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Volumetric Glassware

A REAGECON GUIDE

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1.0 Volumetric Glassware:

1.1. Introduction

Volume measurement is one of the routine tasks in the laboratory. Typical volumetric instruments, such as one-mark and graduated pipettes, burettes, volumetric flasks and cylinders are therefore part of the basic requirement. Volumetric equipment are either calibrated 'to contain' (In) or 'to deliver' (Ex).

1.1.1. 'To Contain':

The contained quantity of liquid corresponds exactly to the capacity indicated on the instrument. However, the delivered quantity differs and is reduced by the residue adhering to the wetted glass surface, (e.g. graduated cylinders and volumetric flasks).

1.1.2. 'To deliver'

The delivered quantity of liquid corresponds exactly to the capacity indicated on the instrument, as the wetting residue remaining has already been taken into account, (e.g. graduated and bulb pipettes and burettes).

For the laboratory various types of technical glasses with different properties are available. Soda-lime glass has good chemical and physical properties suitable for short-term chemical exposure and limited thermal stress. Borosilicate glass has very good chemical and physical properties with very good chemical and thermal resistance.

1.2. General Guidelines for use and general Information on Volumetric Laboratory Glassware:

1.2.1 Volumetric Flasks ('to contain'):

These flasks are used in diluting a sample or solution to a certain volume. Volumetric flasks come in a variety of sizes from 1L or more to 1mL and are designed 'to contain' an accurate volume at the specified temperature (20 or 25°C) when the bottom of the meniscus (i.e. the concave curvature of the upper surface of water in a column caused by capillary action) just touches the etched 'fill' line across the neck of the glass.
For ambient temperature fluctuations, the volume can be considered constant, as the coefficient of expansion is small.

Good Laboratory Practice:
When using a volumetric flask, a solution should be diluted stepwise. The solution to be diluted is added to the flask, and the diluent (usually distilled water) is added to fill the flask about two-thirds (ensuring that any reagent on the ground glass lip is rinsed down). It helps to swirl the flasks' solution before diluent is added to obtain most of the mixing (or dissolving in the case of a solid).
Diluent is then added so that the bottom of the meniscus is even with the middle of the calibration mark (at eye level).

If there are any droplets of water on the neck of the flask above the meniscus, blot these out with a tissue paper. Dry the ground-glass stopper joint.

The solution is then thoroughly mixed. Keeping the stopper on securely by using the thumb or palm of the hand, invert the flask and swirl or shake it vigorously for 5 or 10 seconds. Turn right-side-up and allow the solution to drain from the neck of the flask. Repeat 10 times.

1.2.2. Pipettes('to deliver'):

A pipette is used to transfer a particular volume of solution. It is often used to deliver a certain fraction (aliquot) of a solution. Two common types of pipettes are used in laboratories; the volumetric or transfer pipette and the measuring pipette. Pipettes are designed 'to deliver' a specified volume at a given temperature. The volume can be considered to be constant with small changes in temperature.

Pipettes are calibrated to account for the drainage film remaining on the glass walls. This drainage film will vary somewhat with the time taken to deliver, usually the solution is allowed to drain under the force of gravity and the pipette is removed shortly after the solution is delivered. A uniform drainage time should be adopted.

a. Volumetric/transfer pipette

The volumetric/transfer pipette is used for accurate measurements, since it is designed to deliver only one volume and is calibrated at that volume. Accuracy to 4 significant figures is generally achieved, although 5 significant figures may be obtained with proper calibration.

Note: Most volumetric pipettes are calibrated to deliver with a certain small volume remaining in the tip. This should not be shaken or blown out.

In delivering, the pipette is held vertically and the tip is touched on the side of the vessel to allow smooth delivery without splashing and so that the proper volume will be left in the tip. The forces of attraction of the liquid on the wall of the vessel will draw out a part of this. Volumetric pipettes are available in sizes of 100 to 0.5ml or less.

b. Measuring pipettes

Measuring Pipettes are straight-bore pipettes that are marked at different volume intervals. These pipettes are not as accurate as volumetric pipettes because of nonuniformity of the internal diameter which will have a relatively larger effect on total volume than is the case for pipettes with bulb shape. Also, drainage film will vary with the volume delivered. At best, accuracy to 3 significant figures can be expected from these pipettes – unless the pipette is calibrated to deliver a given volume. Measuring and serological pipettes are available in sizes from a total capacity of 25 to 0.1mL. These pipettes may be used for accurate measurements (especially small volumes) if they are calibrated at the particular volume required. Larger measuring pipettes usually deliver too quickly to allow drainage as fast as the delivery and these too have a large bore for accurate reading.

Good Laboratory Practice:

In using a pipette, one should always wipe the tip dry after filling. If a solvent other than water is used, or if the solution is viscous, pipettes must be recalibrated for the new solvent or solution to account for the difference in drainage rate.

Pipettes are filled by suction, using a rubber pipette bulb or other pipetting device. Corrosive or toxic solutions must never be pipetted by mouth.

In general, some pipettes are 'blowout' types (including measuring pipettes calibrated to the entire tip volume). The final volume of solution must be blown out from the tip to deliver the calibrated amount. The solution is not blown out until the pipette has completely drained by gravity. Blowing to increase the rate of delivery will change the volume of the drainage film. These pipettes are easy to identify, the word BLOWOUT and/or a white enamelled (etched or sandblasted) band, 3 to 5 mm wide approximately 15-20mm from the top of the suction tube.

Note: Coloured rings are used as coding for the volume of the pipette, ref. ISO 1769, Laboratory Glassware – Pipettes – Colour coding.

c. Other pipettes:

Syringe pipettes:

These may be used for both macro and micro volume measurements. While the calibration marks may not be accurate, the reproducibility can be excellent if an automatic deliverer is used, such as a spring load device that draws the plunger up to the same preset level each time.

The volume delivered is free from drainage errors as the solution is forced out by the plunger. The volume delivered may be accurately calibrated. µLitre syringe pipettes are used for the introduction of samples into Gas Chromatographs. These pipettes are useful for accurate delivery of viscous solutions and volatile solvents.

Syringe pipettes with a disposable tip are convenient for rapid, one-hand dispensing of fixed volumes in routine procedures, widely used in the clinical chemistry laboratory.

The disposable non-wetting plastic tip reduces both film error and contamination. A thumb button operates a spring-loaded plunger, which stops at an intake or a discharge stop, the latter stop is beyond the former to ensure complete delivery. The sample never contacts the plunger being contained entirely in the plastic tip. These pipettes are available in volumes of 1 to 1000µL being reproducible to 1 to 2%. When using such pipettes, precision in delivery is usually more important than the absolute volume delivered. Frequently the actual volume delivered does not need to be known, because they are used in relative measurements.

1.2.3. Burettes('to deliver'):

A burette is used for the accurate delivery of a variable amount of solution. Principally used in titrations, where a standard solution is added to the sample solution until the end-point is reached. Burettes may be obtained in 10, 25, 50 and 100mL capacities, where the volume delivered can be read to the nearest 0.01mL. Microburettes are available in capacities down to 2mL volume marked in 0.01mL. Ultramicroburettes of 0.1mL capacity with graduations of 0.11mL (1µL) are used for microlitre titrations.

Burettes are available where titrant is dispensed by a teflon plunger. The plunger is moved by a micrometer or digital read-out dial. This may be calibrated in µL intervals as small as 0.002µL per division or less.

For conveniental burettes, drainage film is a factor, this may be a variable if the delivery rate is not constant.

Good Laboratory Practice:

The usual practice is to deliver at a fairly slow rate; about 15 to 20mL per minute, and then wait several seconds after delivery to allow the drainage to 'catch up'. In practice, near the end point the rate of delivery is only a few drops per minute, hence there is no major difference between flow rate and drainage rate. Fractions of a drop may be administered as the end-point is approaching by 'cracking' open the stop-cock and then touching the tip of the burette to the wall of the titration vessel. The fraction of a drop should then be washed down into the solution with distilled water.

1.2 Care and Use of Volumetric Glassware:

1.3.1. Cleaning of Volumetric Glassware:

To attain greatest accuracy glassware should be efficiently cleaned, obvious loose contamination should be removed mechanically from the glass vessel, by shaking with water and brushing. Oil or grease may be removed by suitable solvents. The vessel should then be almost filled with an aqueous solution of a soapless detergent and shaken vigorously. Then repeatedly rinsed with distilled water, until all traces of detergent are removed.

To ascertain whether a piece of glass apparatus is satisfactorily clean, it should be observed during filling. For a delivery vessel, which should be filled from below the liquid surface (i.e. through the stopcock in the case of the burette and through the jet of a pipette). The rising liquid meniscus shall not change shape i.e. it shall not crinkle at its edges. After over-filling and drawing a little liquid, the surface of the glass shall be again uniformly wetted and the meniscus shall not crinkle at the edges.

If the walls are not sufficiently clean – then the vessel should be filled with either one of the following:

(i) A mixture of equal parts of a saturated solution of potassium dichromate and conc. sulfuric acid.

(i) A mixture of equal parts of 30g/l solution of potassium permanganate ($KmnO_4$) and a 1mol/l solution of sodium hydroxide (NaOH)

A residue of MnO_2 will result, this can be removed by dilute HCl or oxalic acid. The vessel should then be rinsed with distilled water and one should then ascertain if the walls are sufficiently clean; if the vessel is not sufficiently clean then the above procedure should be repeated.

Finally vessels cleaned should be kept filled with distilled water if not required for immediate use.

Cleanliness of glassware is of the utmost importance. If films of dirt or grease are present, liquids will not drain uniformly and will leave water breaks or droplets on the walls.

- Pipettes should be rotated to coat the entire surface with detergent
- Small volumetric flasks can be filled with detergent/cleaning solution. While larger volumetric flasks may be partially filled and tilted and rotated to coat the entire surface.
- After cleaning the volumetric glassware must be rinsed thoroughly with tap water and finally with several small portions of distilled or deionised water.

Prior to use:

Pipettes and burettes should be rinsed at least twice with the solution with which they are to be filled. If they are wet, they should be rinsed with water and then a minimum of 3 times with the solution to be used. About 1/5 of the volume of the pipette or burette is adequate for each rinsing.

A volumetric flask if wet should be rinsed with 3 portions of water prior to use.

Note:
Analytical Glassware should not be dried in an oven or with a towel or by rinsing with a volatile organic solvent e.g. acetone (used in organic chemistry labs). The glassware usually does not have to be dried, it can simply be rinsed with the solution that will fill it.

Ref. Annex A BS6696 : 1986 Recommended method for cleaning of Volumetric Glassware.

1.2. Calibrated Glassware

Volumetric glassware is a measuring instrument and its accuracy should be no less reliable than any other. It may be certified or uncertified (more expensive when accompanied by certificate as glassware has been tested to meet specifications).

Important Definitions:
Delivery Time: The time in seconds for the delivery of a specified volume of liquid from a burette or pipette by a standard procedure excluding drainage time.
Waiting Time: Time in seconds before the reading is taken.

1.2.2. Introduction:

Most countries have their own glassware specifications. In the US there is 3 bodies with 3 individual specifications for laboratory glassware: USP, ASTM and ACS. All other countries have their own regulatory bodies.
In Europe there are two bodies; the European Body for Standards and the International Organisation for Standardisation (ISO), these two organisations work very closely together. All ISO standards have been accepted by europeans.
In Britain glassware is manufactured to meet BS specifications. However, the familiar BS (British Standard) is being replaced by ISO standards. (e.g. The ISO9000 replaced the quality management system BS5750).
In Germany, glassware is manufactured to meet DIN standard specifications.

1.4.2. Glassware Classifications:

It is common in DIN, BS, ISO and American systems(USP) to have glassware calibrated to 2 different levels of accuracy; Class A and Class B. Very often though not always the tolerances for Class A glassware are half those for Class B.

1.4.3. Volumetric Flasks 'To Contain':

- DIN and BS Class A flasks comply with the ISO standard (published last year)
- USP Class A flasks have tighter tolerances than those outlined in DIN, BS and ISO standards

The table below illustrates the tolerances for USP Class A Volumetric Flasks as compared to DIN/ISO/BS specifications.

Table 1: Tolerances of Class A Volumetric Flasks (USP, DIN, ISO and BS) BS1792:1982(93) (ISO1042:1983)

Size	USP	DIN/ISO/BS
25ml	±0.03	±0.04
50ml	±0.05	±0.06
100ml	±0.08	±0.10
500ml	±0.15	±0.25

1.4.4. Measuring Cylinders – 'To Contain'

- DIN and BS standards for measuring cylinders do not conform to ISO (ISO standard not written as yet)
- There is a BS standard for Class B measuring cylinders
- As there is no BS standard for Class A measuring cylinders, some British glass manufacturers adopted the USP Class A standard specifications.
- There are DIN Class A and Class B standards for measuring cylinders
- The USP Class A standard has much tighter specifications than the DIN Class A tolerances.

1.4.5. Bulb Pipettes, Graduated Pipettes and Burettes – 'To deliver'

General Information:

- For Class B glassware 'to deliver' there is no difference between BS and DIN specifications
- In practice, there is a major difference between BS and DIN Class A specifications, all DIN Class A glass (to deliver) involves a long waiting time*
- BS Class A glassware 'to deliver' does not have a waiting time but enforced a controlled time of flow.
- USP Class A glassware 'to deliver' does not have a waiting time but enforced a controlled time of flow.

(*Waiting time for DIN Class A glassware: one has to allow liquid to run from the vessel and wait 30 seconds prior to taking the reading, allowing time for the liquid to drain down the walls of the vessel).

- The DIN Class A glassware is virtually defunct due to the impractical long waiting times involved. Hence, the DIN Class AS standard was developed, the Class AS glassware still has a waiting time but it is much shorter than 30 seconds.

- DIN Class AS standard uses the same accuracy tolerances as BS Class A.

- It is hoped that current discussion in the ISO committee, will help resolve and differentiate between Class B, A, and AS.

a. Bulb Pipettes:

- Class A pipettes (USP) specifications differ from the ISO and BS specifications, USP specifications being tighter on some volumes and identical in others.

The table below illustrates specifications for Grade A bulb pipettes (USP, DIN, ISO, BS)

Table 2: Specifications for Bulb Pipettes (USP, DIN, ISO, BS)(ISO648)

Size	USP	DIN/ISO/BS
1ml	±0.006	±0.008
2ml	±0.006	±0.01
5ml	±0.01	±0.015
10ml	±0.02	±0.02

b. Graduated Pipettes:

- Class A pipettes (USP) specifications differ from the ISO and BS specifications, USP specifications being tighter on some volumes and identical in others.

The table below illustrates the specifications for graduated pipettes Type 2* (USP, DIN, BS, ISO)

Table 3: Specifications for Grade A Graduated Pipettes Type II* (USP, DIN, ISO, BS)(ISO835)

Size	USP	DIN/ISO/BS
1ml	±0.006	±0.006
5ml	±0.02	±0.03
10ml	±0.03	±0.05
25ml	±0.05	±0.10

***Type 2 graduated pipette with zero at outlet and capacity indicated at top, non blowout**

Type 1 : Graduated pipette calibrated to deliver with zero at the topand capacity indicated at shoulder, non blowout
Type 3: Graduated pipette calibrated to deliver from zero at the top to any graduation line down to jet, non blowout
Type 4: Graduated pipette calibrated to deliver with zero at the top down to jet with last drop expelled by blowing

d. Burettes:

- USP Class A burettes specifications are identical to that of BS Class A burettes.

The table below illustrates the specifications for burettes (USP/BS) as per BS 846 :1985(93), ISO385/1; 385/2

Table 3a: Specifications for Grade A Burettes, (USP/BS) BS846:1985(93) ISO385/1;385/2

Size & graduation capacity	USP/BS/ISO Specification	Delivery Time Seconds Min/Max
25ml in 0.05	±0.03	70-100
25ml in 0.1	±0.05	45-75
50ml in 0.1	±0.05	60-100
100ml in 0.2	±0.10	60-100

1.5. Important Documentation and Guidelines: Governing the design and construction of volumetric glassware

1.5.1. Specification for Principles of design and construction of volumetric glassware for laboratory use: BS 5898 :1980, ISO 384-1978

This document outlines the principles of design and construction of glassware, including:

- Volumetric accuracy i.e. Class A or B
- Graduation patterns – 3 types
- Inscriptions
- Colour coding pipettes – ISO1769, BS 3996
- Delivery and waiting times to be specified
- Setting meniscus guidelines
- Configuration of graduation lines

The inscriptions on glassware should be the following:

- A number indicating the nominal capacity
- Symbol cm^3 or ml to indicate the unit
- '20°C' to indicate the standard reference temperature
- 'In' indicates the article in constructed 'to contain'
- 'Ex' indicates the article is constructed 'to deliver'
- 'A'/'B' to indicate the class of accuracy to which the article is intended to belong
- To indicate that the article is intended for use with a specified waiting time e.g. 'Ex + 15s'
- Vendors/makers name

In addition, all Class A (and if desired, Class B) should have the following inscriptions:

1.An ID no. with the same no. marked on the handles of stopcocks, if required and on stoppers which are not interchangeable

2. If glass stoppers are interchangeable then the stopper and neck should be marked with the joint size according to ISO383.

3. On articles with delivery through a jet the time in seconds for unrestricted delivery of the contents using pure water

4. Name/chemical formula of liquid if the article of volumetric glassware was specifically constructed for direct reading of capacity when used with a specified liquid other than water.

5. The limit of volumetric error valid e.g. ±ml.

6. Finally, articles of glass having a coefficient of thermal expansion outside the range $25x10^{-6}K^{-1}$ to $30x10^{-6}K^{-1}$ (outside range of soda-lime glass). This should be indicated so that during calibration the appropriate correction table may be selected.

7. The word BLOWOUT and/or a white enamelled (or etched or sandblasted) band 3-5mm wide approximately 15-20mm from the top of the suction tube.

1.6. Calibration of Glassware

The guidelines outlined below are as per British Standards Methods for Use and testing of capacity of volumetric glassware: BS 6696: 1986, ISO 4787-1984.
This International Standard provides methods for the testing of volumetric glassware in order to obtain the best accuracy in use.

a. Test-laboratory requirements:
Full temperature control (air conditioning):
The standard reference temperature, i.e. the temperature at which the article of volumetric laboratory ware is intended to contain or deliver its nominal volume shall be 20°C.

Atmospheric Pressure Barometer – capable of providing atmospheric pressure measurements consistent with appropriate tolerances is required having limits of error of 1 mbar.

Certified Thermometer – required to measure the temperature of the water. Its limit of error shall be 0.1°C.

Accurate (to 5 decimal places) calibrated weighing balance
A laboratory balance is required with sufficient capacity to weigh the loaded vessel. A single-pan balance self-indicating instrument or an equal-arm balance of adequate capacity may be used.
The balance shall have a discrimination not greater than 1/10 of the limits of error of the instrument to be tested.

1.6.1. Factors affecting the accuracy of the volumetric laboratory ware:

In general, the same sources of error are naturally inherent both in testing and in use. In the former every attempt is made to reduce these errors to a minimum. In the latter, the care needed is dependent upon the degree of accuracy required; when the greatest possible accuracy is desired, the article should be used (as nearly as possible) in the manner in which it is tested.

Temperature of the vessel:

The capacity of a glass vessel varies with change of temperature; the particular temperature at which a vessel is intended to contain or deliver its nominal capacity is the “reference temperature” of the vessel.

Temperature of the liquid:

The temperature of the water used for the testing of volumetric glassware shall be accurately measured to within ±0.1°C. Corrections for differences in temperature from the reference temperature are applied. When using volumetric glassware it is important to ensure that all solutions used in connection with each other are close to a common temperature when their volumes are measured.

Cleaning and Drying of Glassware:

- Wash and clean glassware thoroughly
- Ensure that a satisfactory method of cleaning is employed, since any contamination will affect the meniscus shape/level.
- During calibration it is critical that all internal surfaces are clean and dry to avoid moisture droplets and contaminants.

The volume contained in or delivered by a glass vessel depends on the cleanliness of the internal glass surface of the vessel. Lack of cleanliness can give rise to error through a badly shaped meniscus involving two defects,
(i) incomplete wetting of the glass surface, i.e. the liquid surface meets the glass at an appreciable angle instead of forming a curve such that it meets the glass tangentially.
(ii) a generally increased radius of curvature, due to contamination of the liquid surface reducing the surface tension.

1.6.2. Some Considerations in calibrating glassware:

Reading Meniscus:

The meniscus is read so that the plane of the upper edge of the graduation line is horizontally tangential to the lowest point of the meniscus the line of sight being in the same plane. Lighting should be arranged so that the meniscus appears dark and distinct in outline. It should be viewed against a white background and shaded from undesirable illumination.

Delivery time:

For vessels/articles of glassware for delivery of a liquid, the volume delivered is always less than the volume contained, due to the film of liquid left on the walls of the vessel. The volume of the film depends on the time taken to deliver the liquid, and the volume delivered decreases with decreasing delivery time. Therefore, such a vessel can deliver a particular volume for one value only of the delivery time.

Delivery times are specified in the international standards of volumetric glassware adjusted for delivery, using water as the liquid.

The delivery time may be marked on burettes/pipettes made to Class A tolerances which enables one to determine whether the jet is damaged and/or blocked (by measuring the delivery time).

The table below indicates the appropriate ISO documentation for use and testing of capacity of volum etric glassware.

Table 4: The British standard BS6696:1986, ISO 4787 – 1984- Use and testing of capacity of volumetric glassware: (outlining the specifications for calibrated glassware)

Ref	Glassware
ISO385/2	Lab glassware Burettes part 2 – burettes for which no waiting time is specified
ISO385/3	Burettes for which a waiting time of 30s is specified
ISO648	Lab glassware – one-mark pipettes
ISO835/1	Graduated pipettes Part 1 – general requirements
ISO835/2	Graduated pipettes Part 2 – pipettes for which no waiting time is specified
ISO835/3	Graduated pipettes Part 3 –pipettes for which a waiting time of 15s is specified
ISO835/4	Graduated pipettes part 4 – blow out pipettes
ISO1042	Lab glassware – one mark volumetric flasks
ISO 4788	Lab glassware – Graduated measuring cylinders

In summary, the general procedure is based upon a determination of volume of water either contained in or delivered by the vessel. This volume of water is based upon knowledge of its mass and its tabulated density.

1.7. Calibration Test Procedure:

a. Cleaning and Drying:

Wash, clean and dry glassware thoroughly. Ensuring that a satisfactory method of cleaning is employed since any contamination will affect the meniscus shape/level. During calibration it is critical that all internal surfaces are clean and dry to avoid moisture droplets or contaminants.

b. Timing Delivery:

Delivery glassware should be timed before calibration to ensure that total delivery time is within tolerances specified by the relevant British and ISO standards.
The table below illustrates specifications for one mark bulb pipettes as outlined in ISO 648 : 1977

e.g. Table 5: One Mark Bulb pipettes: as per ISO 648 : 1977

Capacity ml	Colour code	Delivery time in seconds	Max. allowed observed difference in seconds
1.0	Blue	10-20	2
2.0	Orange	10-25	2
3.0	Black	10-25	2
4.0	2 red	10-25	2
5.0	White	15-30	3
10.0	Red	15-40	3
15.0	Green	15-40	3
20.0	Yellow	25-50	4
25.0	Blue	25-50	4
50.0	Red	30-60	5
100.0	Yellow	40-60	5

c. Weigh and Tare

With delivery glassware such as pipettes and burettes, weigh and tare a suitably sized weighing vessel. Balances should accurately read to five decimal places. Glassware should be maintained at a controlled room temperature (air conditioning).

d. Filling

Fill with purified water a few millimetres above the graduation line. Pipettes and burettes should be filled from below, i.e. through the tip. If burettes are filled from the top for added convenience, take care to avoid wetting the walls above the upper graduation line and check that no air is entrapped in the stopcock. For pipettes and burettes control the flow of excess liquid from the tip to allow the meniscus to settle exactly on the calibration line. For flasks and cylinders remove excess water to match the meniscus and calibration line exactly using a pipette and bulb.

e. Setting the Meniscus

When setting the meniscus ensure that the glassware is vertical. Ensure parallax error is avoided by viewing the meniscus from a level height against a white background. A black shade should be secured either around the article to be tested or placed behind it. The shade should be below the setting height (approx. 1mm lower). Ensure the meniscus edge is smooth, straight and level.

f. Calculation of Final Result:

(i) For graduated/bulb pipettes and burettes, dispense water into the tared weighing vessel and weigh. For flasks and cylinders weigh the tared and filled glassware. Record the result from the balance.
(ii) Use a certified Class A thermometer to measure the water temperature. Add the water temperature correction figure from Tables outlined in BS1797 (note the type of glassware i.e. borosilicate or soda/lime).

(iii) Measure the barometer reading and air temperature and add (or subtract if minus) the correction figure in the appropriate table outlined in BS1797. This gives the final gravimetric result which has already been converted to the volumetric figure in millilitres.
(iv) This result is compared to that set out in the ISO/BS specification tables.

The procedures outlined above must be followed to ensure consistently accurate results are obtained.

See table below for Specifications on volumetric flasks as set out in ISO/BS tables

e.g. Volumetric flasks:
Table 6 : BS1792:1982(93) ISO 1042 : 1983

Capacity ml	Class A accuracy limits ±ml	Stopper size
5	0.025	10/13
10	0.025	10/13
15	0.03	10/13
20	0.04	10/13
25	0.04	10/13
50	0.06	10/13
100	0.10	12/14

The following page illustrates a certificate that would accompany a certified, calibrated piece of glassware.
In the laboratory one should employ Good Laboratory Practice and check calibrate Class A Volumetric glass on receipt before allowing it into the laboratory for general use.

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volac

SPECIMEN

CALIBRATED GLASSWARE

Correction Certificate of Test

CLASS A

This **Burette** No. 11587 has been gravimetrically tested in our Works for conformity with BS 846 and ISO 385 and found to deliver at 20°C. in 95 Seconds as follows:-

GRADUATION MARK	RESULT OF TEST	
10	10.00	
20	20.01	ml
30	30.02	
40	40.01	(cm_3)
50	50.00	

Accuracy of Determination + 0.02 ml.

The allowed tolerance for Class A is ± 0.05 ml.

The Burette has been tested on Balance No. 551 This Balance is regularly checked with weight set Nos. 163140790 & 165471091 which has been certified by European Instruments traceable to the National Physical Laboratory.

Date 4-3-01 Signed

Time of outflow is marked on all articles calibrated for delivery. Such time is within the limits specified in the appropriate British Standard.

Poulten & Graf Ltd.

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Makers of Laboratory and Industrial Glassware

1.8. Worked Example:

Following instructions as outlined in section 7.7. for a One mark 5ml bulb pipette (Borosilicate).

		RESULT/VALUE
Type of Glass	Borosilicate	
Clean & Dry	Yes	
Time Delivery[d]		20Sec (spec. 15-30)
Tare and weigh vessel	Yes	
Fill to meniscus	Yes	
Dispense water to vessel	Yse	
Record weight		4.9999
Water temperature Correction figure [b]		21°C
Net weight		+0.015 5.0149
Barometer reading		102kPa/765mmHg
Air temperature		25°C
Correction figure [c]		-
Final result in millilitres		5.0149ml
Specification as per appropriate table (!SO 648 1977) [d]		±0.015
PASS specifications		

NOTES:

a. **Refer to Table 7**
b. **Refer to Table 8**
c. **Refer to Table 9**
d. **Refer to Table 10**

Table 7: Water Temperature Correction Table (Soda Lime Glass)

British Standard Schedule (BS1797).

	NOMINAL CAPACITY ml	TEMPERATURE OF WATER t°C										
		20	21	22	23	24	25	26	27	28	29	30
SODA LIME GLASS	1	0.003	0.003	0.003	0.0035	0.0035	0.004	0.004	0.0045	0.0045	0.005	0.005
	2	0.0055	0.006	0.0065	0.007	0.0075	0.0075	0.008	0.0085	0.009	0.0095	0.0105
	3	0.009	0.009	0.010	0.010	0.011	0.012	0.012	0.013	0.014	0.015	0.015
	4	0.011	0.012	0.013	0.014	0.015	0.015	0.016	0.017	0.018	0.019	0.021
	5	0.014	0.015	0.016	0.017	0.018	0.019	0.021	0.022	0.023	0.024	0.026
	10	0.028	0.030	0.032	0.034	0.036	0.039	0.041	0.043	0.046	0.049	0.051
	15	0.043	0.045	0.048	0.051	0.055	0.058	0.062	0.065	0.069	0.073	0.077
	20	0.057	0.061	0.064	0.069	0.073	0.077	0.082	0.087	0.092	0.097	0.103
	25	0.071	0.076	0.081	0.086	0.091	0.097	0.103	0.109	0.115	0.122	0.128
	50	0.142	0.151	0.161	0.171	0.182	0.193	0.205	0.217	0.23	0.243	0.257
	100	0.284	0.303	0.322	0.343	0.364	0.387	0.41	0.435	0.46	0.486	0.513
	200	0.570	0.610	0.640	0.69	0.73	0.77	0.82	0.87	0.92	0.97	1.03
	250	0.710	0.760	0.810	0.86	0.91	0.97	1.03	1.09	1.15	1.22	1.28
	500	1.42	1.51	1.61	1.71	1.82	1.93	2.05	2.17	2.30	2.43	2.57
	1000	2.84	3.03	3.22	3.43	3.64	3.87	4.1	4.35	4.60	4.86	5.13
	2000	5.69	6.06	6.45	6.86	7.29	7.74	8.21	8.69	9.20	9.72	10.26

Table 8: Water Temperature Correction Table (Borosilicate Glass)

British Standard Schedule (BS1797).

	NOMINAL CAPACITY ml	TEMPERATURE OF WATER t°C										
		20	21	22	23	24	25	26	27	28	29	30
BOROSILICATE GLASS	1	0.003	0.003	0.0035	0.0035	0.0035	0.004	0.004	0.0045	0.0045	0.005	0.0055
	2	0.0055	0.006	0.0065	0.007	0.0075	0.008	0.0085	0.009	0.0095	0.010	0.0105
	3	0.009	0.009	0.010	0.010	0.011	0.012	0.013	0.013	0.014	0.015	0.016
	4	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.018	0.019	0.020	0.021
	5	0.014	0.015	0.016	0.017	0.019	0.020	0.021	0.022	0.024	0.025	0.027
	10	0.028	0.030	0.033	0.035	0.037	0.040	0.042	0.045	0.047	0.050	0.053
	15	0.043	0.046	0.049	0.052	0.056	0.059	0.063	0.067	0.071	0.075	0.080
	20	0.057	0.061	0.065	0.070	0.074	0.079	0.084	0.089	0.095	0.100	0.106
	25	0.071	0.076	0.081	0.087	0.093	0.099	0.105	0.112	0.118	0.125	0.133
	50	0.142	0.152	0.163	0.174	0.186	0.198	0.210	0.223	0.237	0.251	0.265
	100	0.284	0.305	0.326	0.348	0.371	0.395	0.42	0.446	0.473	0.501	0.530
	200	0.570	0.610	0.650	0.700	0.74	0.79	0.84	0.89	0.950	1.00	1.06
	250	0.710	0.760	0.810	0.870	0.93	0.99	1.05	1.12	1.18	1.25	1.33
	500	1.42	1.52	1.63	1.74	1.86	1.98	2.1	2.23	2.37	2.51	2.65
	1000	2.84	3.05	3.26	3.48	3.71	3.95	4.2	4.46	4.73	5.01	5.3
	2000	5.69	6.09	6.52	6.96	7.42	7.91	8.41	8.93	9.47	10.03	10.6

Table 9: Air Pressure and Temperature Correction

Use for both Soda Lime and Borosilicate Glass. Add (+) or subtract (-) from weight reading.
British Standard Schedule (BS1797).

AIR TEMP °C		15°C				20°C				25°C			
AIR PRESSURE KPa		98	100	102	104	98	100	102	104	98	100	102	104
AIR PRESSURE mmHg		735	750	765	780	735	750	765	780	735	750	765	780
NOMINAL CAPACITY (ml)	1	—	—	—	—	—	—	—	—	—	—	—	—
	2	—	—	—	—	—	—	—	—	—	—	—	—
	3	—	—	—	—	—	—	—	—	—	—	—	—
	4	—	—	—	—	—	—	—	—	—	—	—	—
	5	—	—	—	—	—	—	—	—	—	—	—	—
	10	—	—	—	—	—	—	—	—	-0.001	—	—	—
	15	—	—	—	+0.001	-0.001	—	—	—	-0.001	—	—	—
	20	—	—	+0.001	+0.001	-0.001	—	—	+0.001	-0.001	-0.001	—	—
	25	—	—	+0.001	+0.001	-0.001	—	—	+0.001	-0.001	-0.001	—	—
	50	-0.001	—	+0.001	+0.002	-0.002	-0.001	—	+0.001	-0.003	-0.002	-0.001	—
	100	-0.002	—	+0.003	+0.005	-0.004	-0.001	+0.001	+0.003	-0.005	-0.003	-0.001	+0.001
	200	—	—	+0.01	+0.01	-0.01	—	—	+0.01	-0.01	-0.01	—	—
	250	—	—	+0.01	+0.01	-0.01	—	—	+0.01	-0.01	-0.01	—	—
	500	+0.01	—	+0.01	+0.02	-0.02	-0.01	—	+0.01	-0.03	-0.02	-0.01	—
	1000	-0.02	—	+0.03	+0.05	-0.04	-0.01	+0.01	+0.03	-0.05	-0.03	-0.01	+0.01
	2000	-0.03	+0.01	+0.05	+0.1	-0.07	-0.03	+0.01	+0.06	-0.11	-0.07	-0.03	+0.02

Note: Tables compiled from data in BS 1797 -1987. Complete standards and tables can be obtained through National Standards Bodies

Table 10: One mark bulb pipettes as per ISO 648:1977 (BS 1583:1986 (93))

Capacity ml	Colour code	Delivery time in seconds	Max. allowed observed difference in seconds	Class A accuracy Limits ±ml
1.0	Blue	10-20	2	0.008
2.0	Orange	10-25	2	0.01
3.0	Black	10-25	2	0.015
4.0	2 red	10-25	2	0.015
5.0	White	15-30	3	0.015
10.0	Red	15-40	3	0.02
15.0	Green	15-40	3	0.025
20.0	Yellow	25-50	4	0.03
25.0	Blue	25-50	4	0.03
50.0	Red	30-60	5	0.05
100.0	Yellow	40-60	5	0.08