

EXPERIMENTING SKILLS

Measuring

Try this puzzle. Suppose that you are given a bottle of water and three beakers. One of the beakers holds 30 mL, one holds 40 mL, and the largest of the three beakers holds 200 mL when full. There aren't any markings on any of the beakers. Describe how you could put exactly 20 mL of water in the large beaker without using any other equipment.

Tools of the Trade

You probably already know that beakers are used for measuring liquid volume. We say that the **dimension of measurement** for a beaker is volume. Examine the following chart, and fill in the empty boxes.

Measurement device	Dimension of measurement
beaker	volume
stopwatch	
beam balance	
graduated cylinder	
	distance or length
	temperature

Precise measurements and accurate readings are very important aspects of scientific experimentation.

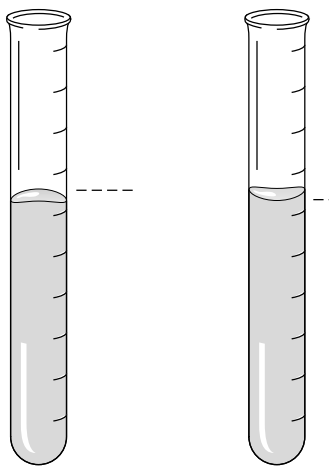
Here are some pointers for accurately measuring the volume of a liquid:

- Place the container on a flat surface.
- Make sure the container is at eye level when you read the volume.
- If you have trouble seeing the level, hold a blank piece of paper behind the container while you read the volume of the liquid.

Measuring, continued

In a graduated cylinder or beaker, most liquids form a **meniscus**, or a curved upper surface. A meniscus is caused by surface tension. When a liquid, such as water, is more attracted to the walls of the container than to itself, it curves up at the edges like a smile. When some liquids, such as mercury, are more attracted to themselves than to the walls of the container, they curve down like a frown.

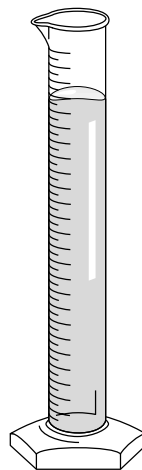
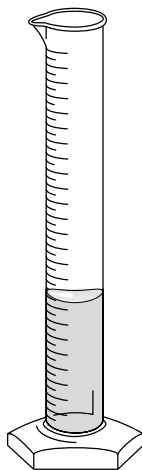
When you read the volume of a liquid, read it from the center of its meniscus, not from the curved edges.



For practice, read the volume of the following liquids. Each longer graduation represents one milliliter.

1. Volume: _____

2. Volume: _____



Measuring, continued

Uncertainty in Measurement

Anne brought a 1 L bottle of vinegar from home to use in an experiment on volcanoes in science class. She poured the contents of the bottle into a large beaker and carefully measured it. She was surprised to find that the vinegar’s measured volume was actually 1.02 L. Anne thought the bottle contained exactly 1 L of vinegar. What possible explanations can you think of for the difference?

Accuracy in Measurement

No measurement is 100 percent accurate. All measurements have some degree of uncertainty. When taking measurements, you should always ask yourself, “How accurate is this measurement?”

For a measurement to be of any worth, it must have something that indicates its reliability. A measurement’s **accuracy** is expressed as its potential amount of error. For instance, the smallest unit of measurement on a metric ruler is usually a millimeter. The most accurate measurement you could possibly make with that ruler is to the nearest millimeter; thus, the measurement’s accuracy is ± 0.5 mm.

This is important because not all measurements have the same accuracy. The total accuracy of your work is only as reliable as your *least* accurate measurement. Following is an example:

Ricardo added the following three liquids to a beaker:

- 7.9 mL of liquid A
- 2.1 mL of liquid B
- 250 mL of liquid C

Measuring, continued

Ricardo measured liquids *A* and *B* with a narrow graduated cylinder that had markings for every 0.1 mL. He measured liquid *C* in a beaker that had markings only for every 10 mL. Thus, the volume of liquid *C* was only accurate to within about 5 mL.

As a result, Ricardo correctly stated that the total volume of the mixture in the beaker was $(7.9 + 2.1 + 250) \text{ mL} = 260 \text{ mL} \pm 5 \text{ mL}$.

Matchmaker

Match the measurement devices below with their level of accuracy.

- | | |
|---|------------------|
| 1. _____ metric ruler with markings as small as millimeters | a. about 0.5 g |
| 2. _____ graduated cylinder with markings as small as 2 mL | b. about 1 mL |
| 3. _____ scale with markings as small as 0.01 g | c. about 0.5°C |
| 4. _____ thermometer with markings as small as 1°C | d. about 1 mm |
| | e. about 0.5 mm |
| | f. about 0.005 g |
| | g. about 0.1°C |

TROUBLESHOOTING

Think of accuracy in terms of money. When someone says, "That costs about \$20," which of the following would you think is most accurate: (a) the price is correct, give or take \$10; (b) the price is correct, give or take \$1; or (c) the price is correct, give or take 1 cent? The most accurate estimate is probably (b).

TRY THIS!

The next time your family buys gasoline, pay attention to how accurately the gas pump tracks the volume of gas—very accurately! For contrast, notice how accurately the car's gas gauge measures the amount of gas in the gas tank—not very accurately!