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LABORATORY GLASSWARE

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Introduction

Laboratories require an assortment of laboratory ware to mix, heat, store, measure and dispense solutions. The good and recommended laboratory wares help researchers to perform scientific experiments safely and accurately.

Most laboratory wares are made from glass. Some laboratory glassware are still made from ordinary flint glass. Volumetric glassware and similar items and nearly all laboratory glassware, without glass tubing, are made from borosilicate (Corning, Pyrex, Bomex, Endurel and Kimax are some of them). Borosilicate glass is suited for any task that involves heat, whether that heat is applied externally or produced by a reaction. For example, Pyrex glassware has superior thermal and chemical resistance and is better suited for storing solutions. But soda lime glass or soda glass has low thermal and chemical resistance, unlike borosilicate.

Some laboratory wares are made of plastic. An advantage over glass is that it does not break if you drop it. Plastic laboratory ware is often (but not always) less expensive than glassware, because the former is produced by using easy and inexpensive techniques such as injection molding to form complex shapes in plastic ware. However, it is expensive to produce such shapes in glass. Against these advantages plastic ware has several disadvantages. Obviously plastic ware is less heat resistant than glassware. Although good plastic ware withstands autoclaving, it cannot be heated over a flame or used for reactions that produce heat. Plastic ware may be damaged by organic solvents, oxidants and some other chemicals, because it does not possess the vitreous surface of glassware. It is more difficult to clean thoroughly and may be permanently stained by some chemicals. These aspects should be considered when using plastic ware.

Laboratory glassware are commonly available in at least two grades. They are Laboratory grade glassware and Student grade glassware.

1. Laboratory grade glassware
   Laboratory grade glassware is also called Professional grade glassware. It is more expensive, better finished, often more precisely graduated, more durable and better annealed. Laboratory grade glassware is very well adapted for scientific laboratory research.

2. Student grade glassware

   Student grade glassware is called either economy grade or educational grade glassware, is less expensive, cruder in appearance, often less precisely graduated and poorly annealed. Thus student grade glassware can be used for general purpose.

Plastic ware can also be classified in a similar way.

Glass Standards

Various standards govern the classification of glass into types suitable for specific uses. These standards include ASTM (American Society for Testing and Materials), EP (European Pharmacopoeia), USP (United States Pharmacopoeia) and DIN (*Deutsches Institut für Normung*, meaning "German institute for standardisation"). An individual laboratory ware has a specific function. Sometimes some laboratory ware can be used for another purpose. According to the specific function of glassware, they are broadly classified under: volumetric measuring glassware, measuring and transferring glassware, containers, and other miscellaneous glassware. This chapter is concerned with volumetric glassware, their accuracy and proper use.

Volumetric Measuring Devices

There are only five volumetric measuring devices recognized as suitable for analytical work. They are:

1. Burettes
2. Volumetric flasks
3. Volumetric (transfer) pipettes
4. Glass measuring pipettes
5. Graduated cylinders

Of these, 1 to 4 are suitable for accurate and precise analytical work.

Erlenmeyer flasks and beakers are not volumetric measuring tools. They are, in many cases, marked with approximate volume indication. However, even in the most reliable flasks and beakers, there is an uncertainty of ±5% in determining where the volume line is. Volumetric glassware is manufactured and calibrated in accordance with international standards to carry out very accurate determination and measurement of specific volumes. They are available in three accuracy classes: class A, class AS and class B. Class B is sometimes called student or economy grade, although in certain cases these designate containers of even lower quality than Class B.

The standards define the tolerances within which the markings are placed on the glass, with Class A glassware having the smallest tolerance. The Class B tolerances are, in general, twice the acceptance range of the Class A values. A comparison of Class A and Class B tolerances for volumetric flasks, pipettes, graduated cylinders and burettes are given in Table 1. Class A glassware has the highest accuracy and Class B accuracy is approximately half that of Class A. All plastic (Teflon®, polypropylene, polymethylpentene and polyethylene) volumetric containers are Class B. Class A volumetric glassware will always have a large "A" marked prominently near the label. Glassware without an obvious "A" is Class B or that of lesser accuracy.

Class AS is the European standard and the United Kingdom is now adopting this standard. Class AS and Class A share the same high accuracies and tolerances as the relevant ISO and DIN standards. Class AS offers faster delivery (the time taken to dispense the total volume), with the addition of a waiting time before reading is taken or vessel is emptied (the time taken for the meniscus to settle).

Some of the glassware manufacturers offer two types of Class A calibrated volumetric ware. The first is a generic Class A line of glassware; the second type is a certified/serialized Class A and comes complete with documentation and traceability to the National Institute for Standards and Technology (NIST), which is required for certification to ISO 9000 standards.

Table 1. Comparison of Class A and Class B tolerances for Volumetric Flasks, Pipettes, Graduated cylinders and Burettes. Volumes and Tolerances are in ml.

Nominal volume	Volumetric flasks		Pipettes		Graduated cylinders		Burettes	
	Class A tolerance	Class B tolerance	Class A tolerance	Class B tolerance	Class A tolerance	Class B tolerance	Class A tolerance	Class B tolerance
1			±0.006	±0.012				
5			±0.01	±0.02				
10	±0.02	±0.04	±0.02	±0.04	±0.08	±0.1	±0.02	±0.04
25	±0.03	±0.06	±0.03	±0.06	±0.14	±0.3	±0.03	±0.06
50	±0.05	±0.10	±0.05	±0.10	±0.20	±0.4	±0.05	±0.10
100	±0.08	±0.16	±0.08	±0.16	±0.35	±0.6	±0.10	±0.20
250	±0.12	±0.24			±0.65	±1.4		
500	±0.20	±0.40			±1.10	±2.6		
1000	±0.30	±0.60			±2.00	±5.0		
2000	±0.50	±1.00			--	±10.0		

Source:
https://www.sigmaaldrich.com/content/dam/sigma-aldrich/countries/italy/Documents/volumetrics_a_b.pdf

Volumetric Flasks


Figure 1. Volumetric flasks

Volumetric flasks (Fig. 1) are used to prepare solutions to an accurate volume (i.e. accurate up to two decimal places). For the volume to be accurate, solutions must be at room temperature. When reading the volume, the bottom of the liquid meniscus must line up with the volume level mark on the neck of flask and the eye level of the observer. When preparing a solution in a volumetric flask, first the solute should be completely dissolved in a minimum amount of the solvent, and the level of total volume be brought to the volume mark on the flask by adding solvent. **Never hold the flask by hand below the volume mark during solution preparation;** the solution inside the flask may expand, due to the heat of the hand, and give an erroneous reading.

Volumetric pipettes

Pipettes are used for accurate volume measurements and transfer. There are two types of pipettes commonly used in the laboratory: volumetric pipettes and graduated (measuring) pipettes. Volumetric pipettes are used to deliver a single volume. Graduated (measuring) pipettes will deliver fractions of the total volume. Serological pipettes are used to deliver viscous liquids.

Graduated pipettes can be differentiated from volumetric pipettes by the presence of a graduated volume scale on the side of the measuring pipette. There are two types of graduated pipettes commonly found in the laboratory. They are Mohr pipettes and serological pipettes. The Mohr pipette is graduated from a zero mark near the top of the pipette to a baseline near the tip of the pipette. Mohr pipettes are intended to indicate the delivered volume of liquid by the difference between the initial and final positions of the liquid, with delivery of the maximum calibrated volume, leaving the tip of the pipette full of liquid. Mohr pipettes come in calibrations with Class A/AS and Class B tolerances, which are the same as those of the volumetric pipettes.

A serological pipette is graduated from a zero mark near the top of the pipette to the very tip of the pipette. The volume is indicate by the difference between the initial and final liquid levels similar to the Mohr pipette; however, to deliver the whole calibrated amount, the pipette is blown out with a pipette bulb such that no liquid remains in the tip. The best serological pipettes are available only with Class B tolerances. Pipettes with wide tips for measuring sludges and other viscous liquids are serological pipettes. Disposable serological pipettes made of glass or plastic are available and calibrated to Class B or lesser accuracy.

Pipettes come in a variety of shapes and sizes. Volumetric pipettes have a bulb in the shaft of the pipette and, in general, a single calibration mark. Volumetric pipettes come in "To Contain" (**TC** or **In**) and "To Deliver" (**TD** or **Ex**) calibrations. There is a special volumetric pipette called a Dual Purpose pipette which has calibration marks with Class A tolerances for both TC and TD use. The recommended procedure for emptying volumetric pipettes is as follows:

- hold pipette in the vertical position
- allow unrestricted outflow
- hold the pipette in such a way that its tip touches the wet surface of the receiving vessel; keep in contact until the pipette is empty.

Handling Pipettes

Pipettes are used to transfer a specific amount of a liquid. Two types of pipettes are commonly used for this purpose. They are glass pipettes and micropipettes

Glass pipette

These are used to transfer liquid volumes in the milliliter scale. There are two different types of glass pipettes and selecting the appropriate type according to the purpose is crucial. Volumetric pipettes (often called bulb pipettes) must be used to measure a liquid volume extremely accurately (accurate up to four significant figures). As the volumetric pipettes are calibrated for a single volume, the correct pipette must be selected to measure a specific volume. For instance, 10 mL volumetric pipette can only be used to measure 10.00 mL, but not less or more. The other type is the graduated pipette which can be used to measure volumes less than the maximum volume measurable by the pipette. However, graduated pipettes are less accurate than volumetric pipettes. Further, A-grade pipettes are more accurate than B-grade pipettes.

Always read the specifications on the pipette before use. When using a graduated pipette, check from where the graduations end. A pipette filler, such as a rubber three-valve filler (Fig. 2), must be used to draw the liquid up in to the pipette and to release it. **Never use your mouth to fill the pipette.** Make sure the pipetting liquid is at the room temperature. When reading the pipette, the bottom of the liquid meniscus should line up with the desired graduation mark on the pipette and the eye-level of the observer (Fig. 3). The pipette should be held vertically and the pipette tip should touch the inside of the container while ejecting the liquid. **Never**

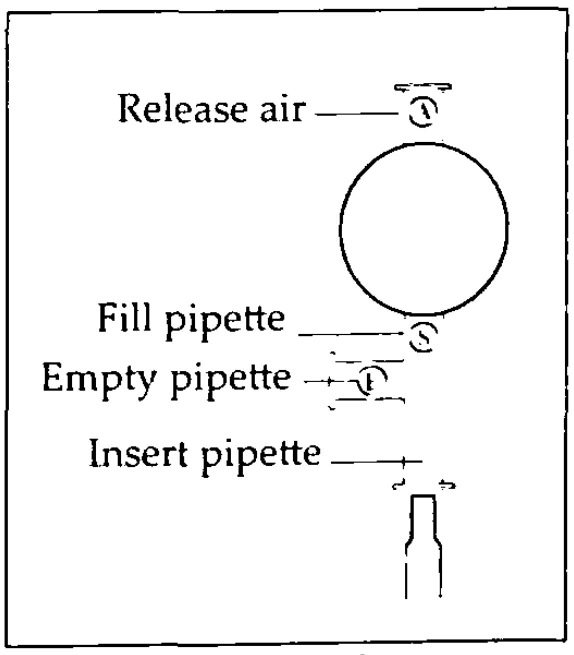


Figure 2. Three-valve rubber filler

blow out the last drop remaining in the tip after releasing the liquid, unless the pipette is a "blow-out type". These blow-out type pipettes have a frosted band or two thin rings marked around the neck.

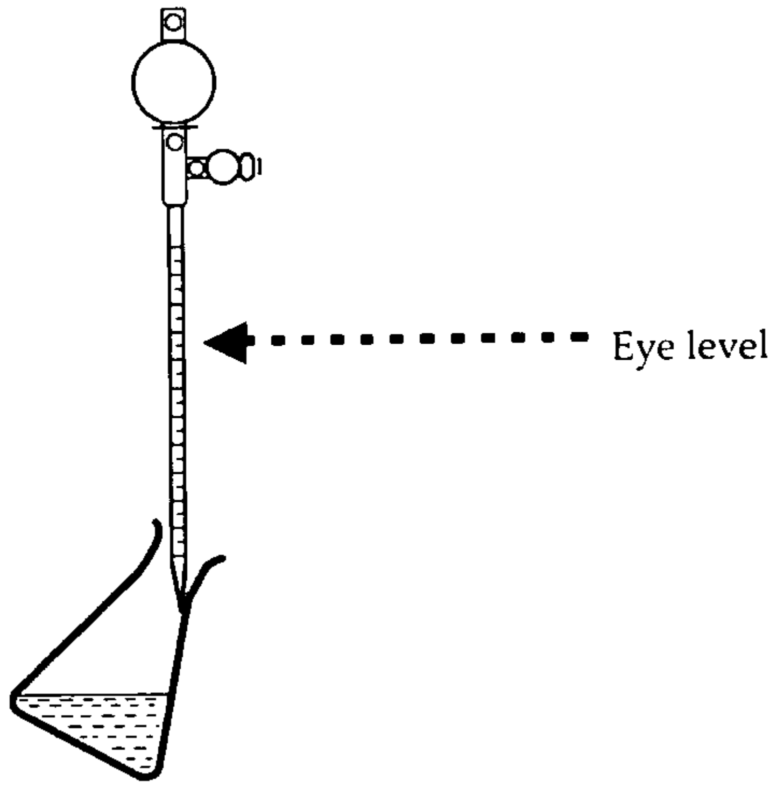


Figure 3. Correct holding of pipette

Micropipette

Micropipettes are used when dealing with liquid volumes in micro litre (µL) scale. These pipettes must be handled with more care as they are extremely expensive. Micropipettes must never be used for acids or highly acidic solutions as they cause corrosion inside the pipette. Only the volumes that lie within the volume range specified on the pipette, can be measured.

There are two plunger stopping positions in the pipette. After setting the pipette to the desired volume, the plunger should be depressed to the first stop to draw up the liquid into the pipette tip while it should be pressed down to the second stop to dispense the entire content in the tip. Make sure the pipette tip is adequately immersed below the liquid level before withdrawing the sample. Always keep the pipette tip downwards when a liquid is inside it.

Pasteur Pipette

Pasteur pipettes are useful to dispense low volumes of 1 – 5 mL. They are either made of glass with a detachable rubber bulb or completely of plastic. The plastic pipettes can be used for aqueous solutions but not for organic liquids. The illustration (Fig. 4) shows the correct usage of a Pasteur pipette. The pipette should be held vertical. The thumb and index finger are used to squeeze the rubber bulb, while the middle and last two fingers support the barrel. The liquid should not be sucked into the bulb. This

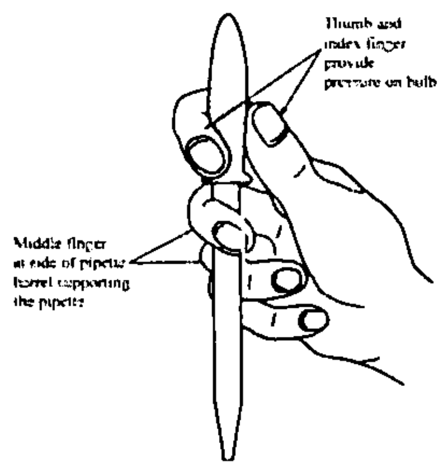


Figure 4. Using a Pasteur pipette

would happen if the capacity or volume of the bulb is greater than that of the barrel. Do not remove the tip of the pipette from the liquid while the liquid is being sucked into the pipette.

Caution: Volatile liquids such as dichloromethane, ethanol, acetone and ether may cause the liquid to squirt out from the pipette due to the warmth of the glass pipette (from the finger), even without any pressure from the bulb. To avoid this, the pipette should be cooled by drawing liquid in and out several times.

Eppendorf tubes (Fig. 5) are used to centrifuge small volumes of suspensions. When sucking out or decanting the supernatant, the pellet should always lie on the upper side of the tube.

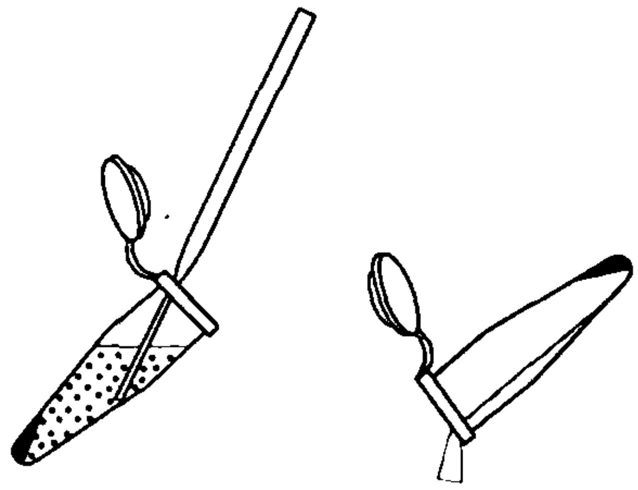


Figure 5. Removing supernatant from an Eppendorf tube: pellet should lie above

Some examples of the markings on the volumetric glassware with DIN standards are as follows. Markings on a Class B volumetric flask are shown in Fig. 6. NS refers to 'neck size' of the flask. The glassware is calibrated 'to contain' (**TC** or **In**) 1000 ± 0.80 ml of liquid at 20 °C. According to the American Society for Testing and Materials (ASTM) E287-02 standard specification for laboratory glass, tolerance of Class A 1000 mL volumetric flask should be ± 0.300; that means the tolerance for Class B flask is ± 0.600, which is twice the Class A tolerance.

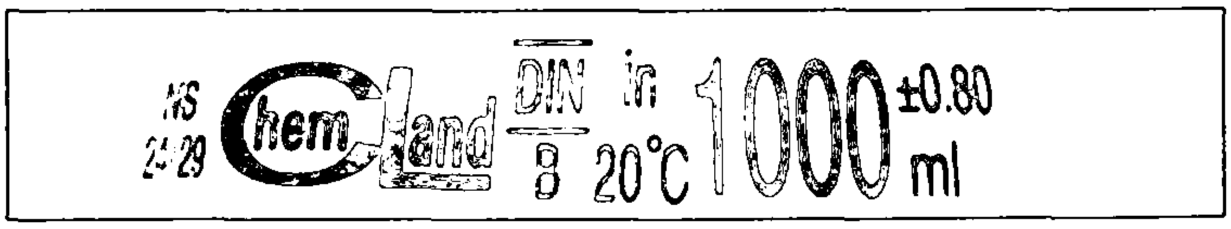
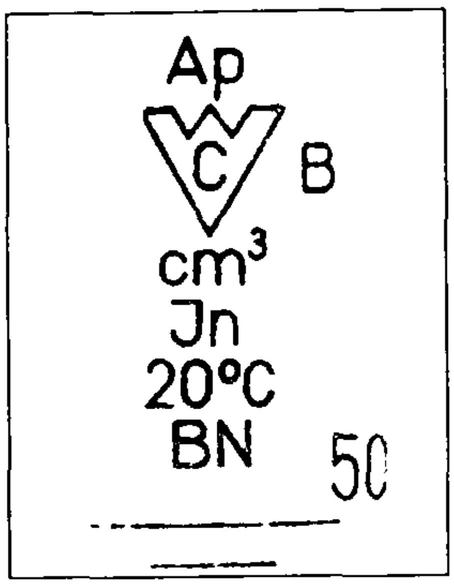


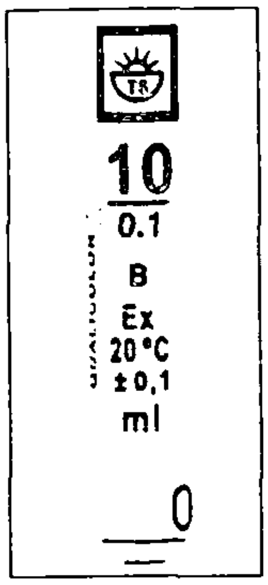
Figure 6. Markings on the volumetric glassware with DIN standards for Class B

Proper use of Volumetric Glassware

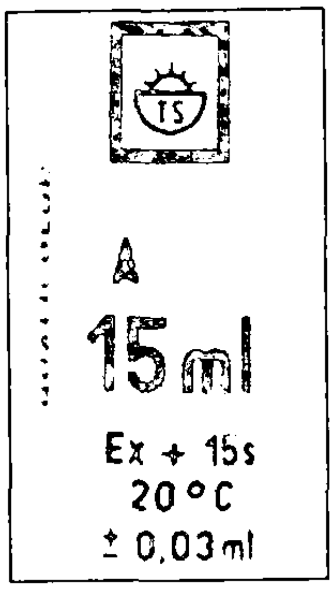
The first consideration in the use of volumetric glassware is the temperature. Glass more closely resembles a very viscous solution than it does a crystalline solid. The properties of glass can be varied greatly by varying the additives. For example, addition of boric oxide (B_2O_3) produces a glass called borosilicate glass that expands and contracts little under large temperature changes. Thus it is useful for laboratory ware and cooking utensils. Glass is an amorphous solid which lacks order. Different types of glass have different rates of expansion and also different areas of the same piece of glass have different rates of expansion. Therefore there is no universal correction factor for temperature variation. Instead, the temperature at the time of calibration is normally etched on the body of the glassware. When none is etched, 20 °C is assumed.



Markings on the volumetric cylinder. B to the right means Class B, calibrated to contain (In) at 20 °C.



Markings on Class B 10 mL pipette. Calibrated to deliver (Ex) at 20 °C. Once again tolerance slightly differs - according to ASTM E287-02, it should be ± 0.04.



Markings on Class A single volume pipette. Calibrated to deliver (Ex) 15 mL ± 0.03 at 20 °C, you should wait for at least 15 seconds, touching the side of the pipette tip against the inside of the flask (beaker) till the solution is delivered.

Figure 7. Markings on volumetric cylinders and pipettes.

Furthermore, the volumes of solutions change with temperature, expanding when the temperature is raised. Water is significantly unique in its behavior, shrinking in volume from 0 to 4 °C, thereafter expanding with temperature rise. This variation in volume affects the reagent concentration. Dilution of most acids and bases in water is exothermic, whereas dissolution of ammonium chloride is endothermic. Therefore, adjustments of final volume should always be delayed until the temperature of the solution has stabilized at the initial temperature.

'Dilute to the mark' and 'read the meniscus' are common instructions for preparation of solutions or titrations. Most calibration marks on volumetric glassware extend all the way around, aiding orientation of the eye and the container in order to see a single straight line just intersecting with the bottom curve of the liquid.

If the container is a TC device, the entire contents are the correct volume. Then transferring the contents to another container, a quantitative transfer must be made. This entails blowing out the pipette with a pipette bulb and rinsing the inside of the pipette with additional solvent from a squeeze bottle, or rinsing the flask or cylinder with additional solvent.

For TD containers, a flow time must be observed. Proper dispensing of solution from a TD pipette requires touching the pipette tip to the inside wall of the receiving container and maintaining contact for at least the time determined by Table 2. The reason is to allow all of the water film on the inside of the pipette to drain off, so you get the full accuracy the pipette is capable of. If you watch, you can see that it takes a while. Really accurate pipettes, like Class A type, should be designed with narrow enough holes in the tip to make them drain so slowly that draining of the film would keep up with bulk draining, and the timing could take care of itself.

Table 2. Flow times for 'To Deliver' (TD) pipettes

Nominal Volume /ml	Flow time /sec	
	Class A	Class B
1	10	3
10	15	8
25	25	15
50	25	15
100	30	30

For solutions which have a different density or viscosity than pure water, the flow times are not correct. The student should consider using a TC pipette, because the error associated with the retained solution in the tip of the TD pipette generally exceeds the manufacturing tolerance of the TC pipette. Similar consideration applies to the use of pipette pumps and pipette bulbs. One should never pipette by mouth, especially in a laboratory that handles wastewater; instead pipetting aids should be used. However, the pipette is calibrated assuming that only gravity is affecting the liquid flow and that it is not being pushed out of the pipette rapidly by air pressure.

Containers

Scientists use containers for storing substances and mixing and observing chemical reactions. These containers are typically made of glass so that you can watch what is happening inside. Beakers, flasks and test tubes are common types of containers. Beakers (Fig. 8) make excellent containers for observing chemical reactions and storing liquid and solid samples.

Their cylindrical shape, wide mouth and spout facilitate convenient transfer of solution from one container to another. The Erlenmeyer flask (Fig. 9) has a conical base and tapered neck. Its neck is ideal for grabbing, holding and swirling liquid samples. Test tubes (Fig. 10) are useful for running small-scale experiments that require multiple solutions. Stoppers placed in the mouths of flasks and test tubes prevent spillage and evaporation. Other laboratory containers include watch glasses, crucibles, glass desiccators, reagent bottles and plastic wash bottles.

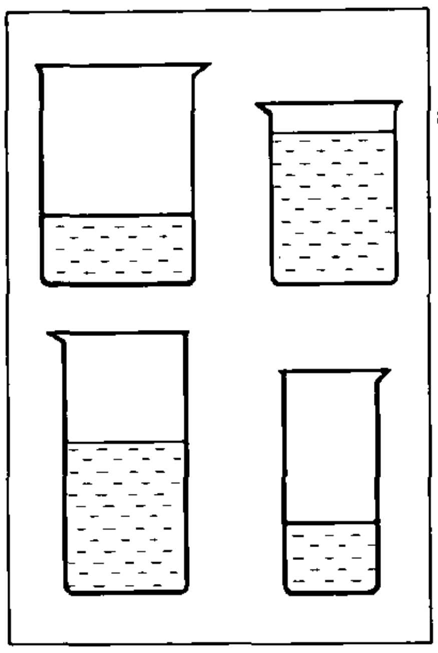


Figure 8. Beakers

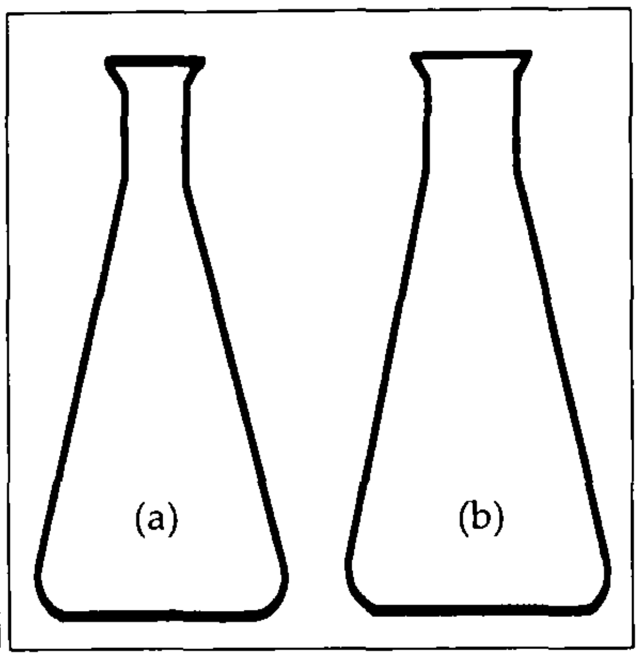


Figure 9. Erlenmeyer flasks
(a) with a narrow mouth
(b) with a wide mouth

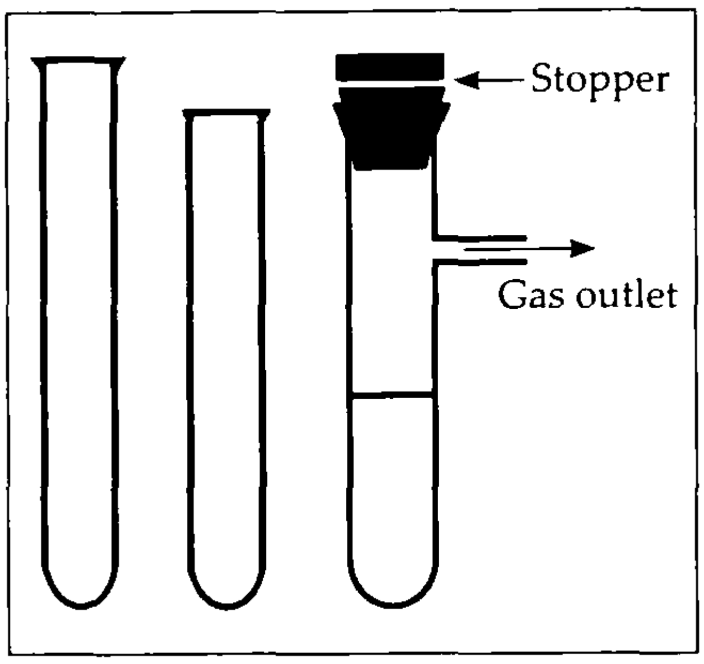


Figure 10. Test tubes

References and Further reading

1. http://www.astm.org/Standards/laboratory-testing-standards.htm