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BASIC AND ADVANCED TECHNIQUES USED IN LABORATORIES

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Abstract

Laboratories are specialized facilities, and conditions within the labs can be greatly varied. There are basic techniques that apply to all labs, such as cleaning and safety. In addition, many labs have special requirements dictated by their purpose, which can include highly specialized procedures and specific equipment. In some labs, there can be unique tools and advanced techniques, such as specialized tests or knowledge of instrument-specific procedures. The purpose of the review is to provide an overview of these topics with an emphasis on basic safety, cleaning, and general laboratory skills, and to then provide an in-depth look at field-related lab tests and techniques associated with different geology subdisciplines. A teaching lab may have very different user requirements from a quartz assay lab. Furthermore, even within the same laboratory, procedures can be different due to different check-out requirements and/or reagent usage. Therefore, instrumentation-specific training may also be required. The purpose of the review is to provide an overview of specialized geology-related laboratory techniques to help standardize laboratory operations. The aim is to make the tasks and personnel safety more predictable so other lab team members are better informed and better equipped to facilitate regular user traffic and reduce the risk of accidents. Better in-depth knowledge of basic, advanced, and field-related general techniques should raise preparedness and comfort levels. (Holland & Davies, 2020)

Keywords

Clinical lab, physical access control, logical access control, systems and application security, application and clinical data storage, setting up connection, viewer and report studio, contact relationships chart, various techniques in menu creation, using dashboards, viewing, scheduling and managing reports

1.Introduction to Laboratory Techniques

Laboratory glassware comes in a variety of shapes and sizes and is used as containers and instruments to perform specific functions. Special laboratory-grown glassware is manufactured to withstand heat and resist chemical reactions. Other types of glassware are more common, and pieces of these are available in all homes. These common pieces of glassware for working in a laboratory are Corning glass products and are very efficient for heating, sterilizing, and for chemical changes or reactions that have to be done on a stove. The laboratory glassware is also the ideal container for hot and icy drinks because of its high temperature resistance properties. (Zubrick, 2020)

An important aspect to bring out is that when we are using glassware, we must consider the rules of sterilization. We cannot use any laboratory glassware without first sterilizing it. The sterilization of all laboratory glass products is done with alcohol. Once it is sterilized, we can use either boiling water or any other boiling hot food or drink, as long as when we put the boiling glass it is not in contact with a cold surface, as this will rapidly cool the glass and it will break. (Bharti et al., 2022)

2. Safety Precautions in the Laboratory

One of the most important aspects of laboratory work refers to safety and health precautions that instructors and students alike must take in the laboratory. In the laboratory, potentially harmful chemicals, electrical appliances, and sharp-pointed objects, which can all cause accidents, are widely used. It is stressed that during all laboratory activities, safety rules should be taken seriously, and one should be aware of all the dangers of the laboratory. Never conduct experiments without the knowledge of the subject. Every experiment to be carried out in the laboratory requires a specific method and techniques that can be applied properly and should be done with care. Research conducted carefully will be successful and will not result in material losses or accidents. In this section, some of the laboratory work to be performed and the requirements for the experiment will be explained in such a way as to ensure a good passage and observation by taking the necessary precautions. The laboratories are not places for play or rest during technical work. The first rule to follow in the laboratory is discipline. The laboratory is the place where the experimental findings of the courses are revealed. Within the research and safety rules, freedom is to take control of an application one hundred percent. In laboratories, only studies defined in the curriculum are carried out. Items such as eating, drinking, talking loudly, wandering around, and disturbing other research areas are absolutely forbidden. The periodically changing bulletin of the 'Principles of Laboratory Health and Discipline' signed by the students is for acquainting the students with the rules to be obeyed in the courses and for ensuring that each student understands the rules. All students are warned in the courses about creating laboratory safety and hygiene. Students are asked to refrain from actions contrary to the rules. (Ménard & Trant, 2020)

3. Basic Laboratory Techniques

Whether chemistry is a profession or simply an avocation—a hobby—safety is a concern for everyone working in the laboratory. Laboratory safety is a very important aspect of science education and science. The following safety rules must be observed at all times. Laboratory equipment should be used only as directed. Contaminated chemicals with which a laboratory worker comes into contact should be immediately brought to the attention of the science teacher. A first aid kit is available for use in an emergency, so students must be familiar with the contents and the proper way of using it. A student should act intelligently and obey the teacher when instructions require proper safety precautions. A student should not use chemicals, burners, or matches, or perform any other operations not authorized by the teacher. Students must wear safety goggles. Students should not drink water from a lab sink, use lab glassware for food or drink, or generate trash in the lab. They should not breathe through a piece of apparatus. Work areas should always be kept clean. Return all equipment to its proper place. Clean any experimental area in the lab, as directed by the teacher, and return the used equipment to its proper location. Food, drink, and chewing gum are not allowed in the lab area. Lab instructions must be referred to before the student begins an experiment. Water will be used in the lab only when, and as, approved by the teacher. Any broken glassware should be brought to the attention of the teacher and disposed of properly. The students must be quiet and orderly. Horseplay is not to be tolerated. A student must dispose of all waste material in the proper containers. Students are not allowed to wander aimlessly in the lab. (Makransky et al.2020)

3.1. Weighing and Measuring

The starting point to any laboratory analysis is usually the weighing of a specific sample to be analyzed. It is important to know how the sample behaves under certain conditions, and thus the minimum and maximum range to be used in any subsequent tests. Usually, a wide range of balances is available in almost all laboratories. A widely recognized scale reduces the uncertainty of a measurement result and improves quantitation. It is important to use the same balance for these particular tests developed by one demand for a precise measurement resolution. Care should also be taken when selecting the container in which the sample will be weighed. For example, a large bucket will add little weight to a large sample, while a small powder will add a significant difference in weight. It is also important to include in the final weight a precise amount from one analysis to the next. If a weight appears to be variable on the same balance, take into account the temperature, humidity, drift that needs to be corrected daily, electricity, and power source fluctuations. All balances should be standardized, and the process should be included in a standard operating procedure. Balances must be located in a stable location to ensure accurate sample, reagent, and standard weighings. The location should be evaluated before each use. (Zhang, 2024)

3.2. Pipetting Techniques

Pipetting is a very common laboratory task; however, it may not be as straightforward as it seems. To ensure good experimental results, it is important to improve accuracy during pipetting, irrespective of the sample being aqueous liquid, expensive solutions, or chemicals approved for environmental use. Many times during pipetting work, it is not a safety risk that is threatening but a hermetic damage to the container or a possibility of laboratory contamination. To avoid this kind of unwanted situation and to improve daily watchfulness, both good practices and safe circumstances have to be taken into account. (Dettinger et al.2022)

The main sources of error in pipetting are due to the instrument itself, the user, or the volume compared to the tip sizes. There are many approaches employing the human sense of perception or precision, even though the basic industry definitions have not yet become harmonized. They can encompass various analytical methods and systems, both automated and operator-driven, and others of an industrial nature. Hand-operated pipettes are extensively used tools with fine-division markings for measuring the volume of liquid. Tips of pipettes, with specific kinematic limits, located in accordance with pipette shafts, meet the reality of various volumetric requirements. The tips, together with the pipette, produce an optimal sealing surface for each different liquid that passes through the pipette, being the most critical method used in liquid handling.

3.3. Titration Methods

A standard solution of a substance may be prepared by weighing a known mass of the substance and making it up to a definite volume with solvent. Molarity is calculated from moles and volume. Example: calcium oxide weighing 1.0024 g and forming 39.2 ml of hydrochloric acid solution was 0.09524 M. The acid was then used to standardize 0.1051 M of NaOH solution as 47.1 ml was required to neutralize the acid and 46.2 ml instead of 50 as expected. The percentage purity of the calcium oxide was calculated as 92.6%. (DelRe et al.2021)

In some cases, it is difficult to weigh exactly. A primary standard is a substance that may be obtained in a stable and soluble form and weighed accurately. There are two ways of producing primary standards. The substance may be dried to eliminate volatile impurities, and a solution then weighed from a mass. Alternatively, a solution may be prepared with a known concentration, and the molarity then calculated from the mass or volume used. This second method is used for the standardization of solutions against one another. Once a primary standard is known, it must be the basis of accurate molarities for standard solutions.

4. Advanced Laboratory Techniques

Advanced laboratory techniques are significant for novel complex perovskite materials. To optimize the single crystalline film texture and crystallinity, with consistent parameters, thermal evaporation, a simple, efficient, low-cost, and reproducible technique, was explored to grow $CsPbBr_3$ single crystalline films for device application. The development of epitaxial growth of the perovskite materials as thin films or heterostructures is challenging, but well developed for bulk, so many of the chemical properties are often still mostly inferred from measurements on bulk single crystals. The electronic properties are highly influenced by the thickness of the perovskite layer in the best performing devices. Reports present the highest efficiency of over 20% at the illumination of 0.2 cm^2 devices and of over 14% at the realistic illumination using high quality perovskite single crystalline films. Numerous reports have found that the perovskite single crystals have longer absorption length and a much longer carrier lifetime compared to the polycrystalline films. However, the large, expensive-to-fabricate perovskite single crystal is inappropriate for large scale application. The chemical and physical development of high quality devices mostly depends on high quality, large scale $CsPbBr_3$ single crystalline film. (Kim et al.2021)

4.1. Chromatography Techniques

Chromatography is used in laboratories for separating and analyzing compounds in mixtures through the use of gases or liquids. Chromatographs offer much greater separative ability than distillation, at least in dealing with low-boiling-point compounds. Gas chromatography is an important tool for environmental and clinical testing, and those in the petrochemical and pharmaceutical industries will tell the same story. There are also two commonly used liquid chromatography techniques: affinity chromatography and supercritical fluid chromatography. (Robards & Ryan, 2021)

Affinity chromatography uses a specific type of biospecific support in which the biological molecule is either located on the surface and exposed to the solvent or buried within the surface. Once the biospecific species is communicated to the solvent, retardation is high and the compound will be eluted slowly. In the ideal situation, only one other characteristic of the macromolecular structure of a given solute would also permit a high affinity for the support. Because affinity chromatography results from a relatively high interaction energy that the solute experiences near the gel surface, the separation is very sensitive to interactive solutes in the mobile phase as well as on the support. In many cases, it is preferable to eliminate interactions.

4.2. Mass Spectrometry

This section provides an overview of the mass spectrometric terms, the ionization sources, the analyzers, and the detectors used in mass spectrometry. It reviews routines and sophisticated experiments focusing on the free radicals formed as intermediate species in mass spectral analysis. Mass spectrometry is an analytical technique that deals with the determination of the molecular weights and the structural information of compounds. It is based on the measurements of the mass-to-charge ratios of the ionized molecular constituents in a specimen. It provides a means to perform quantitative and qualitative analyses of the compounds. The quantitative analyses are achieved by measuring low- to high-abundance ratios of certain ions in samples and those of the model ions obtained by spiking samples with known amounts of standard compounds. The qualitative analyses are possible by comparing the measured mass-to-charge ratios with those from the spectra libraries and by obtaining sample constituents separately with the mass-tunable mass filters. (Tamara et al., 2021)

4.3. Polymerase Chain Reaction (PCR)

One of the most valuable and widely used techniques for discovering the presence of a given sequence of DNA or verifying its identity is known as the polymerase chain reaction. PCR allows one to clone important sequences using a pair of mixed primers. DNA is usually amplified (or copied) by PCR, which is not RNA sensu stricto in the field of molecular genetics. DNA is universal with more potential as the basis of biotechnology than RNA. PCR was made entirely possible with the knowledge of the process of DNA replication and already important tools in molecular biology investigations.

A very limited amount of DNA is required in order to make its presence known and verify its length using PCR technology, often called DNA fingerprinting. The theoretical grounds for the unique ability of this technique to indicate absolute precision, detect trace amounts, and have what might be considered an infinite degree of sensitivity are founded in the procedures and chemistry of DNA replication. Using PCR, the specific DNA sequence becomes amplified. Primer design allows the experimenter to dictate the sequence that is to be amplified. Such a designed primer is a form of artificial DNA sequence. Primers are pairs of synthetic oligonucleotides about 20 to 25 nucleotides long that are complementary to two 3'-ends on both DNA strands at the respective specified ends of the DNA image. At the ends of this are specified DNA strand lengths. These days, under the typical conditions of the polymerase reaction, a primer oligonucleotide is composed of 18 to 40 residues.

5. Methodology

There are several levels of safety available to protect laboratory workers from chemical exposure. The highest are those precautions which have been designed and built into the safety features of the apparatus being used. The next level is that precaution which is designed into the method being used. This level is followed by the submission of a project to computerized evaluation of environmental and experimental factors. In essence, the responsibility for safe lab work is delegated to the laboratory worker him/herself. By requiring the appropriate attention to training of laboratory workers, the laboratory safety officer provides the third level of protection. The final levels of protection, in decreasing order of importance, are those provided by safety engineering programs, exposure control devices, and personal protective equipment. The systems and operations control features, safety review procedures, and toxic substance management systems are case examples of safety engineering programs. Exposure control devices include fumehoods, glove boxes, solvent resistant gloves, and the like while personal protective equipment consists of safety glasses, protective clothing, mask, etc. which are not designed for exposure control. Administrative control features are those which allow for noxious exposure only under controlled and limited conditions and are normally used when the other protective systems have failed. They are a last resort in a properly managed laboratory. (Nath et al., 2020)

6.Fining

In winemaking terms, fining is the process of removing unwanted material from wine. In wine, fining carries colloidal substances, including phenolic and tannic substances and their associated substances. Examples of unwanted material that may require removal through the use of fining agents include excess coloring, excessive tannins, and proteins that might cause a filter pad to clog. Fining agents are added to the wine and are adsorbed by the suspended solids. The clumps become heavier and eventually fall out. (Kemp et al.2022)

The older vintages of wine were usually fined with fresh egg whites to remove unwanted sediment. This is because egg whites are positively charged, while the suspended particles in wine are negatively charged. This causes particles and egg whites to attract each other and form clumps that are heavy enough to fall out of the wine. However, egg whites are not the only fining agent that can be used to remove these substances. Other fining agents that may be used include casein, gelatin, charcoal, and polyvinylpyrrolidone.

7. Discussion

This chapter aimed at discussing the basic and advanced techniques employed daily in chemical and biochemical laboratories in academia and industry around the world. Biochemistry and analytical techniques, singly or combined, are mandatory in laboratories that specialize in separation, determination of organic molecules in complex samples, toxicity analysis, or high-throughput screening. Similar protocols have been developed for performing nucleic acid electrophoresis, although electrophoretic methods for the resolution of different conformational forms of nucleic acids, their interactions with proteins or lipids, or their recognition by small molecules are far more complex and laborious than for simple organic molecules. In the last decade, capillary gel electrophoresis and microfabricated systems have shown relevance when dealing with the determination of size and conformation or during high-throughput screening assays with nucleic acids. Special protocols are also implemented for the visualization, manipulation, and excision of specific DNA, RNA, or protein regions of interest in electrophoretic gels. (Simundic et al.2020)

8. Conclusion

In conclusion, the basic and advanced techniques used in medical laboratories can be applied in other laboratory environments, that is, in teaching basic techniques and in solving problems that arise in the implementation of advanced techniques. As basic techniques, we can refer to a microscope, cell staining, spectrophotometry, and bacterial growth detection. These techniques are essential in the training of students who conduct fieldwork in forests and other ecosystems. The advanced techniques are widely used in research and in the implementation of new techniques and are also used for pedagogical reasons. In practical classes, it is important to gradually introduce more advanced macroscopic techniques, such as the electrophoresis of plant leaf proteins. This is very important, as the number of students who participate in fieldwork that ends with the isolation of fungal endophytes is limited. For the teacher, it is important to have some prepared samples that the student can observe. The preparation of a given sample can be developed by students who are interested in going further in their inquiries into the subject, either by using techniques already taught or by using others that suggest themselves when dealing with a more complex target. (Zhang et al.2022)

The basic and advanced techniques used in medical laboratories also have applications in other laboratory environments, especially in textiles, where fabrics treated with silver maintain a powerful antimicrobial function even after they pass through different washing cycles. However, these techniques were not taught to students in the field, so the conditions were not controlled. The integration of scientific research into practical classes is important in order to make the fieldwork an attractive proposition. In addition, the formative function of practical classes is important for the teaching of basic techniques as well as more advanced help in troubleshooting. Although the presence of a laboratory technician is vital, technical assistance can hardly use resources, which are always scarce, available in teaching laboratories. The use of basic techniques can result in teaching or in difficulties during the practical classes. It should be noted that practical classes play a fundamental role in the training of students, as they allow the execution of experiments which, given the time limitations characteristic of theoretical classes, cannot be performed. Although fieldwork is unattractive and tends to discourage students, the interest and motivation of the participants are generally very high, especially when equipment or techniques used are different from those used in the usual classes. Although there are teaching staff responsible for all aspects of practical work, problems may arise, which is a challenge for the laboratory technician. (Chen et al.2021)

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