Beakers:** Beakers are the most inaccurate way to measure volume, and are used only when the volume of a liquid is not important. They are inaccurate because of the large meniscus.

**Graduated Cylinders:** A graduated cylinder is a quick and easy (though less accurate) way to measure the volume of a liquid. They are useful for measuring any volume of liquid.

**Plastic Pipets:** Pipets come in two general types. Plastic pipets are used to quickly measure a volume of liquid when accuracy and precision do not matter. It is often assumed that 1 drop from a pipet is equal to 0.05 mL, thus there are 20 drops/mL.

**Volumetric Flasks:** These flasks are generally the most accurate measuring device, but are only designed to measure one specific volume. Common volumes are generally 100.0 mL, 200.0 mL, 250.0 mL, 500.0 mL, and 1000.0 mL.

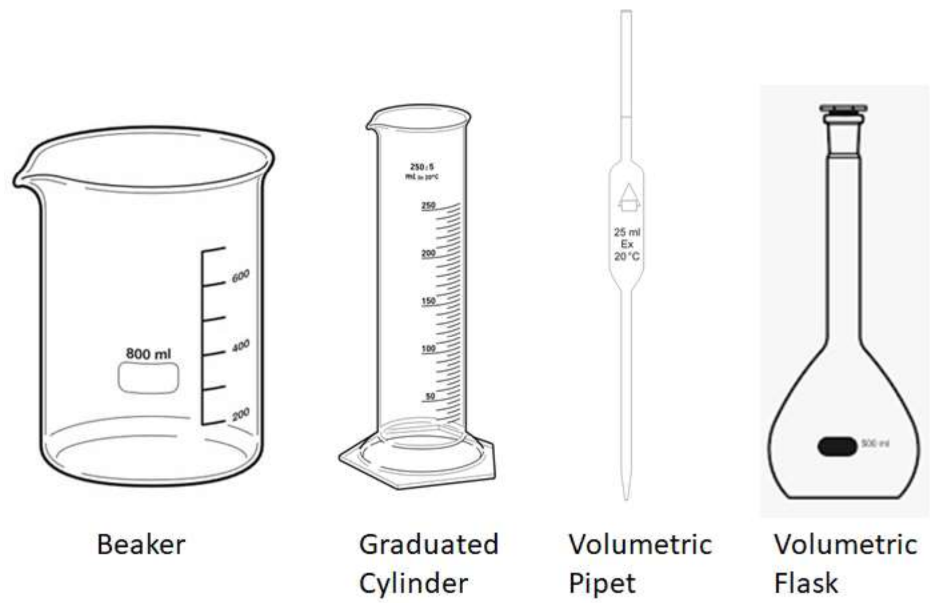


Figure 5.2: 4 different methods for measuring volume - beakers, graduated cylinders, volumetric pipets and volumetric flask. Each gives a different level of accuracy and precision. credit: author

**Burets:** A buret is used for measuring varying volumes of liquids and for delivering volumes of liquids accurately.

The proper use of burets is not obvious, the following steps should be followed:

1. Set up the buret as shown in Figure 15.1.
2. When reading the meniscus level your line of sight should be level with the meniscus to obtain the most accurate reading.
3. Note the numbering is reversed on a buret.
4. Add between 40 and 45 mL of distilled water to the buret using a funnel placed on the top of the buret. Be sure to check for air bubbles in the tip of the buret, if found you need to dispense your liquid until they are removed. Record your initial reading on your data sheet. Verify the reading.

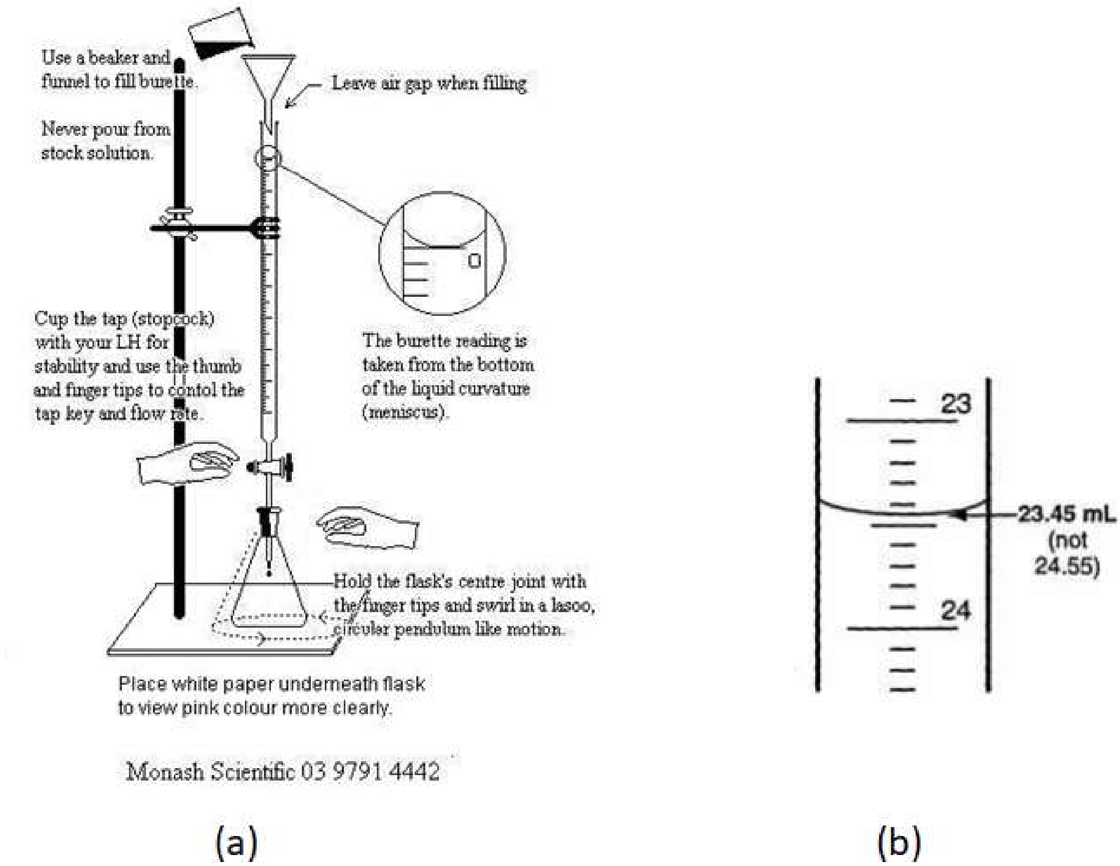


Figure 5.3: (a) How to setup and fill a buret. (b) Note the scale on a buret goes in the reverse direction. Be careful when making measurements. credit: (a) Monash Scientific 03 9797 4442 (b) `https://effectiveness.lahc.edu/`

5. Weigh an empty beaker.
6. Place an empty beaker below your buret and dispense 10 mL of distilled water into it. Record your final reading. Verify the reading.
7. Record the mass of water dispensed.
8. Calculate the volume of water dispensed into your beaker. (Show work)
9. If you have any troubles with this portion of the lab, or your mass and volume measurements disagree too much, consult your instructor, and do a second trial if needed.
10. Any water used in this part of the experiment may be disposed of down the sink.

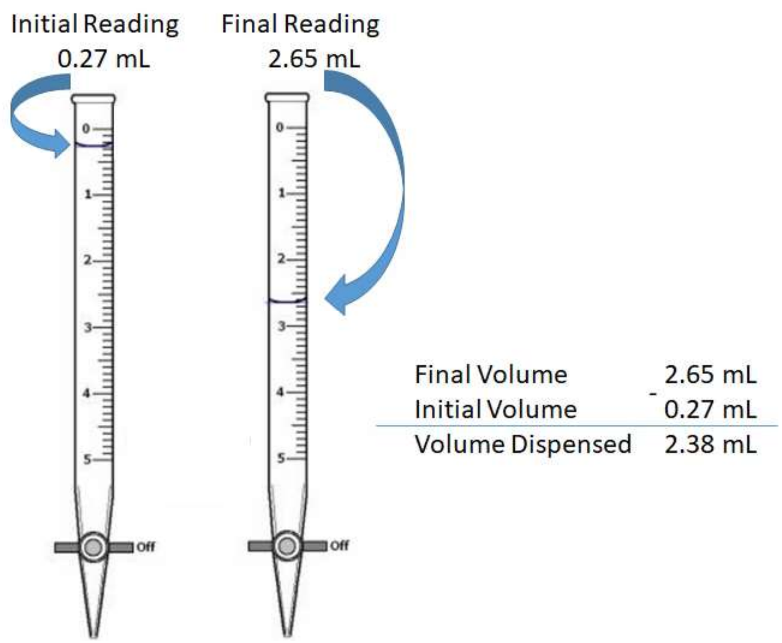


Figure 5.4: How to read a buret. Take the final volume - Initial volume = Volume dispensed. credit: author

**Volumetric Pipets:** Glass pipets are commonly called volumetric pipets because they are a simple, yet very accurate way to measure volume. Volumetric pipets are so accurate because the long neck decreases the error in measuring volume of the meniscus. They are only designed to measure one specific volume and commonly come in sizes 5 mL, 10 mL, 25 mL, and 50 mL. The accuracy of a volumetric pipets is commonly taken to be $\pm$ 0.01 mL. The pipet is read by placing the bottom of the meniscus on the measuring line. They are designed to leave one drop of liquid in the tip.

The proper use of pipets is not obvious, the following steps should be followed:

1. Place the pipet or suction bulb over the top of the pipet.
2. Evacuate air from the suction bulb by squeezing open the top valve (Labeled A) and gently squeezing air out of the bulb. When the bulb is empty release the top valve.
3. Place the pipet in the liquid being measured. Do not place the bottom of the pipet on the bottom of the container as this may damage the pipet.
4. Slowly open the valve between the suction bulb and the pipet (Labeled S) and allow liquid to fill the pipet to just past the reference line. Release the valve. Be careful not to overfill the pipet or get liquid into the bulb, as this may ruin the bulb.
5. Use the side valve (Labeled E) to lower the level of liquid in the pipet until the bottom of the meniscus is on the reference line. Close the valve.
6. Remove the pipet from the liquid being measured and place it over the container you are placing the liquid into. Use the side valve to release the liquid.
7. There will be a tiny amount of liquid left in the tip of the pipet, this is normal and the pipet is calibrated to leave this amount in the tip. If you blow out this liquid, your measurement will be inaccurate.

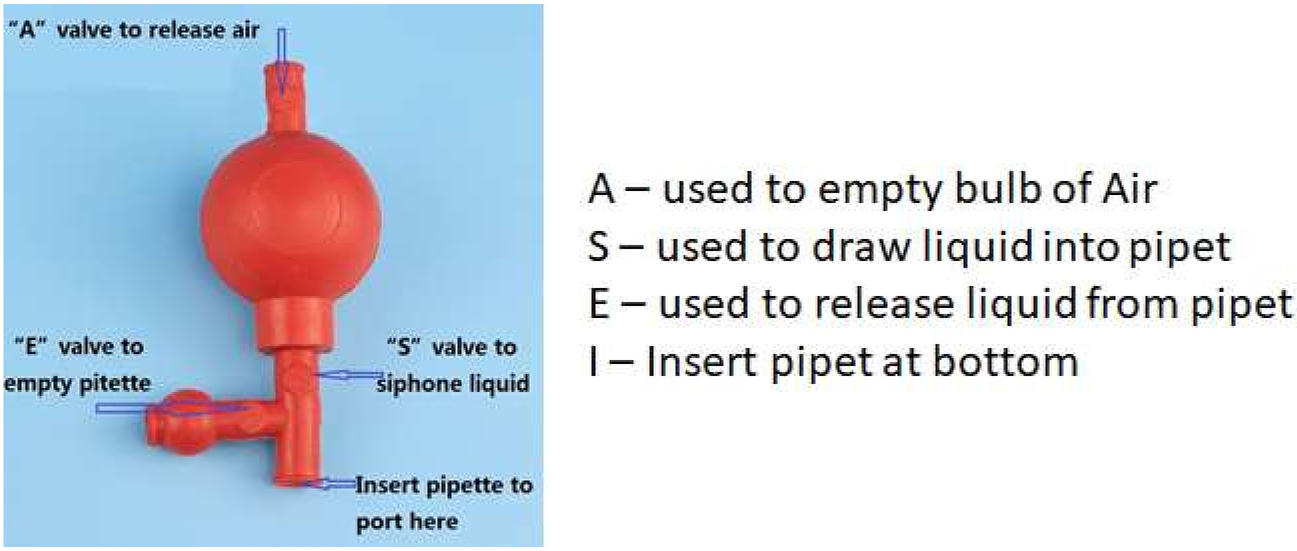


Figure 5.5: How to use a pipet bulb. Insert pipet into bulb, remove (Air) from pipet, (S)iphon liquid into pipet, (E)mpty pipet. credit: author

**Density**

Mass measures the amount of matter in an object, while volume measures that space the object takes up. Both mass and volume are **extensive** properties, meaning that they depend on the size of an object. The larger the object the larger its mass and volume. Extensive properties are not very useful for determining the identity of the object since they are size dependent.

**Density** is the ratio of an objects mass to its volume. Density is an **intensive** property and does **not** depend on the size of the object. The density of any substance is the same no mater the size of the object. Density is also relatively unique for each substance (best seen by examining the density of different elements in a future experiment).

The density of water (by definition) is 1.000 grams/mL. We can use this fact to verify the volume of water measured by different laboratory equipment by comparing the volume measured to the mass measured which should be the same.

**Accuracy and Precision**

Recall in earlier labs we learned that the accuracy of a measurement is determined by how close the measurement is to the true value and we learned how to calculate the Percent Error in the measurement. To determine the precision of a measurement, multiple trials are required and the average and standard deviation are calculated using the following formulas, the **average** is given below in two forms, on the left is the formal mathematical expression, on the right is the more standard form.

The **sample standard deviation (s)** is used to measure how close each value is to the average value, and quantifies the amount of variation in set of data values. A low sample standard deviation indicates that the data points tend to be very close to the average value, while a high sample standard deviation indicates that the data points are far from the average value. Thus, a small sample standard deviation means that the experimental result is reproducible (precise), while a large sample standard deviation means the experimental results are not very reproducible (not precise). The equation for the sample

$$\text{Average} = \frac{x_1 + x_2 + x_3....}{n}$$

$$\bar{x} = \frac{1}{n} \times \sum_{i=1}^{n} x_i$$

$\bar{x} = \text{Average}$

$i = \text{individual measurement}$

$n = \text{number of measurements}$

Figure 5.6: (a) Standard Definition of Average. (b) Formal Mathematical Definition of an Average.

standard deviation is given below:

$$s = \left( \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1} \right)^{\frac{1}{2}}$$

Figure 5.7: Standard Deviation

The following example shows the calculation of the average and standard deviation for an example set of data. A student measures the change in temperature of a sample 5 times with the following results:

| Trial | ΔT (℃) |
|---|---|
| 1 | 25.0 |
| 2 | 24.0 |
| 3 | 23.0 |
| 4 | 23.5 |
| 5 | 26.0 |

$$\bar{x} = \frac{25.0 + 24.0 + 23.0 + 23.5 + 26.0}{5} = \frac{121}{5} = 24.3$$

$$\sigma = \left( \frac{(24.3 - 25.0)^2 + (24.3 - 24.0)^2 + (24.3 - 23.0)^2 + (24.3 - 23.5)^2 + (24.3 - 26.0)^2}{5 - 1} \right)^{\frac{1}{2}} = 1.204$$

Figure 5.8: Example Calculation for Average and Standard Deviation

Based on the example above, one would report the measured value as $24.3 \pm 1.2$℃.

## Procedure

1. Use your 100 mL graduated cylinder to measure out 10 mL of distilled water.
2. Weigh the mass of your water on the electronic balance. The graduated cylinder will probably overload your balance, so use a small beaker to measure the mass of the water. **DO NOT** pour water over the balances, take the beaker off the balance before pouring the water in. Remember to tare the beaker before making your measurement. Record your result.
3. Repeat the above measurement (steps 1 and 2) 2 more times. Record your results.
4. Calculate the average for your three measurements.
5. Repeat steps 1-4 using a 10 mL graduated cylinder.
6. Repeat steps 1-4 using a 10 mL volumetric pipet.
7. Repeat steps 1-4 using a buret.

Name: ______________________ Class: ________________ Date: ________________

# Results

## 100 mL Graduated Cylinder

1. Volume can be read to what uncertainty? ($\pm$): ____________
2. Weight of water in trial 1: ____________
3. Weight of water in trial 2: ____________
4. Weight of water in trial 3: ____________
5. Average weight of water in trials 1-3: $\left(\frac{\text{Trial 1}+\text{Trial 2}+\text{Trial 3}}{3}\right)$ ____________
6. Standard Deviation (show calculation) ____________

## 10 mL Graduated Cylinder

1. Volume can be read to what uncertainty ($\pm$): ____________
2. Weight of water in trial 1: ____________
3. Weight of water in trial 2: ____________
4. Weight of water in trial 3: ____________
5. Average weight of water in trials 1-3: $\left(\frac{\text{Trial 1}+\text{Trial 2}+\text{Trial 3}}{3}\right)$ ____________
6. Standard Deviation (show calculation) ____________

## 10 mL Volumetric Pipet

1. Volume can be read to what uncertainty ($\pm$): ____________
2. Weight of water in trial 1: ____________
3. Weight of water in trial 2: ____________
4. Weight of water in trial 3: ____________
5. Average weight of water in trials 1-3: $\left(\frac{\text{Trial 1}+\text{Trial 2}+\text{Trial 3}}{3}\right)$ ____________
6. Standard Deviation (show calculation) ____________

## Buret

1. Volume can be read to what uncertainty ($\pm$): ______________

2. Initial volume of water in the buret (trial 1): ______________
3. Final volume of water in the buret (trial 1): ______________
4. Difference in volume (trial 1): ______________
5. Weight of water (trial 1:) ______________

6. Initial volume of water in the buret (trial 2): ______________
7. Final volume of water in the buret (trial 2): ______________
8. Difference in volume (trial 2): ______________
9. Weight of water (trial 2:) ______________

10. Initial volume of water in the buret (trial 3): ______________
11. Final volume of water in the buret (trial 3): ______________
12. Difference in volume (trial 3): ______________
13. Weight of water (trial 3:) ______________

14. Average volume of water in trials 1-3: $\left(\frac{\text{Trial 1}+\text{Trial 2}+\text{Trial 3}}{3}\right)$ ______________

15. Average weight of water in trials 1-3: $\left(\frac{\text{Trial 1}+\text{Trial 2}+\text{Trial 3}}{3}\right)$ ______________

16. Standard Deviation for weight of water (show calculation) ______________

## Questions

1. When making volume measurements one should read the level of water at the top, middle, or bottom of the meniscus?

2. What mass should your water have if you measured out 10.0 mL of water? Show your calculation or Explain.

3. In this lab are we measuring Accuracy or Precision? Explain.

4. Based on your measurements made in class, which measurement device was the most accurate? Explain.

5. Based on your measurements made in class, which measurement device was the most precise? Explain.

6. What sources of error could lead to imprecise and inaccurate measurements in measuring volume with the graduated cylinders? (Give 2 sources of error) Exlain.

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