

Basic Instruments Used in Clinical Chemistry Laboratory: A Mini Review

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Abstract

Clinical chemistry is an area of laboratory medicine that deals with the analysis of body fluids for diagnostic, therapeutic, and research purposes. Modern laboratory practice in industrialized nations has long progressed beyond piecemeal manual techniques and uses completely automated systems with minimum human intervention, allowing many tests to be performed by analytical machines with the minimal need of an analyst. Nevertheless, there is need for understanding the basic instruments used in clinical chemistry laboratory especially in resource limited settings where there is unavailability of advanced instruments. This review x-rayed the common and basic instruments in clinical chemistry highlighting the underlying principles, maintenance and storage.

Keywords: Clinical Chemistry, Instruments, Diagnosis, Automation.

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1.0 INTRODUCTION

Clinical chemistry is one of the branches of Laboratory medicine which is concerned with the analysis of bodily fluids for diagnostic, therapeutic or research purposes. Clinical Chemistry is a polyglot discipline combining chemistry, biochemistry, immunochemistry, endocrinology, toxicology (abused and therapeutic drug testing), analytical chemistry, engineering, informatics and doubtless other specialties, to provide the necessary support to physicians and other healthcare providers to improve the diagnosis and treatment of patients (David *et al.*, 2018). Clinical chemistry is the biochemical analysis of body fluids in support of the diagnosis and treatment of disease. Testing in this specialty utilizes chemical reactions to identify or quantify levels of chemical compounds in bodily fluids. Clinical chemistry refers to the biochemical analysis of body fluids. It uses chemical reactions to determine the levels of various chemical compounds in bodily fluids (Susha, 2019). Several simple chemical tests are used to detect and quantify different compounds in blood and urine, the most commonly tested specimens in clinical chemistry.

Early on, Clinical Chemistry relied on traditional analytical methods such as atomic absorption,

flame emission photometry, gasometry, potentiometry and amperometry, spectrophotometry, immunonephelometry (for competitive and sandwich immunoassays) and electrophoresis and the wide variety of analysers needed for these methodologies. Modern laboratory practice in developed nations has long moved beyond piecemeal manual procedures and uses fully automated systems (Kumar and Gill, 2018). Automation is the use of various control systems for operating equipments and other applications with minimum human intervention. The use of automation in clinical laboratory enables to perform many tests by analytical instruments with minute use of an analyst. The automated instruments have advantages that laboratories can process more workload with minimum involvement of manpower (Kumar and Gill, 2018). Also, automation minimizes the chances of variability of results and errors that generally can occur during manual analysis. The use of integrated computer hardware and software into analyzers has made the job very easy for clinical laboratories as it provides automatic process control and data processing. The use of automated analyzer has many advantages including reduction of workload, less time consumption per sample analysis, more number of tests done in less time, use of minute amount of sample,

decreased chances of human errors, and high accuracy and reproducibility (Kumar and Gill, 2018).

Techniques such as spectrophotometry, immunoassays, and electrophoresis are also used in clinical chemistry to measure the concentration of substances such as glucose, lipids, enzymes, electrolytes, hormones, proteins, and other metabolic products present in human blood and urine (Susha, 2019). Some of the common specimens analyzed in the clinical chemistry laboratory are; serum, plasma, urine, CSF etc.

2.1. Clinical Chemistry Analyzer

Clinical chemistry analyzers are laboratory equipment that tests clinical samples such as blood serum, plasma, urine, and cerebrospinal fluid to detect analytes related to body metabolism, disease, or drugs. They are used in small clinics, research laboratories, and large clinical laboratories. They allow the detection of analytes that commonly include enzymes, metabolic products, electrolytes, specific proteins, drugs of abuse and therapeutic drugs. The results provide information on kidney, heart, liver function and toxicological status (Kalstein, 2021).

Among the recommendations that are provided for the use of chemistry analyzers is that they have an adequate supply of water of the highest quality, use exclusively the reagents supplied or suggested by the commercial company, and that the laboratory staff be highly trained in using equipment. Onboard refrigerated reagent storage, connection to a water supply and

automated recalibration allow long periods of operation without intervention.

Benefits Offered by Chemical Analyzers

- A. The analyzers are highly automated to maximize performance
- B. They improve user safety against biological hazards, and decrease the risk of cross contamination.
- C. They offer process speed, consistency of results and prevent cross contamination.

A probe measures an aliquot of sample and places it in a reaction vessel. Reagents are added from a refrigerated supply on board. Incubation time is allowed, if necessary; then the photometric or ion selective electrode (ISE) test determines the analyte concentration. Results are displayed on the screen or sent to a printer or computer (Kalstein, 2021).

Care of Chemical Analyzers

This type of analyzers need both preventive and corrective maintenance. The first has the advantage that it allows adequate continuity in the operation of the equipment, reducing the frequency, duration and cost of interruptions for repairs, improving the quality of service that the laboratory can provide. It is important to know that proper hygiene and handling of this equipment can significantly extend its useful life. In the same way, the maintenance of the chemical analyzers must be carried out in the hands of a professional from time to time; depending on use and model.



Fig. 1: Chemistry analyzer (Kalstein, 2021)

2.2. Laboratory Water Bath

This is a laboratory equipment that helps in maintaining constant temperature providing heat source for varieties of devices that need heating. They serve a very important function in incubation of samples. The circulating water bath is used to keep water at a constant temperature for incubating samples in a laboratory. A water bath generally consists of a heating unit, a stainless-steel chamber that holds the water and samples, and a control interface (Samruddhi, 2021). Different types of water baths offer additional functionality such as a circulating water bath that keep a more even

temperature or a shaking water bath that keeps the samples in motion while they are heated. The inbuilt anticorrosion circulating pump can provide circulating constant temperature heat source for glass reactor and rotary evaporator. The liner of Lamphun GY series circulating water bath is made from imported stainless steel, shell is made from excellent cold rolled steel sheet spraying plastics, and electric heated tube plays the function of enhancing heating speed in conduction oil. It is protected by heat insulation cotton, and Lamphun has improved the instruments. Some water baths have smart PID constant temperature heating device, double-screen

LED temperature-controller which has been widely praised for its accuracy in temperature control and controllable output flow (Samruddhi, 2021).

Working Principle of Water Bath

The sensor transfers the temperature of water to resistance value, amplified and compared by integrated amplifier, then gives out the output via the control signal, efficiently control the average heating power of electric heating tube and maintain water in constant temperature.

Uses of Water Bath

- A laboratory water bath is used to heat samples.
- Some applications include maintaining cell lines or heating flammable chemicals that might combust if exposed to open flame (Samruddhi, 2021).

Types of Water Bath

- i. A shaking water bath in action
- ii. Circulating water baths
- iii. Non circulating water baths

2.2.1. Shaking Water Baths

This type of water bath has extra control for shaking, which moves liquids around. This shaking feature can be turned on or off. In microbiological practices, constant shaking allows liquid-grown cell cultures grown to constantly mix with the air (Samruddhi, 2021).

Some key benefits of shaking water bath are;

- They are user-friendly operation via keypad
- They have convenient bath drains
- The shaking frequency can be adjusted
- They are usually incorporated with bright LED-display
- They normally have lift-up bath cover
- Usually, power switch are integrated in keypad
- They also have warning and cut-off protection for low/high temperature.

2.2.2. Circulating Water Baths

Also called stirrers, are ideal for applications when temperature uniformity and consistency are critical, such as enzymatic and serologic experiments. Water is thoroughly circulated throughout the bath resulting in a more uniform temperature.

2.2.3. Non-Circulating Water Baths

This type of water bath relies primarily on convection instead of water being uniformly heated. Therefore, it is less accurate in terms of temperature control. In addition, there are add-ons that provide stirring to non-circulating water baths to create more uniform heat transfer (Samruddhi, 2021).

Operation of Water Bath

1. Connect the power supply.

2. Ensure the water level in water bath is sufficient to pour the heating element.
3. Switch "ON" the main power supply and instrument mains.
4. For temperature settings, Press SET key to set the required temperature. press ↑ to increase the temperature and ↓ to reduce the temperature
5. The temp. Sensor will maintain the set temp. During use of water bath.
6. Switch "OFF" the instrument mains & main power supply after use (Samruddhi, 2021).

Safety in the use of Water Bath

- Excessive water should not be added, so as not to overflow during water is boiling for settings up to boiling point.
- After using the water bath, you should drain away water in time, clean the working chamber, so as to extend life span of instrument.
- Always ensure platform and surrounding are dry.
- Use only clean water to fill water bath.
- Always switch "OFF" the mains after using the water bath.
- Do not disturb the capillary (Temperature Sensor) located near the heater (Samruddhi, 2021).

Maintenance of Water Bath

- Regular maintenance of the water bath should always be carried
- Only clean water should be used in filling the water bath. Distilled or deionized water work best, as tap water often has minerals that can build up over time and make cleaning more difficult. It's important to never use anything but water in the pan, as other materials when heated can create hazardous fumes and/or cause a fire danger when heated.
- When the pan is removed for cleaning, ensure the unit is unplugged.
- Always wipe any debris off of the seal, and avoid spilling water into the unit to avoid damage to electrical components.
- Use only a damp cloth with mild detergents, avoiding any corrosive cleaning agents in cleaning the water bath.
- Unit must be turned off each day to avoid water evaporation and overheating of unit.
- Discard any old water in the pan.
- When cleaning the unit with pan removed, care must be taken not to damage the thermostat. Damage could cause the unit to overheat.
- To prevent electrical shock do not remove ground prong. Use only in properly grounded outlet.
- Unplug the unit before any maintenance or repair.

- The removable stainless-steel pan and lift tray can be autoclaved with other instruments as needed (Samruddhi, 2021).

Following these simple Water Bath maintenance and care tips can help ensure its longevity.



Fig. 2: Water bath (Samruddhi, 2021).

2.3. Micropipette

A micropipette is a common yet an essential laboratory instrument used to accurately and precisely transfer volumes of liquid in the microliter range. Micropipettes are available in single channel and multi-channel variants. While the single channel micropipettes are used in labs that perform research related to molecular biology, microbiology, immunology, cell culture, analytical chemistry, biochemistry and genetics, the multichannel micropipettes are recommended for

ELISA (diagnostic test), molecular screening, kinetic studies and DNA amplification (Microlit, 2021).

Components of a Micropipette

Micropipettes are available in different designs and sizes. However, there are certain components that are basic and common to all the micropipettes. These include the plunger, digital display, tip cone, tip ejector and grippy. Certain micropipettes are provided with a calibration tool and a micropipette stand as an accessory.

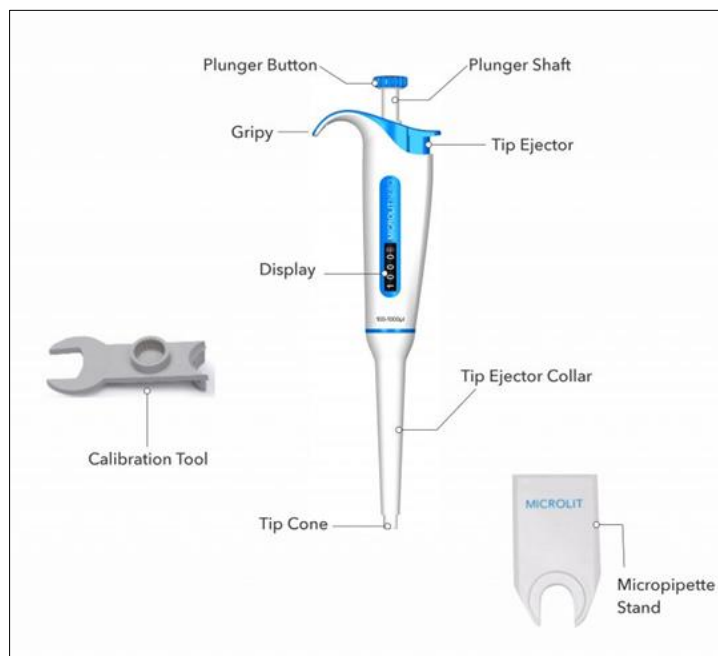


Fig. 3: Components of a micropipette (Microlit, 2021)

Plunger: The plunger performs the following two functions;

Volume Adjustment:

Rotating the plunger clockwise/ anticlockwise decreases/increases the volume setting. A distinct click

sound at every volume change ensures perfect volume setting and prevents any accidental volume change.

Liquid Aspiration/ Dispensing: Pressing and depressing the plunger aspirates or dispenses liquid.

Tip Ejector

The internal mechanism of the micropipette does not come in direct contact with the sample/liquid. Instead, a disposable pipette tip is used to draw the liquid into and dispense from the micropipette. So in order to allow the safe, effortless and quick ejection of tips, micropipettes are provided with a tip ejection system. The tips can be easily removed from the micropipette by pressing the tip ejector button (Microлит, 2021).

Volume Display: This shows the volume of the liquid to be aspirated or dispensed.

Tip Cone

The tip cone provides fitment to the tips. A micropipette with a universal tip cone is preferred as it enhances the compatibility of the instrument with most of the standard tips.

Types of Micropipette

Micropipettes can be classified depending upon:

1. Working Principle
2. Operating Mechanism
3. Number of Channels
4. Volume/Capacity

1. Working Principle

a. Air Displacement Micropipette

This type of micropipette works on the air displacement principle. It consists of a piston which aspirates and dispenses liquid samples as the air pocket moves up and down, respectively. The internal mechanism of the pipette does not come in direct contact of the sample/liquid. Instead, a disposable pipette tip is used to draw the liquid into and dispense from the pipette (Microлит, 2021).

b. Positive Displacement Micropipette

In these micropipettes, the piston comes in direct contact of the sample. The disposable tip in a positive displacement micropipette is a microsyringe composed of a capillary and a piston (movable inner part) which directly displaces the liquid.

2. Operating Mechanism

a. Mechanical Micropipette

These micropipettes are operated manually based on a piston-shaft spring mechanism.

b. Electronic Micropipette

An electronic micropipette is mostly automated. The aspirating and dispensing of liquid is performed by the one touch buttons instead of manual plunger pressing and depressing. Electronic pipettes also

often enable the user to create custom programs on the device allowing the pipettes to suit diverse application needs (Microлит, 2021).

3. Number of Channels

a. Single Channel Micropipette

A single channel micropipette is the one which has a single channel to aspirate or dispense the liquid.

b. Multi-Channel Micropipette

A multi-channel micropipette has multiple channels to aspirate or dispense the liquid. The commonly available multi-channel micropipette variants are the 8 channel, 12 channel and 16 channel. Multichannel micropipettes reduce the workload of a single channel micropipette when working with large volumes of samples (Microлит, 2021).

4. Volume/Capacity

a. Fixed Volume Micropipette

In a fixed volume micropipette, the volume of liquid to be aspirated or dispensed remains fixed. These micropipettes are used when the same volume of liquid is to be dispensed multiple times.

b. Variable Volume Micropipette

This micropipette comes with a specific minimum and maximum volume range. The volume of the liquid to be aspirated or dispensed can be adjusted (within the instrument's volume range) depending upon the requirement of the user (Microлит, 2021).

Working Principle of a Micropipette

a. Air Displacement Micropipettes

These operate by piston-driven air displacement. When the piston is pressed downwards, the air within the sleeve of the micropipette gets expelled out due to the force of which the liquid present in the micropipettes tip also gets removed. When the piston moves upwards, a vacuum is created in the space left vacant by the piston. This causes the air from the tip to rise in order to fill the vacant space, and the tip air is then replaced by the liquid, which is drawn up into the tip.

b. Positive Displacement Micropipettes

They operate by piston-driven displacement. The piston in a positive displacement micropipette is in direct contact with the liquid. When the piston is pressed downwards, the liquid which is present in the sleeve of the micropipette also moves downwards and gets removed through the tip. When the piston is pulled upwards, it also draws the liquid along with it in the upward direction (Microлит, 2021).

Using an Air Displacement Micropipette

Precise measurement of liquid depends on the correct micropipette usage. The air displacement micropipettes work on the common air displacement principle. A plunger is depressed by the thumb and as it is released, liquid is drawn into a disposable tip. When

the plunger is pressed again, the liquid is dispensed. In between these steps, there are several small steps which

help in making the liquid dispensing process more precise (Microlit, 2021).



Fig. 4: Use of micropipette (Microlit, 2021)

Position 1: In this position, the micropipette is at rest. The micropipette is held in the right way without directly touching the tip.

Position 2: In this, the plunger is depressed till the first stop. To aspirate the liquid in the tip, the plunger is pressed to the first stop and pipette tip is immersed vertically in the liquid. The plunger is slowly released while the tip is still immersed in liquid. The liquid will be aspirated into the pipette tip. Liquid is filled in the tip as per preset micropipette volume.

Position 3: To dispense the liquid, the tip is placed on the inner wall of the receiving vessel at a steep angle. The plunger is pressed slowly to the first stop to dispense the liquid. To empty the tip completely, the plunger is pressed to the second stop. Wipe the tip on the inner wall while taking the tip out of the vessel (Microlit, 2021).

Some micropipettes deliver the fixed volume of liquid. However, majority are adjustable with the

variable volume setting. Variable volume micropipette comes with different ranges and upper and lower limits of measurement. In such cases, error percentage may vary as per the measured liquid. Trying to dispense less than the lower value of the range will result in inaccurate liquid measurements whereas trying to dispense over the upper range will completely fill the tip and allow the liquid to enter into the pipette body (Microlit, 2021).

Size and Range /Technical Specifications of Micropipette

Micropipettes are available in different volumes ranging from 0.1 μl to 10,000 μl . The commonly used variants of single channel variable volume micropipettes are listed below along with their permissible error limits as specified in the ISO 8655-2 standard. They are sometimes referred to as P10, P20, P1000, P5000 pipettes based on the maximum volume that can be aspirated/dispensed using the pipette. For instance, a 0.5-10ul micropipette may be commonly referred to as a P10 pipette (Microlit, 2021).

Table 1: Technical specifications of micropipettes (Microlit, 2021)

Volume Range (ul)	Classification	Increment (ul)	Accuracy (\pm %)	Accuracy (\pm ul)	CV (\pm %)	CV (\pm ul)
0.2-2	P2	0.002	2	0.04	1.2	0.024
0.5-10	P10	0.02	1	0.1	0.5	0.05
2-20	P20	0.02	0.8	0.16	0.4	0.08
5-50	P50	0.1	0.8	0.4	0.4	0.2
10-100	P100	0.2	0.6	0.6	0.2	0.2
20-200	P200	0.2	0.6	1.2	0.2	0.4
100-1000	P1000	1.0	0.6	6	0.2	2
500-5000	P5000	10.0	0.6	30	0.2	10
1000-10000	P10000	20.0	0.6	60	0.2	20

Use of Micropipettes

It enables the convenient and precise handling of very small liquid volumes, making it of paramount importance to most laboratory work, and has contributed significantly to the rapid progress of molecular biology.

Cleaning, Maintenance and Storage of a Micropipette

The care and maintenance of a micropipette is an important routine in laboratories. Implementing a proper maintenance schedule can reduce the cost of a new purchase of this expensive equipment. Cleaning the micropipette takes time, focus and practice; otherwise the micropipette can be damaged. So, it is important to handle the micropipette carefully while cleaning. Below are comprehensive guides for proper cleaning of micropipettes (Microlit, 2021).

External Cleaning:

Most of the pipette can be cleaned externally with typical laboratory cleaning agents, soaps or alcohol. To ensure the full sterilization, let the cleaning solution sit on the micropipette for 10-15 min before wiping it off.

Internal Cleaning:

Cleaning the interior of the micropipette can be more time consuming because it requires full disassembly. Also, every part of micropipette will need to be cleaned properly depending on the liquid used in sampling.

- Refer to the instructions manual for specific direction of micropipette
- Use a cotton swab with cleaning solution and distilled water
- Lightly grease the pistons with the lubricant provided upon purchase
- Reassemble all parts and check to ensure the micropipette operates smoothly

Contamination Cleaning:

If micropipette becomes contaminated with a known substance, there are specific cleaning steps that must be taken depending on the type of substance. Above cleaning routine will not be sufficient if the micropipette is cross-contaminated.

For Aqueous Solutions, Organic Solvents and Proteins

Rinse the contaminated parts with distilled water or 70 percent ethanol and air dry at approximately 60°F temperature.

For Infectious Liquids

Autoclave the lower section at a temperature of 120°C for 15-20 minutes then allow it to return at room temperature before reassembling (Microlit, 2021).

For Radioactive Substances: Place the pipette in a solution like Decon and then rinse and air dry.

For Nucleic Acids

Boil lower parts of micropipette in glycine/ HCl buffer (pH2) for 10 minutes, rinse with distilled water, and air dry.

A well-maintained and clean pipette ensures the lab safety from hazardous solutions. It makes the pipette more accurate, reliable, long-lasting and reduces the cost of sampling.

Storage of Micropipettes

Proper storage of micropipettes is as important as cleaning and calibrating them. The micropipette and its accessories should be stored in a clean, cool and dry place. The storage place should have a temperature ranging from -20 °C to 50 °C (from -4 °F to 120 °F) with relative humidity between 5% and 95%. Another point to be remembered is that the instrument should be stored in an upright position. To store pipettes, Microlit recommends the use of its carousel stand, Microlit Faveo (Microlit, 2021).

Points to Note When Pipetting

- a) Press and release the plunger slowly, at all times, particularly when working with high viscosity reagents/solutions. Make sure that the plunger does not snap.
- b) Make sure the tip is firmly attached to the tip cone.
- c) Before starting your experiment, fill and empty the tip 2-3 times with the reagent or solution that you will be pipetting.
- d) Hold the micropipette in an upright position while aspirating. The Grippy must rest on your index finger.
- e) Make sure that the tips, the micropipette and the reagent/solution are at the same temperature.

Pipetting Techniques

A. Forward Pipetting Technique:

- i. To aspirate the liquid in the tip, press the plunger to the first stop. Immerse the pipette tip vertically in the liquid.
- ii. Slowly release the plunger while the tip is immersed. The liquid will be aspirated into the pipette tip.
- iii. To dispense the liquid, place the tip on the inner wall of the receiving vessel at a steep angle
- iv. Slowly press the plunger to the first stop to dispense the liquid.
- v. To empty the tip completely, press the plunger to the second stop.
- vi. Wipe the tip on the inner wall while taking the tip out of the vessel (Microlit, 2021)

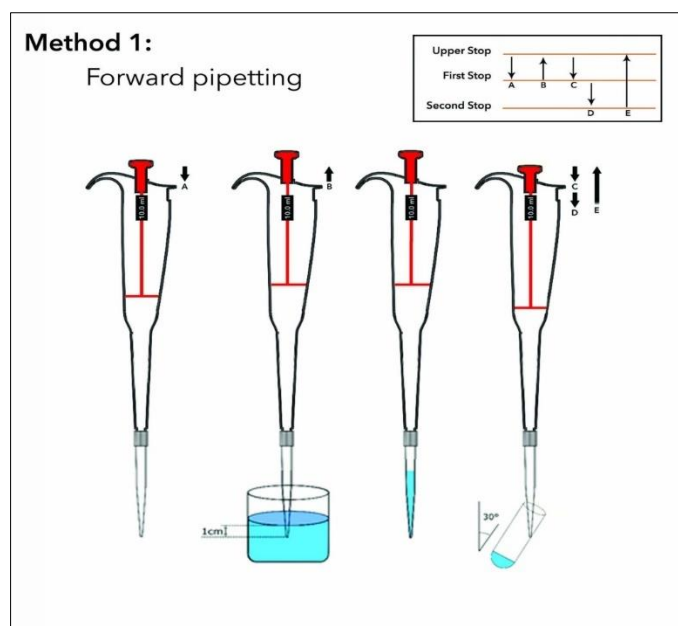


Fig. 5: Forward pipetting technique (Microlit, 2021)

B. Reverse Pipetting Technique:

The reverse technique is suitable for dispensing reagents/solutions that have a high viscosity or a tendency to foam easily. It is also recommended for dispensing very small volumes.

- i. To aspirate the liquid in the tip, press the plunger to the second stop and immerse the pipette tip vertically in the liquid.
- ii. Slowly release the plunger while the tip is immersed. The liquid will be aspirated into the pipette tip.
- iii. To dispense the liquid, place the tip on the inner wall of the tube at a steep angle.
- iv. Slowly press the plunger to the first stop.
- v. Wipe the tip on the inner wall while taking the tip out of the vessel.

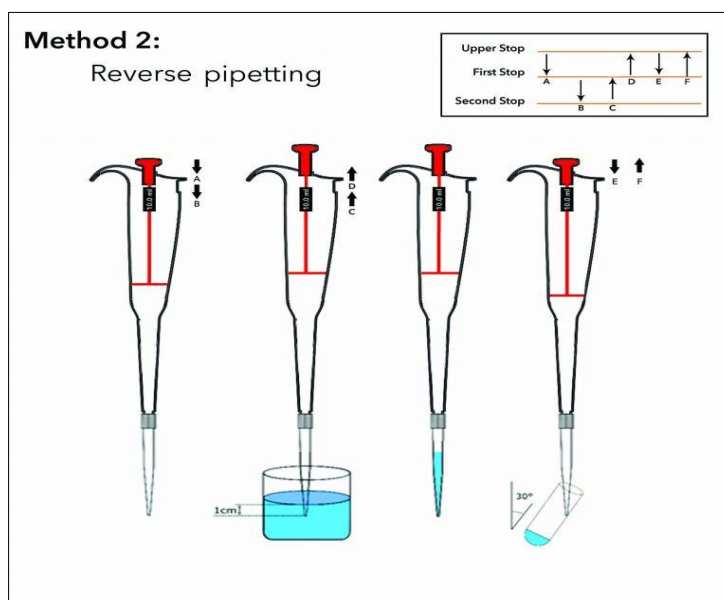


Fig. 6: Reverse pipetting technique (Microlit, 2021)

2.4. Test Tube

A test tube, also known as sample tube, is a common piece of laboratory glassware consisting of a finger-like length of glass or clear plastic tubing, open at the top and closed at the bottom. Test tubes intended for general chemical work are usually made of glass, for its relative resistance to heat. Tubes made from expansion-

resistant glasses, mostly borosilicate glass or fused quartz, can withstand high temperatures up to several hundred degrees Celsius (Pagana *et al.*, 2014). Chemistry tubes are available in a multitude of lengths and widths, typically from 10 to 20 mm wide and 50 to 200 mm long. The top often features a flared lip to aid pouring out the contents. A chemistry test tube typically

has a flat bottom, a round bottom, or a conical bottom. Some test tubes are made to accept a ground glass stopper or a screw cap. They are often provided with a small ground glass or white glaze area near the top for labelling with a pencil (Pagana *et al.*, 2014).

Material Types

There are several material types of test tubes: glass, plastic, metal and ceramic. Glass and plastic are the most common while metal and ceramic are less common. There are several sub-types of glass and plastic test tubes (Globalspec Engineering 360, 2022).

Glass Test Tubes: Glass test tubes are thick-walled and heat and/or chemical resistant. They are sometimes easier to see-through than plastic tubes, but often more expensive.

Fused Silica: This is suitable for applications that require good, long-term thermal stability.

Borosilicate Glass: This can withstand thermal shock and chemical attack, making it a common test tube material for chemistry applications.

Quartz Glass:

This combines high resistance to thermal shock with high transmission of infrared radiation (IR). Chemically pure and chemically resistant, it also has excellent high-temperature properties (Globalspec Engineering 360, 2022).

Kimble Chase (also called KIMAX): This is made of borosilicate glasses and resistant to breakage and chemical attack. It is sometimes disposable and/or recyclable.

Pyrex/Corning:

This is another propriety type of borosilicate glass. Like KIMAX, it has higher mechanical strength and heat resistance than some other types of commercial glasses.

Zerdour/ Schott Glass: This is a lithium aluminosilicate glass-ceramic with a very low coefficient of expansion (Globalspec Engineering 360, 2022).

Plastic Test Tubes:

Suppliers also provide test tubes made from a variety of plastic materials. These products have lighter weight and generally less expensive than glass tubes. They may also be resistant to ultraviolet (UV) light and pressure.

EPDM Tubes: These offer good resistance to sunlight, weathering, and the ozone. The suggested operating temperature for EPDM is -70°F to 275°F.

Fluoroelastomer: These products have good heat, oil and chemical resistance; however, they often have poor low-temperature performance.

Neoprene Tubes: These are useful over a wide range of temperatures and resist degradation from UV light.

Nitrile: This material of test tube has a suggested operating range of -30°F to 275°F, making it a good choice for some low-temperature applications (Globalspec Engineering 360, 2022).

Nylon and polyamide products: These have good pressure ratings and test tubes have high tensile-strength.

Polyethylene (PE) Test Tubes:

These have excellent chemical resistance, but poor temperature resistance. Polyethylene (PE) also has outstanding chemical properties, but is semi-opaque.

Plastic test tubes also include products made from polypropylene (PP), polytetrafluoroethylene (PTFE), polyurethane (PU), and polyvinyl chloride (PVC) (Globalspec Engineering 360, 2022).

Use of Test Tube

They are used to hold, mix and perform chemical reactions within them.

Test tubes come in different sizes but they are generally used to conduct small scale experiments, reactions, and investigations.



Fig. 7: Test tube (Safety and laboratory procedures, 2009)

2.5. Electrolyte Analyzer

The electrolyte analyser is a device for measuring the electrolytes in the human body. They are primarily used in the quantitative measurement of sodium, potassium, chloride, bicarbonate etc. in whole blood, serum, or plasma. The most common methods of electrolyte analysis are the flame emission photometry and ion-selective electrode (ISE). The ISE method of electrolyte measurement is based on the principle of potentiometry in which the voltage that develops between the inner and outer surfaces of an ISE (membrane) is measured. Some electrolyte analysers employ miniaturized ISE, which are fabricated in planar type. The optode technology does not use electrodes or contact points, which eliminates the need for costly electrode maintenance. Electrolyte analysers find applications for measurement of electrolyte levels in the human body to detect metabolic imbalances and measure renal and cardiac functions (Raghib, 2019).

Working Principle of Electrolyte Analyzer

Ion selective electrode is a kind of electrochemical sensor (also called electrode), the activity changes of specific ion could be converted into

the electrical potential changes of electrode, the relation accord with Nernst equation. "Ion-selective electrode" means that each electrode is only sensitive to one type of ions. For example, the Na electrode is only sensitive to Na⁺, but not sensitive to other ions. The key component of electrode is the ion-selective membrane. The two sides of membrane get contact with sample and internal Electrode Internal Solution respectively. The side touching with sample is responding to the ion concentrations change. The other side touch with internal Electrode. Internal Solution, the conversion from ion conduction to electron conduction is carried out by Ag/AgCl inner electrode. The reference electrode provides the reference potential to complete the measuring circuit. This electric potential does not change along with ion concentration, therefore providing a standard reference for measuring potential difference.

Advantages of Using Electrolyte Analyzers

- Operational flexibility
- Low maintenance
- Time saving calibrations
- Easy operation
- Precise control of calibrator volumes



Fig. 8: Electrolyte analyzer

2.6. Test Tube Rack

A test tube rack is a piece of laboratory equipment used to hold multiple test tubes upright at the same time. They are especially useful for organizing test tubes when different solutions are being worked on or collected at once. Test tube racks also provide protective storage for test tubes and make transporting and cleaning test tubes much easier. A laboratory rack for test tubes is also very important in providing safe and efficient environments for scientists and researchers etc. to work in without risk of contamination or broken test tubes (Marlin Steel Wire Products, 2021).

Types of Test Tube Racks

Test tube racks can be designed to be slanted, stackable, interlocking, or made specifically for drying. They are also available made from a variety of different materials.

1. Wooden Test Tube Racks

The first classic test tube racks were made of wood. While they look neat on a shelf as a vintage item, they are rarely used as they can become damaged during autoclave sterilization processes and are tough to sanitize, trapping bacteria (Marlin Steel Wire Products, 2021).



Fig. 9: Picture of wooden test tube rack (Marlin Steel Wire Products, 2021).

2. Stainless Steel Test Tube Rack

Stainless steel wire racks are highly effective as they are non-corrosive to bodily fluids, sterile, and can

hold test tubes during autoclave sterilization processes without becoming damaged.



Fig. 10: Picture of stainless steel test tube rack (Marlin Steel Wire Products, 2021)

3. Aluminium Test Tube Racks

Aluminum may be less expensive than steel wire, however, it is not as strong and is more likely to warp, deform, or bend underweight, force or heat.



Fig. 11: Picture of Aluminium test tube rack (Marlin Steel Wire Products, 2021)

4. Plastic Test Tube Racks

Plastic test tube racks, such as polypropylene test tube racks, Nalgene tube racks, and acrylic test tube

racks, were once thought to be the best solution for material handling due to perceived durability but they're more easily damaged than American steel racks.



Fig. 12: Picture of Plastic test tube rack (Marlin Steel Wire Products, 2021)

5. Foam Test Tube Racks

While they are economical, flexible enough to accommodate many types of test tubes, and able to float

in water baths, open-cell foam racks are easily damaged and are unable to be sterilized in an autoclave (Marlin Steel Wire Products, 2021).



Fig. 13: Picture of Foam test tube rack (Marlin Steel Wire Products, 2021)

Uses of Test Tube Racks

- I. They are used to hold upright multiple test tubes at the same time.
- II. They are most commonly used when various different solutions are needed to work with simultaneously.
- III. They are important for safety reasons.
- IV. They can be used for safe storage of test tubes.
- V. They are used to ease the transport of multiple tubes.

Benefits of Steel Wire Test Tube Racks

Greater Temperature Resistance:

With an operating range of -150 F to +1600 F (-101 C to +871 C) and the ability to withstand rapid or cyclic temperature fluctuations, stainless steel test tube racks easily outperform other types of racks (Marlin Steel Wire Products, 2021).

Better Corrosion Resistance:

Stainless steel resists corrosion in atmospheric and pure water environments and in most acids, alkaline solutions, and chlorine environments.

Cleaner:

Industrial oils, grease, and solvents can stain other types of test tube racks, making them harder to keep clean. Medical-grade stainless steel surfaces are more likely to maintain their original appearance, and with electropolishing, they're easier to sanitize and sterilize.

Stronger:

Steel has greater tensile strength and is more durable than other types of test tube racks. Ventilation holes designed for washing test tube racks also will not compromise the strength of a wire mesh or laser-cut sheet metal rack like it will plastic racks, for example.

Greater Versatility:

Steel can be coated with plastic to gain the benefits of both products. And, while plastics molding is limited, metal can be molded, shaped, cut, bent, welded, and assembled in a myriad of ways to meet specific needs (Marlin Steel Wire Products, 2021).

Greater Heat and Fire Resistance:

American-made steel racks can handle autoclave practices that expose them to high temperatures and steam to kill microorganisms. Special high chromium and nickel-alloyed steels also resist scaling and retain strength even at high temperatures. In contrast, other types of test tubes like those made of plastic may melt when exposed to flames, potentially releasing harmful chemicals in the process.

No Water Absorption:

Steel does not absorb water like plastic, wood, or foam test tube racks. Water absorption can also lead to bacterial growth that can be a health hazard or compromise samples or solutions (Marlin Steel Wire Products, 2021).

Less Expensive to Manufacture:

Steel test tube rack uses simple forming methods to make steel products whereas most plastics require a custom mold, requiring a high up-front tooling cost, which often restricts plastic for only very high volume applications.

Less Expensive Over Time:

When total life cycle costs are considered, including initial tooling, stainless steel is often a less expensive material option and its durability makes it a good long-term investment.

Greater Sustainability:

Plastic test tube racks break down faster than steel ones, but most are made from petroleum, a non-renewable, often imported resource. On the other hand, steel is recyclable and reusable with the ability to be melted down and repurposed. Because they can withstand cleaning and sterilization, steel test tube racks can be reused again and again, making them more sustainable and efficient than other means of holding test tubes (Marlin Steel Wire Products, 2021).

2.7. Spectrophotometer

The spectrophotometer is an instrument which measures the amount of light that a sample absorbs. Spectrophotometer techniques are mostly used to measure the concentration of solutes in solution by measuring the amount of the light that is absorbed by the solution in a cuvette placed in the spectrophotometer. The spectrophotometer works by passing a light beam through a sample to measure the light intensity of a sample. A spectrophotometer is made up of two instruments: a spectrometer and a photometer. The spectrometer is to produce light of any wavelength, while the photometer is to measure the intensity of light. The spectrophotometer is designed in a way that the liquid or a sample is placed between spectrometer and photometer (Byju, 2022). The photometer measures the amount of light that passes through the sample and delivers a voltage signal to the display. If the absorbing of light changes, the voltage signal also changes. Spectrophotometers come in a variety of shapes and sizes and have multipurpose uses to them. The different types of spectrophotometers available are all different from one another, based on their application and desired functionality (Byju, 2022). The most popular spectrophotometers are 45 degrees, sphere and multi-angle spectrophotometers. Another closely related concept is Spectroscopy, that simply measures the absorption of light from its source and the intensity of light as well. The basic spectrophotometer instrument consists of a light source, a digital display, a monochromator, a wavelength sector to transmit a selected wavelength, a collimator for straight light beam transmission, photoelectric detector and a cuvette to place a sample (Byju, 2022).

Basic characteristics of a spectrophotometer include:

- Determines how much light is reflected by a chemical.
- Measures the strength of light as a light beam travels through a sample solution.
- Objective calculation of visible light, UV light, or infrared light emissions or reflection.

Categories of spectrophotometer

A. Portable spectrophotometers – As the name suggests, this type of spectrophotometer can be carried around at anytime and anywhere. One can easily put it in the pocket and take out whenever it is needed.



Fig. 14: Handheld Portable spectrophotometer (A-Matrix, 2021)

B. Bench-top spectrophotometer – It is the ideal choice for laboratory-based procedures, especially in subjects that need the highest level of control and precision.

Types of Spectrophotometer

1. Single beam spectrophotometer
2. Double beam spectrophotometer
3. Split Beam spectrophotometer
4. Based on Light Wavelength, there are Ultraviolet-visible spectrophotometer, Visible spectrophotometer, Infrared spectrophotometer, Fluorescence spectrophotometer and Atomic absorption spectrophotometer.

1. Single Beam Spectrophotometer

This spectrophotometer is suitable for measuring absorbance or light transmittance at a given wavelength, generally not for full-band spectral scanning, requiring high stability of the light source and

detector. Its wavelength measurement is mostly between 200 nm - 1,020 nm. A single beam refers to the light emitted from a light source, passing through series of optical parts, absorption cell, and finally shining on the detector. It consists of a bunch of monochromatic light (the beam can only be alternately through the reference and sample solution), a cuvette, and a photoelectric converter. Work, a light path, first through the reference solution, and then through the sample solution for light intensity determination. Single-beam UV-visible spectrophotometer is characterized by simple structure and low price, mainly for quantitative analysis. However, the measurement results are sometimes affected by the power supply fluctuations causing greater error. So in general, single-beam UV-visible spectrophotometer is not suitable for high demanding facilities and quality inspection industries (Ramzy, 2021).



Fig. 15: Single beam spectrophotometer (Ramzy, 2021)

2. Double Beam Spectrophotometer

This affords automatic recording, fast full-band scanning. Eliminating the instability of the light source, the detector sensitivity changes and other factors, especially for structural analysis. Double beam UV-visible spectrophotometer utilizes two monochromators, you can get two different wavelengths of monochromatic

light. The two light beams alternately irradiate the same sample cell at regular intervals. Dual-wavelength spectrophotometer can not only measure high-concentration samples, multi-component mixed samples, but also perform better in the turbid samples with more sensitivity than the single beam machine (Ramzy, 2021).



Fig. 16: Double beam spectrophotometer (Ramzy, 2021)

3. Split Beam Spectrophotometer

The light emitted by the same monochromator is split into two beams, one of which reaches the detector directly and the other passes through the sample and

reaches the other detector. The advantage of this instrument is that it monitors errors in the light source, but does not eliminate the effects of the reference (Ramzy, 2021).



Fig. 17: Split beam spectrophotometer (Ramzy, 2021)

4. Based on Light Wavelength, there are:

A. Ultraviolet-Visible Spectrophotometer

This is used to measure the material of absorbance and quantitative analysis at the visible or

ultraviolet light (200 ~ 760nm). Nucleic acid and protein concentrations can be measured. UV spectrophotometer can be divided into single beam, split beam, double beam for different applications (Ramzy, 2021).



Fig. 18: Ultraviolet-visible light spectrophotometer (Ramzy, 2021).

B. Visible spectrophotometer

An instrument used to measure absorbance and conduct quantitative analysis at the visible light (400 ~ 760nm).



Fig. 19: Visible light spectrophotometer (Ramzy, 2021)

C. Infrared Spectrophotometer

The general infrared spectrum refers to the infrared spectrum greater than 760nm, which is the most commonly used spectral region of organic compounds and can analyze a variety of conditions (gas, liquid, solid) of the sample. Infrared spectroscopy is

characterized by fast, low sample volume (a few micrograms to a few milligrams), strong characterization (various substances have their own specific infrared spectrum), tests capable of analyzing various states (gas, liquid, solid) without damaging the sample (Ramzy, 2021).



Fig. 20: Infra-red spectrophotometer (Ramzy, 2021).

D. Fluorescence Spectrophotometer

Fluorescence spectrophotometers are instruments used to scan the fluorescence spectrum emitted by liquid fluorescent labels, which is widely used in scientific research, chemical industry, medicine, biochemistry, environmental protection, clinical testing, food testing, teaching experiments and other fields

(Ramzy, 2021). Through the determination of these parameters, the equipment is not only for general quantitative analysis, but also can infer the molecular conformational changes in various environments, thus clarifying the relationship between molecular structure and function (Ramzy, 2021).



Fig. 21: Fluorescence spectrophotometer (Ramzy, 2021).

E. Atomic Absorption Spectrophotometer

The method is mainly applied to detect trace components in the sample analysis. It is a powerful tool for material analysis and elemental analysis of trace metals (semimetals). A flame evaporates water from the sample causing it to dissociate into ions. The dissociation

leads to changes in the intensity of light as seen by the detector. Hence, help in finding out the concentration of the sample. Atomic absorption spectrophotometer's high precision analysis is useful in toxicology, environmental testing, and quality control laboratories.



Fig. 22: Atomic absorption spectrophotometer (Ramzy, 2021).

Parts of a Spectrophotometer

The basic spectrophotometer instrument consists of the following:

- A light source - there are two light sources used in a spectrophotometer. They are a tungsten lamp which generates visible light and a deuterium or hydrogen lamp which generates UV light.
- A digital display - an internal circuit inside a spectrophotometer gives out a final output on a digital meter. The readings in a digital meter can be noted down, and a standard graph between absorption and transmittance can be plotted accordingly (Mary and Laura, 2021).
- A monochromator - monochromators produce radiations of a single wavelength.
- A wavelength sector - to transmit a selected wavelength.
- A collimator - for straight-line beam transmission - It is an optical device containing a tube with a convex lens on one side and an aperture on the other end.
- Photoelectric detector - A photocell is a photoelectric device that converts light energy into electrical energy. This is then amplified, detected, and recorded.
- A cuvette to place a sample - cuvettes are optically transparent cells made of glass, silica, plastic, or quartz.

Functions of Spectrophotometers

Spectrophotometry is a scientific technique used to measure the intensity of light either transmitted through or reflected from gas, liquid, or solid samples. The spectrophotometer is the instrument used for this technique. The functions and benefits of a spectrophotometer include:

Transmission

The spectrophotometer measures how much a substance absorbs a beam of light passing through it. Transmission is directly related to absorbance as stated by Beer-Lambert's law. Beer-Lambert's Law is an equation that relates the attenuation of light to the properties of a material. The law states that the concentration of a chemical is directly proportional to the absorbance of a solution (Mary and Laura, 2021).

Measurement

By measuring the intensity at each wavelength, a spectrum is created, and the information created tells us about the sample through which the light passed.

Reflectance

The spectrophotometer measures the amount of light that is reflected from an opaque specimen (Mary and Laura, 2021).

Working Principle of Spectrophotometers

The spectrophotometer is an instrument which measures the amount of light that a sample absorbs. The spectrophotometer works by passing a light beam through a sample to measure the light intensity of a sample.

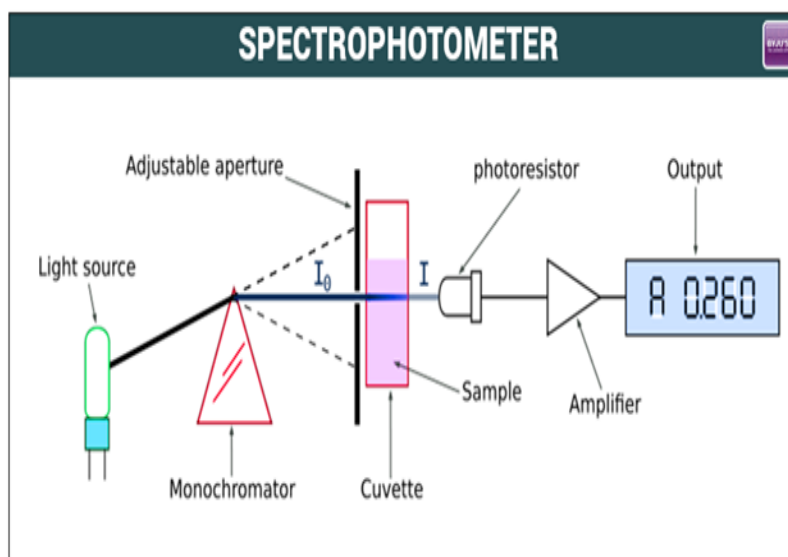


Fig. 23: Internal arrangement of a spectrophotometer (Byju, 2022)

Working of a Spectrophotometer

- A sample solution is placed inside the spectrophotometer.
- A light source shines light toward the sample.
- A device called a monochromator splits the light into each color, or rather, individual wavelengths (just like a raindrop makes a rainbow). An adjustable slit allows only one specific wavelength of light through to the sample solution.
- The wavelength of light hits the sample, which is held in a little container called a cuvette. Cuvettes should be handled with care as even a slight fingerprint can interfere with the results.
- Whatever light passes through the sample is read and displayed on the output screen (Mary and Laura, 2021).

Uses of Spectrophotometer

- The spectrophotometer is essential in biochemical quantitative analysis of sample to determine the unknown concentration of the analytes (Ramzy, 2021).
- Enzyme assay is the primary use of spectrophotometry etc.

Care and Maintenance of Spectrophotometer

- Carefully clean the sample holder, especially after using corrosive or salt solutions.
- Mop up any spilt liquids and brush any spilt chemical from the spectrophotometer and adjacent areas.
- Wash the cuvettes immediately after use (do NOT let the sample dry out in the cuvette).
- Rinse the cuvettes with deionised water at least three times, allow them to drain and dry them inverted.

- The spectrophotometer case and sample compartment should be kept clean.
- Cleaning should be done with a soft cloth slightly dampened with water or a solution of water and a mild detergent. Do not use an excessively damp cloth that liquid can drip into the spectrophotometer.
- Use an electrical supply source that conforms with industry standards
- Place the spectrophotometer in a clean environment and away from other devices that cause vibration (such as centrifuges)
- Ensure routine maintenance by a trained and certified technician. Annual inspection would typically include the inspection of the area where the device is installed as well as electrical installation to ensure user safety
- Test the general structure of the device - check buttons, control switches
- Confirm that the mechanical components are in good condition
- Make sure accessories, cable devices and terminals are clean and intact
- Check the electrical components to avoid overheating.

2.8. Centrifuge

A laboratory centrifuge is a piece of laboratory equipment, driven by a motor, which spins liquid samples at high speed. A centrifuge is a machine that uses centrifugal force to separate the contents of a sample based on their density. A centrifuge is a device used to separate components of a mixture on the basis of their size, density, the viscosity of the medium, and the rotor speed. When the centrifuge spins, it creates a strong centrifugal force. Though separation would eventually happen naturally with Earth's gravity, the centrifuge machine delivers rapid results for laboratory and other

applications (Drucker diagnostics, 2019). There are various types of centrifuges, depending on the size and the sample capacity. Like all other centrifuges, laboratory centrifuges work by the sedimentation principle, where the centripetal acceleration is used to separate substances according to their densities (Susan and Mikkelsen, 2004). Because centrifuge machines are excellent at separating particles by density, they are often found in laboratory settings where it is necessary to isolate certain biological components for testing. In a blood sample, for instance, there are red blood cells and plasma mixed together. After centrifugation, the red blood cells will be at the bottom of the tube and the plasma will be on top. Centrifuging is necessary for research on particular components, such as separating out blood plasma for testing, isolating DNA, and even separating out urine sediment.

Working Principle of Centrifuge

At its core, centrifugation is separation through sedimentation. The denser particles sink to the bottom of the container, while the more lightweight particles remain suspended. Centrifugation will displace particles that are even slightly different in density, and is influenced by these four factors:

- The density of the samples and solution
- The temperature and viscosity
- The distance that the particles are displaced
- The speed of rotation

Relative centrifugal force (RCF), or G-force, is the amount of acceleration that is applied to the sample.

When RCF exceeds the buoyant and frictional forces in the sample, the particles will move away from the axis of rotation and result in sedimentation.

Types of Centrifuge

1. Benchtop Centrifuge

Benchtop centrifuge is a compact centrifuge that is commonly used in clinical and research laboratories. It is driven by an electric motor where the tubes are rotated about a fixed axis, resulting in force perpendicular to the tubes. Because these are very compact, they are useful in smaller laboratories with smaller spaces. Different variations of benchtop centrifuges are available in the market for various purposes. A benchtop centrifuge has a rotor with racks for the sample tubes and a lid that closes the working unit of the centrifuge.

2. Continuous Flow Centrifuge

Continuous flow centrifuge is a rapid centrifuge that allows the centrifugation of large volumes of samples without affecting the sedimentation rates. This type of centrifuge allows the separation of a large volume of samples at high centrifugal force, thus removing the tedious part of emptying and filling the tubes with each cycle. They have a shorter pathlength which facilitates the process of pelleting out the solid part out of the supernatant, thus maintaining the speed of the process. They also have larger capacities which saves time as the sample doesn't have to be load and unloaded over and over again like in traditional centrifuges. Up to 1 liter of samples can be centrifuged by this centrifuge at a time period of 4 hours or less.



Fig. 24: Thermo Scientific™ Sorvall™ ST 8 Small Benchtop Centrifuge (Thermo Scientific, 2018)



Fig. 25: Continuous flow centrifuge (Beckman, 2019)

3. Gas Centrifuge

A gas centrifuge is a centrifuge explicitly used for the separation of gases based on their isotopes. This centrifuge is based on the same principle of centrifugal force as all other centrifuges where the molecules are separated on the basis of their masses. This centrifuge is used mainly for the extraction and separation of uranium-235 and uranium-238. The gas centrifuge works on the design of the continuous flow of gas in and out of the

centrifuge, unlike other centrifuges working on batch processing. These centrifuges are arranged in cascades so that the gases are separated into two units based on their isotopes and then are passed onto the next centrifuge for further processing. Gas centrifuges have replaced other gaseous diffusion methods as they provide a yield of higher concentration of the gases than the previous techniques.

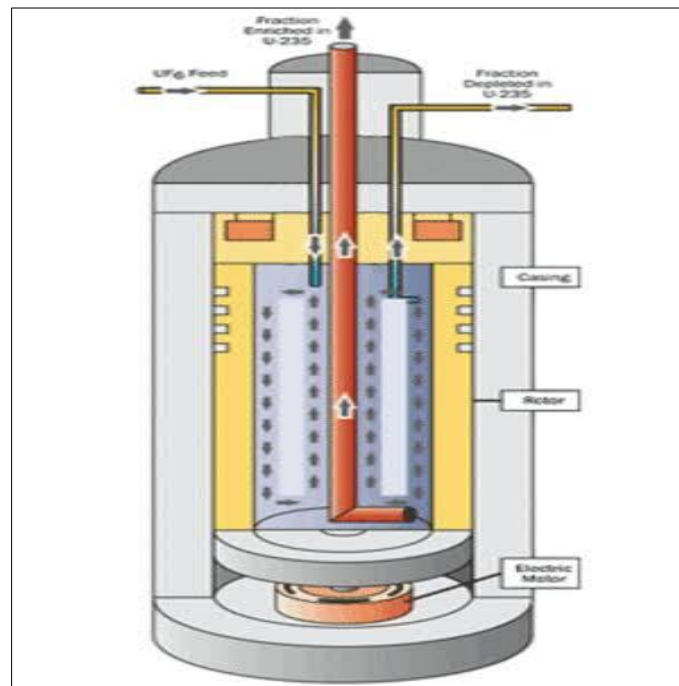


Fig. 26: Gas centrifuge (Beckman, 2019)

4. Hematocrit Centrifuge

Hematocrit centrifuges are specialized centrifuges used for the determination of volume fraction of erythrocytes (RBCs) in a given blood sample. This centrifuge provides hematocrit values that can be used for testing in biochemistry, immunity, blood test, and other general clinical tests. Hematocrit centrifuges may be used to help diagnose blood loss, polycythemia (an

elevation of the erythrocyte count to above-normal levels), anemia, bone marrow failure, leukemia, and multiple myeloma. The microhematocrit centrifuge quickly attains speeds of 11,000 rpm and RCFs of up to 15,000 g to spin tube samples. The components of a hematocrit centrifuge are similar to that of the benchtop centrifuge, but this centrifuge is specialized for the use of blood samples.



Fig. 27: Hematocrit Centrifuge (AHN Biotechnologie GmbH, 2018)

5. High-Speed Centrifuge

High-speed centrifuge, as the name suggests, is the centrifuge that can be operated at somewhat larger speeds. The speed of the high-speed centrifuge can range from 15,000 to 30,000 rpm. The high-speed centrifuge is commonly used in more sophisticated laboratories with the biochemical application and requires a high speed of operations. High-speed centrifuges are provided with a

system for controlling the speed and temperature of the process, which is necessary for the analysis of sensitive biological molecules. The high-speed centrifuges come with different adapters to accommodate the sample tubes of various sizes and volumes. All three types of rotors can be used for the centrifugation process in these centrifuges.



Fig. 28: Avanti JXN-30 Series High-speed centrifuge (Beckman Coulter, Inc., 2022).

6. Low-Speed Centrifuge

Low-speed centrifuges are the traditional centrifuges that are commonly used in laboratories for the routine separation of particles. These centrifuges operate at the maximum speed of 4000-5000 rpm. These are usually operated under room temperature as they are not provided with a system for controlling the speed or

temperature of the operation. Swinging bucket and fixed angle type of rotors can be used in these centrifuges. These are easy and compact centrifuges that are ideal for the analysis of blood samples and other biological samples. The low-speed centrifuge works on the same principle as all other centrifuges, but the application is limited to the separation of simpler solutions.



Fig. 29: Low-speed centrifuges – ScanSpeed 406 and ScanSpeed 416 (LaboGene, 2021)

7. Microcentrifuge

Microcentrifuges are the centrifuges used for the separation of samples with smaller volumes ranging from 0.5 to 2 μ l. Microcentrifuges are usually operated at a speed of about 12,000-13,000 rpm. This is used for the molecular separation of cell organelles like nuclei and DNA and phenol extraction. Microcentrifuges, also

termed, microfuge, use sample tubes that are smaller in size when compared to the standard test tubes used in larger centrifuges. Some microcentrifuges come with adapters that facilitate the use of larger tubes along with the smaller ones. Microcentrifuges with temperature controls are available for the operation of temperature-sensitive samples.



Fig. 30: Microfuge 16 and Microfuge 20 (Beckman Coulter, Inc., 2022)

8. Refrigerated Centrifuge

Refrigerated centrifuges are the centrifuges that are provided with temperature control ranging from -20°C to -30°C. A different variation of centrifuges is available that has the system of temperature control which is essential for various processes requiring lower temperatures. Refrigerated centrifuges have a temperature control unit in addition to the rotors and

racks for the sample tubes. These centrifuges provide the RCF of up to 60,000 xg that is ideal for the separation of various biological molecules. These are typically used for collecting substances that separate rapidly like yeast cells, chloroplasts, and erythrocytes. The chamber of refrigerated centrifuge is sealed off from the outside to meet the conditions of the operations.



Fig. 31: Allegra 64R Refrigerated Benchtop Centrifuge (Beckman Coulter, Inc., 2022).

9. Ultracentrifuge

Ultracentrifuges are the centrifuges that operate at extremely high speeds that allow the separation of much smaller molecules like ribosomes, proteins, and viruses. It is the most sophisticated type of centrifuge that allows the separation of molecules that cannot be separated with other centrifuges. Refrigeration systems are present in such centrifuges that help to balance the

heat produced due to the intense spinning. The speed of these centrifuges can reach as high as 150,000 rpm. It can be used for both preparative and analytical works. Ultracentrifuges can separate molecules in large batches and in a continuous flow system. In addition to separation, ultracentrifuges can also be used for the determination of properties of macromolecules like the size, shape, and density.



Fig. 32: Ultracentrifuges (Beckman Coulter, Inc., 2022).

10. Vacuum Centrifuge

Vacuum centrifuge utilizes the centrifugal force, vacuum and heat to speed up the laboratory evaporation of samples. These centrifuges are capable of processing a large number of samples (up to 148 samples at a time). This type of centrifuge is used in chemical and

biological laboratories for the effective evaporation of solvents present in samples, thus concentrating the samples. These are commonly used in high throughput laboratories for samples that might have a large number of solvents. A rotary evaporator is used to remove the unnecessary solvents and eliminate solvent bumping.

The centrifuge works by lowering the pressure of the chamber, which also decreases the boiling point of the

samples. This causes the solvents to be evaporated, concentrating the particles to be separated.



Fig. 33: Savant™ SpeedVac™ SPD120 Vacuum Concentrator and Kits (Thermo Scientific, 2022).

Parts of a Centrifuge

1. **A motor:** It is in the center that is very powerful and creates a spin.
2. **Containers:** These containers hold tubes with the materials/sample and it rests on the rotor.
3. **Control:** The types of control vary based on the centrifuge selected. Some are preprogrammed, and others are entirely customized with digital display. Regardless of the type of control, the centrifuge will run the motor based on the provided settings.

4. Centrifuge Rotors

Rotors in centrifuges are the motor devices that house the tubes with the samples. Centrifuge rotors are

designed to generate rotation speed that can bring about the separation of components in a sample. There are three main types of rotors used in a centrifuge, which are:

A. Fixed Angle Rotors

These rotors hold the sample tubes at an angle of 45° in relation to the axis of the rotor. In this type of rotor, the particles strike the opposite side of the tube where the particles finally slide down and are collected at the bottom. These are faster than other types of rotors as the pathlength of the tubes increases. However, as the direction of the force is different from the position of the tube, some particles might remain at the sides of the tubes.

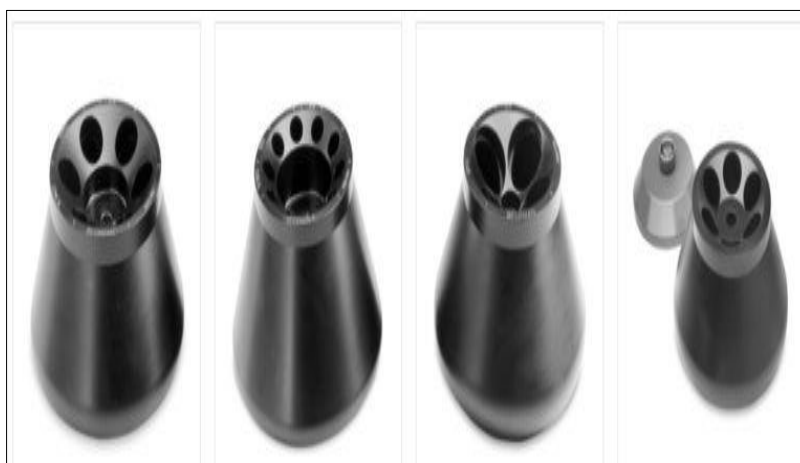


Fig. 34: Fixed angle rotors (Beckman Coulter, Inc., 2022).

B. Swinging Bucket Rotor

Swinging bucket rotors hold the tubes at an angle of 90° as the rotor swings as the process is started. In this rotor, the tubes are suspended in the racks that allow the tubes to be moved enough to acquire the horizontal position. In this type of rotors, the particles are

present along the direction or the path of the force that allows the particles to be moved away from the rotor towards the bottom of the tubes. Because the tubes remain horizontal, the supernatant remains as a flat surface allowing the deposited particles to be separated from the supernatant.



Fig. 35: Swinging bucket rotors/ Horizontal rotors (Beckman Coulter, Inc., 2022)

C. Vertical Rotors

Vertical rotors provide the shortest pathlength, fastest run time, and the highest resolution of all the rotors. In vertical rotors, the tubes are vertical during the operation of the centrifuge. The yield of the rotor is not

as ideal as the position of the tube doesn't align with the direction of the centrifugal force. As a result, instead of settling down, particles tend to spread towards the outer wall of the tubes. These are commonly used in isopycnic and density gradient centrifugation.



Fig. 36: Vertical rotors (Beckman Coulter, Inc., 2022)

Care and Maintenance of the Centrifuge Machine

Education:

Make sure that everyone who uses the centrifuge machine knows how to use it. Teach all laboratory staff how to balance samples, set speeds and take safety measures.

Inspection:

An inspection will alert members of staff about any problems with the centrifuge machine. Look at the components for scratches or effects of chemical exposure. All are signs of wear and should be fixed as soon as possible.

Awareness:

When using the centrifuge, be aware of signs that something is wrong. If the machine is shaking, vibrating or grinding, stop it immediately.

Cleaning and disinfection are key to ensuring good centrifuge functionality in the long term. Using a neutral cleaning solution (like an alcohol-based disinfectant) and a soft cloth, wipe the: Rotors, Rotor chamber, Accessories, Interior area etc (Drucker diagnostics, 2019).

2.9. Colorimeter

A Colorimeter is a light and sensitive laboratory device used to measure the transmittance and absorbance of light that passes through a liquid sample/analyte. The colorimeter device also measures the intensity or colour

concentration that develops upon introducing a particular reagent into a solution.



Fig. 37: Colorimeter (Biotech, 2017).

Parts of Colorimeter: There are 5 essential parts of a colorimeter

Light Source: The most common source of light used in colorimeter is a tungsten filament.

Monochromator: To select the particular wavelength filter or monochromators are used to split the light.

Sample Holder: Test tube or Cuvettes are used to hold the solutions/analytes, they are made up of glass at the visible wavelength.

Photo Detector System: When light falls on the detector system, an electric current is generated, this reflects in the galvanometer reading.

Measuring Device:

The current from the detector is fed to the measuring device, the galvanometer, shows the meter reading that is directly proportional to the intensity of light (Sahil, 2022).

Principle of Colorimeter

A colorimeter is based on the photometric technique which states that When a beam of incident light of intensity I_0 passes through a solution, a part of the incident light is reflected (I_r), a part is absorbed (I_a) and rest of the light is transmitted (I_t)

Working of a Colorimeter

When monochromatic light (light of one wavelength) reaches the cuvette, some of the light is reflected and some part of the light is absorbed by the solution and the remaining part is transmitted through the solution which falls on the photodetector system. The photodetector system measures the intensity of transmitted light and converts it into the electrical signals that are sent to the galvanometer. The galvanometer measures the electrical signals and displays them in the digital form. That digital representation of the electrical signals is the absorbance or optical density of the solution analyzed. If the absorption of the solution is high then there will be more light absorbed by the solution and if the absorption of the solution is low then more lights will be transmitted through the solution which affects the galvanometer reading and corresponds to the concentration of the solute in the solution (Sahil, 2022).

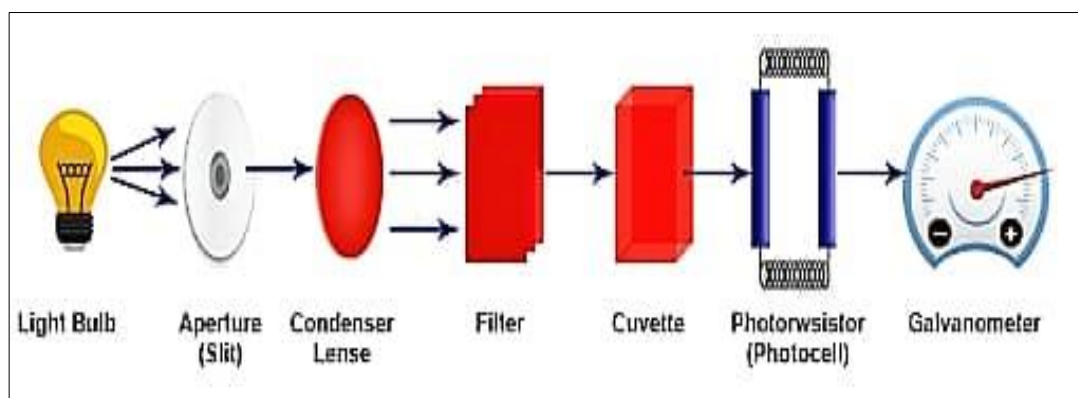


Fig. 38: Internal arrangement of a colorimeter (Sahil, 2022)

Application of Colorimeter in Clinical Chemistry

The colorimeter is commonly used for the determination of the concentration of analytes by measuring the optical density or its absorbance.

Care and Maintenance of the Colorimeter

- Users should always remove the cuvette from the instrument when not using it. If any optical marks are found on the cuvette, gently clean it with tissue paper.
- Switch off the colourimeter when not in use. This will help the lamp to have a much more lasting life and will also save energy.
- After the work is done, it is preferred to disconnect the plug from the switchboard and cover the colorimeter with its' protection cover.
- Make it a habit to always check the main power adapter and cable to know if there is any wear or tear.
- Prolonged use of the colorimeter instrument with even the slightest wear and tear can not only damage the machine but is also dangerous. Replace if the instrument is damaged.
- Always keep it in cool places and at room temperature.
- Do not keep it near harmful chemicals or burning materials.

2.10. Stop Watch

A stopwatch is used to measure the time interval of an event. It is a kind of watch that stands out for the accuracy and precision with which it can measure the time of an event. It works by pressing a start button and then stopping it. It is also known as a chronometer and is used to measure fractions of time and it is usually accurate. Basically there are two types of stopwatch, Digital stopwatch, and Analog stopwatch (Ox Science, 2020).

Types of Stopwatch

1. Digital Stopwatch
2. Mechanical or Analog Stopwatch

1. Digital Stop Watch

It is commonly used in laboratories, it can measure a time interval up to 0.01 second. It starts to indicate the time lapsed as the start/stop button is pressed. As soon as the start/stop button is pressed again, it stops and indicates the time interval recorded by it between the start and stop of an event. A reset button restores its initial zero settings (Ox Science, 2020).

2. Mechanical or Analog Stopwatch

A mechanical stopwatch can measure a time interval of up to 0.1 seconds. It has a knob that is used to wind the spring that powers the watch. It can also be used as a start-stop and reset button. The watch starts when the knob is pressed once. When pressed the second time, it stops the watch while the third press brings the needle back to zero.

Parts of Stopwatch

Face:

This is where all the stopwatch time data is recorded. There are analog or digital and it is divided by separations that measure hundredths and even thousandths of a second. The analogs have hands, while the digital express data on a small screen number (Ox Science, 2020).

Action Buttons:

Both the analog and digital models have buttons to start the stopwatch. A button that starts and can stop time at the same time, as well as a button to restart the count or to make a lap or split the count into partial times.

How a Stopwatch Works

The operation of a stopwatch is to accurately count the time of an event. The timers are easy to use, to start the count one must press a start button. Once the event is over, time stops on the stop button. The time covered by the recorded event will be displayed on the face of the wristwatch, as well as other common data, such as time and date. One can restart the stopwatch to count another event or event. There are wristwatches that have a chronometer, but there are also models that can be hung on the neck or carried in the pocket (Ox Science, 2020).



Fig. 39: Digital stopwatch (Ox Science, 2020).



Fig. 40: Analog stopwatch (Ox Science, 2020).

2.11. Weighing Balance

A weighing balance is an instrument that is used to determine the weight or mass of an object. It is available in a wide range of sizes with multiple weighing capacities and is an essential tool in clinical laboratories. Laboratory balances are used to accurately determine the mass or weight of an item or substance within a specific weight range and to a particular readability. They are typically used to measure the weight of smaller amounts of substances in grams, milligrams, or micrograms. The term “scale” is typically used when referring to similar instruments that weigh larger amounts in kilograms.

Types of Weighing Balance

Mechanical weighing balance

Digital weighing balance

1. Mechanical or Analog Weighing Balance

This kind of machine mainly consists of a platform and a reading display to showcase the weight. Mechanical weighing machines use hanging or a spring scale to operate. The stretch of the spring helps in

measuring the weight. This kind of machine can handle a weight of up to around 120 kg. Mechanical weighing machines are quick in delivering results, and they are also user-friendly. The display readings of the mechanical weighing machine are analog, due to which mechanical weighing machine is also referred to as an analog machine.

The following are mechanical weighing balance.

A. Spring Scale Weighing Machine

A spring scale is a mechanical weighing machine that measures the force or weight by hanging those objects from this spring scale hook. This scale contains a spring that helps in determining the weight of the material when connected with the hook of the machine. In case of measuring loose material, you can pour the material into the bag and then use the hook of the spring scale to determine the weight. These types of weighing machines are travel-friendly as they are small in size and lightweight.



Fig. 41: Spring Scale Weighing Machine (Khan, 2021)

B. Hanging Weighing Balance

Hanging machines are another weighing machine that can be used for measuring the weight of heavy objects. These machines are small in size but can easily calculate weight of heavy objects and substances.

Unlike other weighing machines, these types of machines don't make the product or object stand on the platform but directly hang over the object to determine the weight.



Fig. 42: Hanging Weighing balance (Khan, 2021).

2. Digital Weighing Machine

A digital weighing machine requires a power source in order to function. The digital machine can measure weight to 150 kg, around 30 kg more than mechanical weighing machines. There are two kinds of

digital machines available, one that requires a battery while others need to be plugged into an outlet or a power strip to function. The Digital weighing machines are the best and pretty advanced, and they involve a high range of software programs used for different functions.



Fig. 43: Digital Weighing Machine (Khan, 2021)

Components of Digital Weighing Machine

Digital weighing machines contain a liquid crystal display that helps in presenting the measurement

or weight in the form of numbers. The spring present in the digital machine is deformed, due to which the weight force and the deformation is calculated using strain

gauges. A strain gauge is present in digital machines as it is a conductor that helps in determining the weight. When there is a potential change in the electrical resistance, we witness a change in length simultaneously. Other elements that a digital weighing machine consists of are a voltage and hydraulic transducer. An analog to digital converter is also involved in the machine as the current is converted into a number using this converter. They help in providing the correct units in the display.

2.12. Fully Automated Biochemistry Analyzers

Fully Automated Biochemistry Analyzers measure the concentration of certain proteins, enzymes, electrolytes, metabolites, or even drugs in the provided samples of urine, blood, serum, plasma, or other body fluids. The machine consists of a tray where the samples are loaded to be tested. The tests are programmed either by the bar-code scanner or manual entry. Once the tray is loaded with a sample, a medical dispenser collects a certain amount of sample and sends it over to the reaction tray. After this process, a certain amount of water rinses the dispenser and then the reagents stored inside the machine are released into the reaction vessel. The new mixture attained is carried out in either of the two areas: calorimeter or flow cell. If the mixture goes to the calorimeter, the absorbance can be measured there while

it remains in the reaction vessel. In the case of flow-cell, the mixture is sent to flow through the calorimeter to measure the absorbance. This way the analyzer can calculate the relevant concentration. The entire test once completed produces a report with precise diagnosis through a printer or on-screen display (Medsourc Ozone Biomedicals, 2021).

Key Features

- The user can get random access to reports and go for direct results reading on the scene
- Automatic washing process instilled to clean the sample and reagent vessels/trays
- Very easy to use and user-friendly system
- System packs if available (recommended) improve the results reliability
- Super reliable instant cooling system for reagent tray for temperature maintenance
- Independent thorough reagent and sample mixing procedure
- Low water consumption (less than 20 L a day)
- Alert provision for abnormal absorbance detection
- Works in combination with Windows OS depending upon the latest version



Fig. 44: Beckman Coulter's DxA 5000 Total Laboratory Automation solution (Beckman, 2019)

Advantages of Automation (with reference to TLA)

• Lower Costs on the Long Term

Several lines of evidence now attest that an efficient model of TLA can successfully lower the costs of Laboratory diagnostics (Da Rin *et al.*, 2016). The net benefit (i.e. the return of investment) is indeed more

appreciable on the long term, after reaching the so-called break-even point, when the higher initial costs (discussed in a following section of this article) will be offset. Basically, the major economic revenue of TLA, resulting from merging many diagnostic platforms within a consolidated system, not only encompasses a reduction

of manual workforce (especially auxiliary and technical staff) needed for managing high-volume testing (Archetti *et al.*, 2017) but is also attributable to lower preanalytical and postanalytical expenditures. For example, consolidation of the so-called serum working area would actually need collecting a minor number of blood tubes for performing different analyses and will also require smaller storage units (i.e. stockyards) for storing a lower number of specimens after the tests have been completed. However, the economic saving is variable, depending on the final solution of automation adopted and on the relative volume of tests locally performed, as the larger is the number of tests, the bigger is the consequent economic revenue of automating many steps of the total testing process (Archetti *et al.*, 2017). This aspect may then allow suggesting or justifying the adoption of different model of automation based on local volume and complexity of testing.

- **Decreased Congestion in the Laboratory**

Directly linked to the previous point, the decrease of personnel needed for performing identical volumes of tests after implementing TLA would also produce lower staff congestion within the laboratory (Archetti *et al.*, 2017). An optimized layout of integrated workstations would in fact prevent technicians moving back and forth many times from one analyzer to another, thus minimizing the distance covered by the personnel for performing multiple analyses on different instrumentation.

- **Improved Efficiency**

Beside cost-containment benefits, which are especially cherished by policymakers and healthcare administrators (Lippi, 2018), TLA provides some other advantages within the laboratory environment, most of which are attributable to using customizable assembly lines, which can be organized to meet specific requirements and layouts of different laboratories. Several lines of evidence now demonstrate that an efficiently designed TLA may be variably effective to reduce turnaround time (TAT) and concomitantly increase laboratory productivity (i.e. throughput) (Yu *et al.*, 2019). Notably, modern assembly lines can transport a huge number of blood tubes or secondary aliquots at high speed (i.e. between 3000 and 10,000 tubes per hour at a speed of 20-100 m/s) (Felder, 2018) thus considerably offsetting manual transportation. One valuable example is that recently published by Yeo and Ng (Yeo and Ng, 2018) who showed that the workload of a laboratory service can be substantially increased after implementing TLA, and that such an increased volume of tests may also be accompanied by a notable expansion of the test repertoire. These valuable goals could be essentially achieved by workflow optimization, automatically encompassing diversion or prioritization of samples among the different analyzers, especially when an analyzer is full or has some technical failures. Very understandably, however, the adoption of a model of TLA incorporating several diagnostic lines (e.g.

clinical chemistry, immunochemistry, hematology, coagulation and even microbiology) has an impact on personnel expertise, that will be more comprehensively discussed in a following section of this article.

Alongside this line, TLA offers the additional advantage of allowing a combination of modern preanalytical workstations with analytical platforms (Da Rin, 2009). The former instrumentation now enables check-in, sorting, decapping, centrifugation and fully-automated liquid aliquoting of different tubes types and sizes, followed by circulation of automatically labeled secondary aliquots into TLA, thus overcoming the challenge of adapting different analyzers to different types of tubes. Even here, however, a preliminary analysis of the workflow within the laboratory and a constant monitoring of TAT over time seem critical for implementing the most efficient solution and eventually correcting system flaws. This would enable identifying *ex ante*, or adjusting *ex post*, some critical steps of sample management within the system, ultimately optimizing its performance in terms of managing high volumes and complexity. Notably, some models of TLA are now equipped with input stations (e.g. bulk modules) where blood tubes can be randomly entered by hand or, more efficiently, that can be physically connected with pneumatic tube systems (where available). Except for pre-centrifuged blood tubes (i.e. the quality of some gel separators may be unsuitable to prevent leakage of molecules from blood elements underneath the gel barrier) (Da Rin and Lippi, 2014) bulk input modules reduce manual sorting and save time. Finally, optimization of workflow and shorter TAT would also permit to more timely report data to the requesting physicians, thus reducing the need for priority urgent testing.

- **Improved Sample Management (e.g. Rerun, Reflex and Add-on Testing) and Traceability**

Information technology (IT) has profoundly contributed to improving medical laboratory work and organization. Query-host communication has virtually eradicated some high-risk activity connected to manual transcribing data and has also enabled reducing the TAT (Lippi and Plebani, 2016). The modern generation of laboratory instrumentation is also equipped with advanced software programs, allowing better sample management. Setting decision rules based on predefined criteria now permits autoverification of data, automatic re-analysis of samples with highly abnormal or suspect results, as well as triggering reflex (reflective) and add-on testing, thus ultimately contributing to enhance the quality and safety of diagnostic testing (Mlinaric *et al.*, 2018). The efficiency of performing these important activities is enormously magnified in laboratories using TLA, where sample management within the system is more efficient (i.e. all samples can be stored within on-line stockyards and automatically retrieved and re-analyzed hours or days after initial testing). Moreover, the integration of different instrumentation enables

automatically performing many different types of tests, planning automatic reflex or add-one testing, using different sample matrices. For example, consolidation of hematologic analyzers within the serum working area may allow setting automatic rules for troubleshooting anemia (e.g. generating ferritin, transferrin, folic acid, vitamin B, creatinine and other clinical chemistry tests when hemoglobin values are below the reference range), and thus providing more thorough and timely laboratory data for diagnosis and treatment (Guidi, 2010). Last but not least, specimen traceability is consistently enhanced by maintaining all routine and stat samples within a unique environment, enabling digital traceability of all the processes a tube has been subjected to, from time of delivery to the laboratory, up to storage once testing has been completed.

- **Enhanced Standardization for Accreditation/Certification**

Keeping all the different phases of the total testing process under control, thus including extra-analytical activities, is a mainstay of total quality in laboratory diagnostics (Aita, 2018) which has also become a mandatory requirements of International Standards Organization (ISO) 15189:2012 accreditation (Sciacovelli *et al.*, 2018). It is now undeniable that consolidating different diagnostic areas within the same workspace would require less administrative efforts to develop and update standard operating procedures (SOPs), wherein multiple procedures for preanalytical and postanalytical sample management can be merged when many analyzers are integrated within the same model of TLA. Notably, TLA also seems profitable for many aspects related to the analytical quality, such as quality specifications of the assays, traceability of calibrators, improved quality and stability of reagents, along with some other aspects that laboratory professionals should evaluate in addition to technical planning before the adoption of a specific solution of TLA. The increased accuracy and repeatability throughout the total testing process enabled by automating operations would also grant paramount benefits in terms of standardization, thus simplifying certification and accreditation procedures.

- **Improved Quality of Testing**

Standardization and harmonization are two crucial issues in laboratory diagnostics. Most efforts made over the past decades have been essentially focused on the analytical part of the total testing process whilst major attention has only recently been given to preanalytical (Plebani, 2018) and postanalytical activities. Conventionally, automation allows taking over the bulk of many manual ordinary activities (i.e. specimens sorting, loading, centrifugation, decapping, aliquoting, sealing) from humans, thus enabling to alleviate substantial differences among persons and from sample to sample. Such improved process standardization will yield tangible benefits on the quality of the total testing process, thus lowering the risk of

diagnostic errors, especially those emerging from the manually-intensive activities of the preanalytical phase (Yeo and Ng, 2018). A paradigmatic example has been published by Hawker *et al.*, who showed that implementation of a major automation system in a medical laboratory was effective to decrease the number of lost specimens by over 50% (Hawker *et al.*, 2009). However, the analytical process can also be carried out more safely and efficiently using TLA, as several activities such as dilution of samples with results lying outside the range of linearity, or sample resting when results are alerted, can be both automatically performed, by more efficiently retrieving specimens from the storage unit, without manual intervention. Notably, some integrated preanalytical workstations can also automatically perform quality assessment for monitoring specimen integrity (i.e. sample volume, presence of clots or bubbles, serum/plasma indices and so forth).

- **Lower Sample Volume**

Containment of unnecessary diagnostic-related blood loss and prevention of blood drawing-related anemia are especially important in subjects such as neonates, anemic patients or those needing repeated laboratory testing for critical illnesses. The use of lower blood volumes may also be a viable option in patients with difficult veins, for whom drawing multiple blood tubes may be unfeasible (Simundic *et al.*, 2015). One of the previously mentioned advantages of TLA is the opportunity to reduce the number of blood tubes needed for testing. The so-called serum working area is a paradigmatic example, wherein the same serum (or lithium-heparin plasma) tube can be used for multiple clinical chemistry and immunochemistry tests, thus allowing to consistently reduce the total volume of blood needed for testing. Importantly, a reduced sample volume will also generate a lower impact on biological waste disposal, thus producing an additional economic saving.

- **More Efficient Integration of Tests Results**

The consolidation of many diagnostic areas with the same space (e.g. the so-called “core-lab”) has additional organization and technical benefits. The considerable advancements of IT now allow laboratory staff to navigate and manage data flow of delivery, analytical and archival systems (Yeo and Ng, 2018). The middleware of most models of TLA enables integrating a vast array of test results produced by different analyzers, even before data are transferred to the LIS. This not only would permit to define larger, more complex and accurate auto-validation criteria, but would also allow the laboratory personnel to have a broader picture of patient’s results, thus more efficiently detecting potential errors or identifying critical situations needing timely communication to the clinicians (Yeo and Ng, 2018).

- **Lower Biological Risk for Operators**

Worker safety is one of the most important advantages of automating industrial operations. Automated systems not only remove operators from the workplace, but also safeguard them against the risks of performing biologically hazardous operations and handling biohazardous materials (Genzen *et al.*, 2018).

- **Staff Requalification and Job Satisfaction**

The minimization of manually-intensive labor is one of the major advantages of TLA, which would then translate into a net saving of staff (both technical and auxiliary) needed for managing laboratory workflow (Hawker *et al.*, 2002). Hence, this would enable to requalify the personnel, eliminating manpower and redefining job roles towards value-added tasks such as quality assessment or implementation of new tests (e.g. genomics, proteomics, theranostics), thus ultimately leading the way towards personalized (laboratory) medicine (Lippi *et al.*, 2016). It is also worthwhile mentioning here that personnel requalification can be intellectually satisfying, thus enhancing the morale and productivity of the staff.

2.13. Measuring Cylinder

A graduated cylinder, also known as a measuring cylinder or mixing cylinder, is a common piece of laboratory equipment used to measure the volume of a liquid. It has a narrow cylindrical shape. Each marked line on the graduated cylinder represents the amount of liquid that has been measured. Large graduated cylinders are usually made of polypropylene for its excellent chemical resistance or polymethylpentene for its transparency, making them lighter and less fragile than glass. Polypropylene (PP) is easy to repeatedly autoclave; however, autoclaving in

excess of about 121 °C (250 °F) (depending on the chemical formulation: typical commercial grade polypropylene melts in excess of 177 °C (351 °F)), can warp or damage polypropylene graduated cylinders, affecting accuracy (Pradyot, 2003). A traditional graduated cylinder is usually narrow and tall so as to increase the accuracy and precision of volume measurement. It has a plastic or glass base (stand, foot, support) and a "spout" for easy pouring of the measured liquid. An additional version is wide and low.

Mixing cylinders have ground glass joints instead of a spout, so they can be closed with a stopper or connected directly with other elements of a manifold (Pradyot, 2003). With this kind of cylinder, the metered liquid does not pour directly, but is often removed using a Cannula. A graduated cylinder is meant to be read with the surface of the liquid at eye level, where the center of the meniscus shows the measurement line. Typical capacities of graduated cylinders are from 10 mL to 1000 mL.

Common Uses

- Graduated cylinders are often used to measure the volume of a liquid such as chemicals etc. Graduated cylinders are generally more accurate and precise than laboratory flasks and beakers, but they should not be used to perform volumetric analysis (Pradyot, 2003) volumetric glassware, such as a volumetric flask or volumetric pipette, should be used, as it is even more accurate and precise.
- Graduated cylinders are sometimes used to measure the volume of a solid indirectly by measuring the displacement of a liquid.



Fig. 45: Measuring cylinder (Pradyot, 2003)

2.14. Beaker

In the laboratory, a beaker is generally a cylindrical container with a flat bottom. Most also have a small spout (or "beak") to aid pouring, as shown in the picture. Beakers are available in a wide range of sizes, from one milliliter up to several liters. A beaker is distinguished from a flask by having straight rather than sloping sides. The exception to this definition is a slightly conical-sided beaker called a Philips beaker. The beaker shape in general drinkware is similar.

Beakers are commonly made of glass (today usually borosilicate glass, but can also be in metal (such as stainless steel or aluminum) or certain plastics (notably polythene, polypropylene, PTFE). A common use for polypropylene beakers is gamma spectral analysis of liquid and solid samples (Pradyot, 2003).

Uses of Beaker

- Liquid volume containment
- It is also used in measurement of liquids/chemicals

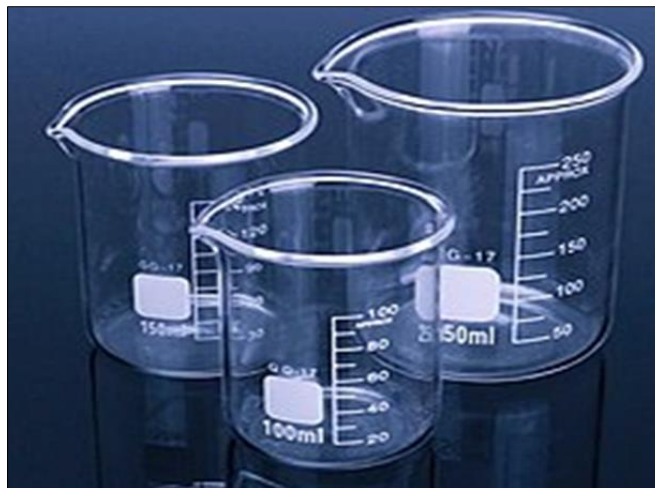


Fig. 46: Beaker (Pradyot, 2003)

2.15. Test tube holder

A test tube holder is used to hold test tubes. It is used for holding a test tube in place when the tube is hot or should not be touched. For example, a test tube holder can be used to hold a test tube while it is being heated. Moreover, when heating the tube with liquid or solid contained inside, the holder ought to tightly hold a test tube in order for the tube to be safely held while heating (Safety and laboratory procedures, 2009). Particularly, for liquid heating, when holding a test tube holder with a test tube, hold it such that it aligns with the lab bench and

also point the open end of the tube away from yourself or anyone nearby. Additionally, while using a test tube holder, the proper distance between the test tube holder and the top of the test tube is approximately 3 centimeters.

Use of Test Tube Holder

The purpose of a test tube holder is to be used only to hold a test tube as it is not structured for flasks or other heavier objects (Safety and laboratory procedures, 2009).



Fig. 47: Test tube holder (Safety and laboratory procedures, 2009)

2.16. Microtitre Plate

A microplate, also known as a microtiter plate, microwell plate or multiwell (Elaine, 2007) is a flat plate with multiple "wells" used as small test tubes. The microplate has become a standard tool in analytical research and clinical diagnostic testing laboratories. A very common usage is in the enzyme-linked immunosorbent assay (ELISA), the basis of most modern medical diagnostic testing in humans and animals.

A microplate typically has 6, 12, 24, 48, 96, 384 or 1536 sample wells arranged in a 2:3 rectangular matrix. Some microplates have been manufactured with 3456 or 9600 wells, and an "array tape" product has been developed that provides a continuous strip of microplates embossed on a flexible plastic tape (Elaine, 2007). Each well of a microplate typically holds somewhere between tens of nanolitres (Weibull *et al.*, 2014) to several millilitres of liquid. They can also be used to store dry powder or as racks to support glass tube inserts. Wells can be either circular or square. For compound storage applications, square wells with close fitting silicone cap-

mats are preferred. Microplates can be stored at low temperatures for long periods, may be heated to increase the rate of solvent evaporation from their wells and can even be heat-sealed with foil or clear film. Microplates are manufactured in a variety of materials. The most common is polystyrene, used for most optical detection microplates. It can be coloured white by the addition of titanium dioxide for optical absorbance or luminescence detection or black by the addition of carbon for fluorescent biological assays. Polypropylene is used for the construction of plates subject to wide changes in temperature, such as storage at -80°C and thermal cycling. It has excellent properties for the long-term storage of novel chemical compounds. Polycarbonate is cheap and easy to mould and has been used for disposable microplates for the polymerase chain reaction (PCR) method of DNA amplification. Cyclo-olefins are now being used to provide microplates which transmit ultraviolet light for use in newly developed assays. There are also microplates constructed from solid pieces of glass and quartz for special applications (Weibull *et al.*, 2014).

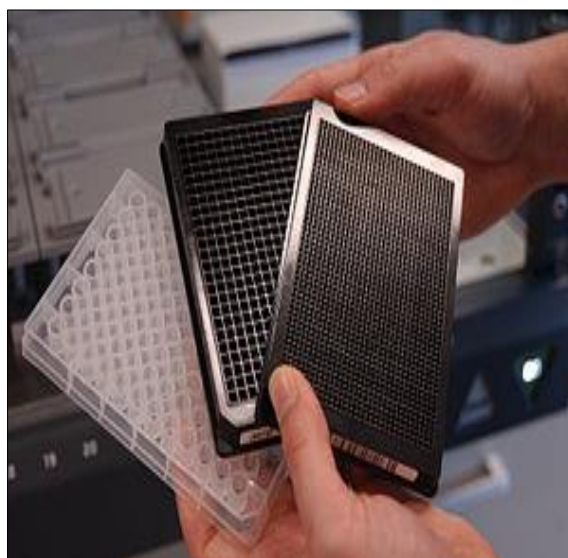


Fig. 48: Microtitre plate (Weibull *et al.*, 2014)

2.17. Water Purification System

Millipore has developed a range of Milli-Q ultrapure water systems designed to match specific water quality requirements. Each of the five new Milli-Q systems is designed to specifically target contaminants detrimental to particular applications such as HPLC, molecular biology and ICP-MS. The systems incorporate a high precision resistivity monitor that records conductivity or resistivity (compensated or not to 25°C), and also feature a built-in TOC monitor with a 1-999 ppb

detection range for accurate analysis of organics. Milli-Q systems meet USP 24 requirements for resistivity and TOC suitability tests. Validation and qualification services are available, and the optional Explore Data software allows easy access to historical data via a computer interface for documenting GLP compliance. All systems can be bench-operated, wall-mounted or bench-integrated for maximizing space requirements (CLST, 2020).



Fig. 49: Water Purification System (CLST, 2020)

2.18. Ultra-Low Temperature Freezers

New Brunswick Scientific's ultra-low temperature (ULT), minus 80 degree C laboratory freezers are exceptionally energy efficient, quiet running and reliable, with a 25-year track record of providing safe and dependable sample storage. We now offer over a dozen -86°C lab freezer models and two product ranges to accommodate a wide variety of storage needs. Innova ULT laboratory freezers utilize Vacuum Insulation Panel technology, to provide up to 30% more internal storage

capacity than conventionally-insulated lab freezers, without increasing the external dimensions (CLST, 2020).

Use of Ultra-Low Temperature Freezers

Ultra low temperature freezers (ULT freezers) typically have a temperature range of -45C to -86C and are used for the storage of drugs, enzymes, chemicals among others.



Fig. 50: Ultra-Low Temperature Freezer (CLST, 2020)

2.19. Eppendorf MiniSpin and MiniSpin Plus

The eppendorf MiniSpin Personal Microcentrifuges Minispin Plus Centrifuges is a reliable and dependable addition to the Eppendorf Centrifuges family of products (CLST, 2020).

Use of Eppendorf MiniSpin and MiniSpin Plus

MiniSpin plus provides speed sufficient for molecular biology separations. Everyday centrifugation tasks become easier with the MiniSpin® and Centrifuge MiniSpin® plus mini centrifuges.



Fig. 51: Eppendorf MiniSpin and MiniSpin plus (CLST, 2020)

2.20. Mastercycler ep Gradient S Thermal Cycler

Faster speeds, highest precision, more user-friendliness and absolute reliability united within a flexible concept: this is the definition of the mastercycler ep system. In the past few years nucleic acid research has been developing dynamically. The same applies to the capabilities required of PCR Systems. To keep pace with these technological advances, the challenges of tomorrow must be considered today. The mastercycler ep system is today's answer for the future. With the mastercycler ep system Eppendorf looks to support those

working in a technologically advanced fashion with experience and a clear commitment to innovation (CLST, 2020).

Use of Mastercycler ep Gradient S Thermal Cycler

The Eppendorf Mastercycler EP thermocycler can be used as a stand-alone device, a mini-satellite system, or connect and controlled by a PC for a modular laboratory environment. Featuring electronic sample protection, or ESP, this PCR makes certain of consistent and efficient heating of samples.



Fig. 52: Mastercycler ep gradient S thermal cycler (CLST, 2020)

CONCLUSION

Clinical chemistry is the branch of laboratory medicine that is generally concerned with analysis of bodily fluids for diagnostic and therapeutic purposes. Instruments are made use of in such analysis. Instrumentation is the development or use of measurement tools for the observation, monitoring or control of chemical processes. Research in this area ranges from development of new instruments to novel applications of existing instruments for understanding complex physical and chemical processes. Many of the instruments used in clinical chemistry labs are the same

types found in conventional analytical labs—colorimeters, spectrophotometers, electrolyte analyzers. Others are flame photometers, fluorometers, pH meters, gas chromatographs, radiation counters etc. These instruments make work easier and reduce turnaround time among other benefits.

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