CHEMISTRY

PRACTICAL MANUAL

Class XI & XII

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Foreword

The Teaching and Learning of Science has been given the highest priority. Science as a subject and the course that guides the way of living of an individual is crucial in building a scientifically literate and science elite professionals much needed for a developing country, Bhutan. It envisages that our young children develop quantum of scientific knowledge through meaningful hands-on engagement in the fundamental of scientific processes to foster skills and attitude and empower learners with abilities to justify their actions and take part in debate related to social, cultural and environmental issues. Towards this, the Science Curriculum at the Royal Education launched the science curriculum reform 2008 and concludes with the publication of the Practical Science textbooks in Chemistry, Biology and Physics for classes XI and XII in 2016.

Though the educational inspiration and insights are drawn from the concepts of 21st Century Learning Framework, the curricular approaches and delivery is largely guided by the principles and values of Gross National Happiness (GNH). The 21st Century Leaning and Innovative skills is founded on the premise of developing critical thinking, collaboration, communication, and creativity skills in learners. This mandates a shift from the existing teacher-centered to a learner-centered constructive approach to teaching and learning. The constructivist approach emphasises on cooperative learning and project based learning using Information, Communication and Technology (ICT) as tools to learning Science through understanding.

The development of these practical science textbooks is inspired by the ideology that science curriculum is not merely to focus on content, but emphasis is also on the scientific processes of questioning, hypothesizing, observing, investigating, recording and communicating. Therefore, Science teaching is not to impart knowledge, rather it is to inspire •1eamers to inquire and probe into the scientific ideas and the world around them. At the same time make learners daring to attempt to try out new possibilities, which may culminate to addition of new knowledge in the field of science at the national and global levels.

The Royal Education Council is optimistic that because these textbooks are designed based on the new breed of curriculum orientations with emphasis on learning by doing, learners enjoy the learning through active engagement and in-depth exploration of scientific concepts and phenomena. The Science curriculum materials present suggestive contents and practices of science only ensuring that both teachers and learners explore further beyond the classroom and school boundaries to embrace the contemporary ways of thinking and doing science.

Wishing both teachers and learners an insightful and enriching engagement in science teaching and learning processes!

(Kesang Choden Dorji)
DIRECTOR
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Introduction

According to the Bhutanese science curriculum framework (DCRD, 2012), one of the goals for science education is "*To develop and apply the skills of inquiry, investigation, problem-solving, logical reasoning and communication*". Towards this, scientific inquiry is crucial. Scientific inquiry is the primary process by which scientific knowledge is gained. It involves the practice of basic skills of questioning, hypothesizing, investigation and experiment, observation, classification, drawing conclusion, and communication. This process engages learners in identification and control of variables, generation of procedures, planning strategies for testing hypotheses and answering questions, collecting and interpreting data to draw conclusion founded on the scientific concepts and ideas.

There is a substantial amount of research evidences supporting constructivism (Fosnot, 1996) and cooperative learning (Educational Resources Information Centre) in science education to equip learners with the 21st Century Learning and Innovative skills. The 21st Century Learning and Innovative skills is founded on the premise of developing critical thinking, collaboration, communication, and creativity skills in learners. These skills fundamental to Life and Career skills are to enhance the academic performance in learners and prepare them to be productive citizens guided by the GNH values, without compromise as globally competitive individuals. This mandates a shift from the existing teacher-centered to a learner-centered constructive approach to teaching and learning (Moursund, 2004). The constructivist approach emphasises on cooperative learning and project based learning using Information, Communication and Technology (ICT) as tools to learning science through understanding.

Chemistry is a branch of science that deals with the study of particle structure of materials, how materials are formed and how the structures of a material determine its properties. They will also learn about how the processing of raw materials results in new materials being produced with different properties and uses, and consider environmental issues of the impact of some materials such as plastics on the environment and other environmental issues. Chemistry practical works provide learners with opportunities to question, observe, sample, experience and experiment with scientific phenomena in their search for knowledge. They are the effective means for comprehension, understanding, and application of biological knowledge.

This handbook is designed to reinforce learners to validate the theoretical knowledge based on the practical probes. Therefore, the book has two sections, Section I and Section II. The Section I, fundamentals of practical in science briefly outlines the purpose of Chemistry practical, general scientific skills, and assessment in Chemistry practical. It is developed with all the necessary information for conducting the experiments. It discusses on the laboratory skills, general procedures, equipment and their uses, chemicals, safety measure, etc. It is incorporated with a motive to provide a general overview of laboratory management and other necessary skills to conduct a practical successfully. Section II is divided into two parts, Part A comprises of experiments identified for class 11 science students. It includes some investigative type of experiment developed in relation to the theory learnt in Chemistry classes. Similarly, Part B contains experiments relevant for class 12 science students. Many experiments are designed to facilitate learners to explore beyond the scope of the syllabus.

The exercises given at the end of each experiment provoke critical thinking; facilitate learners to generalise scientific ideas and concepts inductively and deductively, and enable them to relate these experiences to their immediate environment and lives.

Science, Technology, Engineering and Mathematics Division,

Curriculum Development Centre,

Royal Education Council

Contents

PART A SECTION I - Experiments for Class XI

PART B - Experiments for Class XII

FUNDAMENTALS

OF

CHEMISTRY PRACTICAL WORKS

1. Purpose of Practical Works in Science

1.1. Rationale

Educational paradigm for most of the twentieth century was governed by the philosophy of indoctrinating the young into the logic of the present. This worldview had to evolve when mass exodus of technology, a product of science, infused every strata of society. Science technology and society and scientific literacy therefore gained prominence becoming a popular slogan for science education reform movement. School science, therefore, was carefully realigned to reflect the intellectual and cultural traditions that characterise the practice of contemporary science. It is of outmost importance that students develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture (NRC, 1996).

The goals of school science that underlie the Science Curriculum Framework (DCRD, 2013) and the National Education Framework (REC, 2012) are to educate students who are able to:

1. understand scientific concepts and acquire skills appropriate to their level of learning and for their lives as citizens, or as future science professionals.

2. develop their skills of inquiry in order to carry out investigations and experiments.

3. transfer the skills of inquiry to be active and critical citizens.

4. develop the ability to use information critically from a wide range of sources to answer scientific questions, address misconceptions and issues in society and in life.

5. apply knowledge and understanding of science to solve key problems of science and for the conservation of environment, including adopting the principles of refuse, reduce, recycle and reuse.

6. develop their abilities for meeting the scientific and technological needs and aspirations of the country and day-to-day life.

7. develop a sense of ethics and responsibility by understanding that the knowledge of science has not only contributed positively to the human development, but also has harmful effect both on environment and human life.

8. share the skills learnt in science in order to develop effective scientific communication skills in learners and in the society.

9. acquire qualities of commitment, self-confidence, curiosity, creativity, integrity and adaptability.

10. develop a sense of honesty and the importance of their contribution to their family, community and country, and understand the value of working together as a team.

In essence, Science Education encompasses "*Scientific Content*" and "*Scientific Process*". The content ascribes the quantum of scientific knowledge critical in understanding about living and non-living things around, while the scientific process elicits the variety of skills that facilitate learners to understand "*the nature of the scientific knowledge*" and "*how science works*". The later part is critical in facilitating learners develop the ability of constructing their understanding about the world around them culminating to making individuals lifelong learners and endowed with scientific temper and competencies. On this premise, practical work in all discipline of science classes is pivotal in science teaching and learning processes in Bhutan.

1.2. What is Chemistry Practical Work?

Millar (2009) describes a practical activity as any science teaching and learning activity, which involves students in working individually or in small groups, in observing or manipulating objects and conditions to develop Biological knowledge and understanding. Practical work is viewed by majority of science teachers as an essential and integral part of science education.

1.2.1. Components of Practical works

The practical work is considered as the means and ends and embeds numerous types of scientific activities, which can be categorised into two main groups as described by Woodley (2009), as follows:

1. **Core Activities:** These include 'hands-on' activities such as different investigations, laboratory techniques and procedures, as well as fieldwork. These types of activities can help enhance the development of students' practical laboratory skills, as well as helping them to understand the key scientific concepts and phenomena.

2. **Directly Related Activities:** These are closely connected to the above core activities, and include content based practical demonstrations performed by the teacher, planning and designing scientific investigations, and analysis of data by students.

Chemistry is a natural science based on experimentation and investigations. Chemistry knowledge is cumulative in that, a new knowledge has to be grounded in previously established chemical laws and principles: a chemical phenomenon can be explained by one or more than one principle or laws of chemistry. It is important to support and provide high quality practical work in Chemistry because it:

1. illustrates the chemical processes and complexity of the living world.
2. promotes understanding of how to extract information from complex chemical systems within and and among the living and the non-living.
3. provides experience of analyzing and evaluating variable data.
4. highlights and promotes discussion on ethical issues.
5. gives learners the skills to tackle global challenges.
6. motivate students by stimulating interest and enjoyment.
7. teach laboratory skills .
8. enhance the learning of scientific knowledge.
9. give insight into scientific method and develop expertise in using it.
10. develop 'scientific attitudes', such as open-mindedness and objectivity.

As per the national science curriculum, through the study of Materials and their properties, learners will understand the particle structure of materials, how materials are formed and how the structures of a material determine its properties. They will also learn about how the processing of raw materials results in new materials being produced with different properties and uses, and consider environmental issues of the impact of some materials such as plastics on the environment and other environmental issues.

2. Aims and Objectives of Practical Work

Learning by doing is fundamental to science education. Practical work is one of the means that helps student to develop their understanding of science, appreciate that science is evidence driven and acquire hands-on skills that are essential to development of quantum of scientific knowledge and understanding, and empower learners as scientifically literate citizens to lead productive lives and contribute to nation building.

2.1. Objectives of Practical Work

The practical work as defined by SCORE (2009a) is '*a "hands-on" learning experience which prompts thinking about the world in which we live*'. Therefore, the objectives of doing practical in science classes are to facilitate learners to be able to:

1. create new knowledge and understanding through the process of inquiry.

2. apply scientific knowledge and critical thinking to identify, define and analyse problems, create solutions, evaluate opinions, innovate and improve current practices.

3. design and conduct investigations.

4. disseminate new knowledge and engage in debate around the scientific ideas and issues.

5. recognise and value communication as a tool for negotiating and creating new understanding, interacting with others and further learning.

6. present and interpret data using graph, tables, diagrams and symbols.

7. develop manipulative skills in arranging and handling the apparatus and instruments and taking readings on them.

8. work independently and sustainably embedding the personal qualities of openness, curiosity and a desire to meet new challenges.

9. hold personal values and beliefs consistent with his or her roles as responsible member of the society.

10. demonstrate an understanding of significance and scope of ethical principles with commitment to apply these principles while making decisions.

11. appreciate the importance of sustainability and the impact of science on the economic, environment and socio-cultural context.

12. demonstrate empathy and sensitivity towards others situation, feelings and motivation.

13. demonstrate an understanding of various skills that can be applied to various situations.

14. use manipulative skills to conduct practical and conceptualise learning with respect to various domains of learning.

15. apply basic skills in day to day learning and life situations.

16. demonstrate the use of scientific skills to generate ideas by incorporating the research and investigation as an integral part of science learning process.

2.2.   Learning Outcomes

Students are engaged in the series of learning experiences during the Chemistry practical as   outlined in the Science Curriculum Framework (DCRD, 2013), culminating to the following learning outcomes.

2.2.1. How Science Works

By the end of Key stage 5 (Class XII), learners should be able to:

1. use theories and models to develop scientific explanations.

2. demonstrate that theories and models can help explain some ideas in science, but that they also have their limitations.

3. recognise how the scientific community validates new knowledge generated in research through processes such as peer review and conferences and that these processes help to ensure scientific integrity.

4. state some benefits and risks of the applications of science, and evaluate the implications of these benefits and risks in the society.

5. describe the ways in which science informs decision making at the national level in Bhutan and across the world.

2.2.2. Investigation and Experimentation

By the end of Key stage 5 (Class XII), learners should be able to:

1. **Designing and Planning:**

   (a) identify an appropriate question for investigation using their own knowledge from the Key Stage 5 or from their daily life experiences.

   (b) describe, where necessary, how to use controls and explain why appropriate control experiments should be established for the investigation being undertaken.

   (c) distinguish between the terms accuracy and reliability.

   (d) describe the methods used in their investigation or experiment to obtain accurate and reliable data.

   (e) plan an investigation or experiment that takes account of any safety and environmental issues involved, and state any ethical considerations that occur because of the treatment of living organisms.

6. **Obtaining and Communicating Evidence**

   (a) use apparatus and chemicals with due regard for safety of themselves, others and the environment and the well-being of living organisms.

   (b) carry out the experimental work systematically with a high level of accuracy.

   (c) use a wide range of appropriate ways to present the findings of the investigation including the use of tables, line graphs, pie charts, histograms, writing, labeled drawings and diagrams.

   (d) interpret key trends and patterns in the data collected and communicate these in an appropriate form.

5. **Concluding and Evaluating**

   (a) draw valid conclusions using the scientific knowledge.

   (b) apply simple statistical tests and, where appropriate, assign confidence limits to experimental results.

   (c) assess the reliability and precision of experimental data and the conclusions drawn from them.

   (d) evaluate the techniques used in the experimental activity, recognising their limitations.

   (e) discuss any improvements and adjustments to the plans and methods.

3. Scientific Skills

Learning science entails learners' engagement in the complexities of scientific processes of questioning, hypothesizing, investigating and drawing conclusion. This calls for possession and practice of different types of skills. In broader context, the scientific skills consist of the following categories.

3.1. Manipulative Skills

Manipulative skills in scientific investigation or practical work are the students' ability to conduct an experiment correctly and safely other than writing or reporting about it. They are psychomotor skills that enable students to use and handle instruments, substances, and specimen in a manner that befits a scientific temperament and safety standards. They play an important role in science education and are mastered only through 'hands-on' practical works. Evidences suggesting the possession of manipulative skills for practical works include the following:

1. comprehend the theory and objectives of the experiment.

2. conceive the procedure to perform the experiment.

3. set-up the apparatus in proper order.

4. check the suitability of the equipment, apparatus, and tool regarding their working and functioning.

5. know the limitations of measuring device and find its least count, error, etc.

6. handle the apparatus carefully and cautiously to avoid any damage to the instrument, as well as causing any personal harm.

7. perform the experiment systematically.

8. make precise observations.

9. make proper substitution of data in formula by using appropriate units (SI).

10. calculate the result accurately and express the same with appropriate significant figures justified by high degree of accuracy of the instrument.

11. interpret the results, verify principles and draw conclusions.

12. improvise simple apparatus for further investigations by selecting appropriate equipment, apparatus, tools and materials.

3.2.   Science Process Skills

The skills and practices used by scientists in gathering precision data and deducing relevant conclusion based on authentic data are called scientific process skills. They are a set of broadly transferable abilities, appropriate to different science disciplines reflective of a scientist's behavior.

The Framework for the development of Next Generation Science Standards (NGSS) underpins scientific process skills as practices to emphasise the engagement in scientific investigation not only require the skills, but also the knowledge that is specific to each practice. The Framework presents the following rationale to highlight the importance of process skills.

Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world.

Any education that focuses predominantly on the detailed products of scientific labor- the facts of science- without developing an understanding of how those facts were established or that ignores the many important applications of science in the world misrepresents science (National Research Council [NRC] Framework, 2012. Pp. 42 -43).

The standard practices of scientific investigation and experimentation are dependent upon tacit assumptions regarding their precision. These prerequisite skills to accurately experiment, with a certain acceptable margin of error, can be grouped as basic and integrated science process skills.

3.2.1. Basic Process Skills

1. **Observation**: Observation is the most fundamental science process skills. A person's ability to make good and reliable observation by engaging different sense organs is essential for the development of other scientific process skills. Some of the best practices to make good observations in Physics practical work are as follows:

   (a) read about appropriate instruments to be used in an experiment.

   (b) follow the correct sequence while making observations.

   (c) take observations carefully in a systematic manner.

(d) minimise errors in measurement by repeating the test.

2. **Classifying**: The ability to group, order, and sort objects and phenomena into categories based on properties and varying complexities of criteria. The following competency indicators indicate a good classification system:

(a) use common characteristics of objects and events to classify them.

(b) group objects and events based on their similarities and differences.

(c) use classification systems to categories objects and phenomena.

3. **Measuring and Using Numbers**: Measuring is an important method of observation. The statement of a measurement contains two parts, a numerical value or a number that tells us how much or how many, and an accepted terminology of the unit that tells us how much of what. Classifying without a numerical value makes it a qualitative observation, while the use of a number and its corresponding unit makes it a quantitative observation.

4. **Inferring**: Inferring refers to drawing conclusion based on the gathered data or information. Past experiences play a crucial role in making reliable inferences. The accuracy in inferring improves with experience and repetition of the test.

5. **Predicting**: It is the ability or a skill to state the outcome of a future event based on a series of evidences, which have similar pattern. To make a good prediction of an event, a series of similar observations must be made. For example, predicting the height of a plant in two weeks' time based on a graph of its growth during the previous month.

6. **Communicating**: Communicating skills refer to the ability to use accurate words or graphic symbols to describe an action, object, or an event. It comprises two sub-skills, which are directly related to physics practical works.

Drawing Skills: Drawing are generally used to describe an experimental set up pictorically, which otherwise is a lengthy descriptions of apparatus and their setups. It is essential for students to be able to draw diagrams, observation tables and graphs wherever necessary to replace lengthy descriptions and present a set of data in a comprehensive visual format.

(a) Make schematic diagram of the apparatus and specimen.

(b) Label different parts with appropriate lines and arrows.

(c) Depict the direction of force, tension, current, ray of light, etc., by suitable lines and arrows.

(d) Plot the graphs correctly and neatly by choosing appropriate scale and using appropriate scale.

Reporting Skills: The accuracy of a scientific conclusion drawn from a set of authentic data is dependent on its generalization and reliability. Generalization refers to applicability of the conclusions to other settings, and the reliability refers to the accuracy of the processes involved in arriving to the conclusion. Reporting skills allow others to test the conclusions by conducting similar experiments. Follow the following scheme:

(a) Make a proper presentation of aim, apparatus, formula used, principle, observation table, calculations and result for the experiment.

(b) Support the presentation with labelled diagram.

(c) Record observations systematically and with appropriate units in a tabular form wherever required.

(d) Present the calculations or results for a given experiment along with proper units.

(e) State limitations of the apparatus or devices.

(f) Summarise the findings to reject or accept a hypothesis.

(g) Interpret recorded data, observations or graphs to draw conclusion.

(h) Explore the scope of further investigation in the work performed.

3.2.2. Integrated Science Process Skills

Integrating the different forms of basic science process skills enables a person to make sense of a scientific enterprise. The development of integrated skills occurs gradually as students are sufficiently exposed to experiments, or deliberately taught by teachers as a learning objective. These are pre-requisites to independently design experiments and derive conclusions. The following section provides a brief description of these skills:

1. **Space-time Relationships**: Space form a coordinate system of coexisting objects and states of matter. It means that the objects are juxtaposed to one another, alongside, beside, beneath, above, within, behind, in front, etc., and have certain quantitative relationships. Time is also a form of coordination of objects and states of matter in their succession. Every state is a consecutive link in a process and has quantitative relation with other states. A correct

understanding of the relationship between space and time is required to appreciate the universal form of existence of matter, referred to as the coordinate system.

2. **Defining Operationally**: It is the skill required to state the correct procedure to measure variable in an experiment. The competency indicators of defining operationally are to state the definition of object or phenomena in terms of:

   (a) what the object is doing or what is occurring in the phenomena.

   (b) observable characteristics of the objects or the phenomena.

3. **Identifying and Controlling Variables**: The process skills required to identify and control the variables that can affect an expected outcome are called identifying and controlling variables. It helps in understanding the importance of both dependent and independent variables for a process.

4. **Formulating Hypothesis**: It is the ability to develop an assumption on the expected outcome of an experiment based on limited evidence as a starting point for further investigation. Similarly, it allows a person to generate a theory based on empirical evidences.

5. **Interpreting Data**: This integrated process skill is essential for a student to be able to organise data in a way that makes sense and draw relevant evidence based conclusion. Logical and mathematical reasoning skills are a prerequisite for interpreting data.

6. **Experimenting**: Experiment is the use of all the basic and integrated science process skills. A person with this skill is able to design and conduct scientific investigation independently to either formulate a new or validate the existing theory.

4. Safety in Laboratory

In the science laboratories, students handle equipment and chemicals of different nature. Chemicals can be hazardous, poisonous, and corrosive and can pose health risk, or may injure themselves. In order to minimise or prevent the health risk and accident in the laboratory, safety is a necessary precaution. Adoption of set of laboratory rules is one of the ways. Once students know the need to behave safely, accidents can be prevented.

Some of the factors affecting the level of risk in school laboratories are:

1. *Use of Laboratory Facilities:* All the facilities in the laboratory should be properly utilised under the strict supervision of the teacher or laboratory assistant. This can avoid misuse of facilitates, injuries and risk to oneself and others.

2. *Clothing and Hair:* Improper clothing and untied long hairs can increase the risk of fire accident in the laboratory. Therefore, always be in proper attire and tie long hairs while doing experiments.

3. *Handling of Substances and Appratus:* Careless handling of corrosive substances, hazardous chemicals, glass wares, sharp apparatus and hot materials can put you at risk. It is always advisable to handle such materials with extra care.

4. *Movement:* Avoid unnecessary movement inside the laboratory to minimise disturbance and chances of accident.

5. *Housekeeping and Proper Maintenance:* Laboratory should be kept neat and clean. Always clean work station and other equipment used before leaving the laboratory. Practice safe disposal of waste. It avoids chemical contaminations and other hazards.

4.1. Safety Rules

These are set of safety rules that students need to follow to prevent laboratory accidents.

1. The students should clearly understand the instruction of experiment they are to perform in the laboratory.

2. The instruments, glassware and any other equipment should be kept clean in proper places before and after its use.

3. The microscope and other delicate instruments should be handled gently and properly, and should be at least five inches from the edge of the table to avoid knocking off it accidentally.

4. Dispose broken glassware in a separate bin.

5. Whenever working with sharp instruments such as blade or scalpel etc., be careful not to cut or puncture your skin.

6. Avoid inhaling, tasting or applying stains or chemicals, as they may be harmful.

7. Do not eat in the laboratory to avoid infection.

8. Safety glasses should be worn while handling the chemicals.

9. Avoid wearing ornaments in the laboratory.

10. Hair must be tied up properly.

11. Laboratory coats must be worn while working in the laboratory.

12. Avoid swallowing chemicals, as it may be toxic.

13. The mouth of the test tube should be facing away from you while heating the substances.

4.2. Safety Signs and Symbols

Safety signs are very informative and they can be displayed on walls, doors, etc. There are four categories of signs:

1. Warning signs

2. Mandatory signs

3. Safe condition signs

4. Prohibition signs

4.2.1. Warning Signs

Warning signs are very informative and help reduce laboratory related accidents. These are usually labelled on the container of chemicals to indicate the nature of its contents. These signs must be displayed wherever appropriate to remind anyone in the laboratory regarding the possible hazards.

Poisonous

Most chemicals marked by this symbol are fairly dangerous if ingested or inhaled and many of these are dangerous even on contact

Biohazard

These are living organisms that may cause infection

Corrosive

Most chemicals marked by this symbol will destroy or damage another substance with which it comes in contact.

Oxidiser

Oxidising chemicals are materials that spontaneously evolve oxygen at room temperature or with slight heating, or that promote combustion.

Explosive

Most chemicals marked by this symbol are subjected to explosion when exposed to fire, flame or sparks.

Irritant or Harmful

This symbol covers a wide range of hazards - with precautions such as avoid contact with the skin, do not breathe, etc

Radiation

These substances are radioactive. Radiation can damage cells and cause cancer

Flammable

Most chemicals marked by this symbol are volatile, flammable and pyrophoric materials

Environmental hazard

Most chemicals marked by this symbol are environmental hazardous and if disposed into streams and rivers, these may affect marrine life

Dangerous when wet

Most chemicals marked by this symbol are subjected to react fairly violently with water

Stow away from foodstuffs

Most chemicals marked by this symbol should not come in contact with foodstuffs

Non flammable gas

Most chemicals marked by this symbol are nonflammable in open air

Figure 4.1. Safety warning signs.

4.2.2 Mandatory Signs

The mandatory signs inform students of the specific course of actions that they need to do as precautionary measures while performing experiments in the laboratory or outside. The common signs are:

Laboratory coat must be worn

Eye protection must be worn

Wash your hands

Keep door shut

Figure 4.2. Common mandatory signs

4.2.3 Safe Condition Signs

Figure 4.3. Safe conditions signs.

They are the signposts about the condition, direction of the place or label of safety facilities in the science laboratories or in the public places.

4.2.4 Prohibition Signs

Food or Drinks Prohibited

No Open Flame

Do Not Touch

Figure 4.4. Prohibition signs.

These signs informs the certain behaviour is prohibited in the premises for the safety of oneself and the others.

4.3. Safety Equipment

To protect you from potential hazards, personal protective equipment must be worn at all times while in the laboratory. The common protective equipment are:

4.3.1. Safety Goggles or Spectacles

Protective safety goggles/spectacles, or face shields must be worn in all circumstances when there is recognised risk of damage or injury to eyes. Failure to do so will be regarded as negligence. Eye protection should always be worn when heating chemicals, handling corrosive or irritants such as acids, alkalis, formalin, chloroform etc.

4.3.2. Protective Clothing

Wear suitable protective clothing and gloves while working in the laboratory when:

1. washing apparatus (especially if contaminated with chemicals or microorganisms).
2. handling dangerous chemicals.
3. handling chemicals known to sensitise the skin and cause allergy.
4. handling hot apparatus.

4.3.3. Handling Chemicals

1. Never take acid and alkalis to class room.
2. While adding acids / alkalis into test tubes, it should be gently added down the sides using a dropper.
3. Always use spatula to take out solid chemicals from the container.
4. Use pipette filler to take out the acids and alkalis from the container.

4.3.4. Heating Substances

When heating the substance, the test tube should be moved back and forth over the flame

Figure 4.5. Heating.

and mouth of the test tube pointed away from people. Always use a minimum quantity of substance for heating.

4.3.5. Smelling Gases

While smelling gases, the correct way to do is fanning the gas towards the nose and sniffing cautiously. Direct inhaling of gas should be avoided.

4.3.6. Cleaning of Glass Apparatus

Clean glass apparatus by rubbing with detergent powder and then rinse with water. If stains are not removed by this method, concentrated nitric acid or chromic acid can be used. To remove stains from the container add concentrated nitric acid on the stains and leave it for 15 to 20 minutes. Then dilute the acid with water and throw the diluted acid into the sink. After that add some detergent powder and clean it thoroughly using the test tube brush.

Figure 4.6. Smelling.

4.4. First Aid in the Laboratory

The main purpose of first aid is to make the person feel secure and comfortable during any accident in the laboratory. It is also to prevent deterioration of patient's condition. The following treatments or measures are recommended as first aid in case of injuries.

4.4.1. Fire

In case of fire accident, the following measures can be practiced.

1. Pour water carefully, except when sodium, potassium, oil or spirit is on fire or fire caused due to electricity.

2. Use large quantity of sand if sodium, etc., is on fire.

3. Use a mixture of sand and sodium bicarbonate or fire extinguisher if oil or spirit is on fire.

4. When any liquid or flask is on fire, cover the mouth of the vessel with a damp cloth.

5. In case a cloth of a person catches fire, lay the person on the floor, keeping burning parts of clothes upwards and cover with a fire blanket. Never throw water on the person; it may cause serious injury on the body.

4.4.2. Fainting

It may be caused by fatigue,sitting or standing for a long time in a hot or stuffy atmosphere or due to inhalation of gases. Carry out the following to the person who has fainted:

1. Loosen clothing at the neck, chest and waist.

2. Lay the patient down in comfortable place or let her/him sit down and lower the head between the knees.

3. Do not flush water on the face as this can lead to choking.

4. On recovery, give some water to drink.

4.4.3. Cuts and Bleeding

A sharp, pointed or broken instrument may cause bleeding. The wound with slight bleeding usually stops on its own or is controlled by local pressure. Try the following steps to control bleeding:

1. Place the bleeding part at rest.

2. If the wound is dirty, wash and gently clean it with clean water.

3. Raise the injured part and support it in position.

4. Apply a dressing with a pad and bandage firmly on the position.
For wounds with severe bleeding, stop the bleeding and get medical help immediately.

4.4.4. Burns

Burns are caused by fire, electricity, contact with a hot object, corrosive chemicals (acids, alkalis, etc.) and friction. The best way to treat burns is by immersing the burnt part under slow running water until the pain stops. In case of severe burns get medical help immediately.

Do not:

1. Apply lotions, ointments, etc.

2. Prick blisters or touch the burned area to prevent infection.

4.4.5. Eye Injuries

Whenever there is eye injury, try the following:

1. Prevent the patient from rubbing the eye.

2. If chemical or solid particles has got into the eyes then wash with plenty of water by using a clean wash bottle as shown in Figure 8 below. For any eye injury get medical help immediately.

4.4.6. Poisoning by Strong Acid:

1. If acid gets into the mouth, first spit it out and wash with water repeatedly. Then drink plenty of water to dilute the acid. Refer the patient to the hospital.

2. If alkali gets into the mouth, first spit it out and wash the mouth with water for several times. Then drink plenty of water followed by lemon juice or orange juice.

4.4.7. Poisoning by Strong Acid:

Whenever a person gets an electric shock, switch off the mains supply immediately. Drag the person away using dry clothes or other insulating materials to protect oneself. Make the person lie down with feet raised slightly and keep her/him warm. For mild shock, a person may be given a water to drink.

4.4.8. Poisoning by Strong Acid:

If a person has inhaled poisonous gases like chlorine or bromine, keep him/her in fresh (open) air for sometime and take him/her to the hospital

4.5.   First Aid Box

The content in first aid box contains the following items.

1. *One pair of blunt-ended scissors*
2. *Assorted bandages*
3. *Adhesive plaster and dressings*
4. *Sterilised cotton wool*
5. *Sterilised gauze*
6. *Mild antiseptic solution*
7. *Safety pins*
8. *Small forceps*
9. *Eye bath (clean wash bottle)*
10. *Anti-septic cream*

4.6.   Disposal

Different kinds of waste are produced in the laboratory. Some of them may be harmful to human health and the environment. It is advisable to segregate these wastes appropriately and dispose off them safely.

4.6.1. Chemical Wastes

Disposal with large quantities of water and disposal through the laboratory drainage system may be used for small amounts of acid, alkalis and solutions containing small amounts of metals. However, greater quantity of chemicals must be disposed off in landfills.

4.6.2. Organic Wastes

Organic waste should be collected in labeled bottles for disposal. It should never be flushed down the laboratory sink. However, very small amounts may be disposed by burning.

4.6.3. Biological Wastes

Potentially infectious material, for example, blood, urine, bacteriological and fungal cultures must not leave the laboratory unless they are treated in the autoclave. The remains of non-infectious materials and dissected animals should

be placed in sealed plastic bags and incinerated. The safest method of disposing biological waste is by incineration.

4.6.4. Plastic, Glass and Sharp Wastes

Non-infectious or non-contaminated glass and sharp waste should be placed in metal bins and may be disposed with domestic waste to landfill sites.

4.6.5. Disposable and Ordinary Syringes

1. Disposable syringe should not be obtained second hand from any source as they cannot be sterilised.

2. Syringes used for nutrient solutions may promote the growth of micro-organisms and therefore, should be incinerated after use.

3. The teacher should ensure that no syringes are taken out from the laboratory.

4. Excessive pressure on the syringe with needle may cause the needle to blow off either striking another student with the needle or spraying the liquid from it on oneself or others.

5. Used disposable syringes and needles should be disposed properly.

4.7. Ethical Issues to be Considered

Whenever students are involved as subjects of experiments, ailination or emotional insecurity may arise. Therefore, the following guidelines are suggested:

1. Students should not be forced to take part in such experiments.

2. If parents, guardians or doctors have objections on their wards taking part in experiments for fear of health effects, students should be refrained from activities that have health risk.

3. Experiments must not be carried out in which physical, chemical or biological means such as drug or electrical stimulation, are used to study the mental state of the subject.

5. Laboratory Techniques and Skills

The laboratory technique is the use of standard pieces of laboratory equipment essential in many experiments, as well as how to perform basic laboratory functions as deemed scientifically appropriate and safe. Reading a meniscus, cleaning glassware, making solution of required strength, operating microscopes, etc., students need to exhibit the know how of these equipment.

5.1. Practical Work Record Book

Maintaining proper record is very important for any experimental process as it provides a collection of data that can be used as future references, and also to evaluate accuracy of different experiments. The following points should be considered in maintaining proper practical record.

1. Record should be neat and up to date.
2. Diagrams should be accurate, drawn and labeled correctly using straight lines.
3. Date should be written for each practical.
4. Proper sequence and format should be followed while recording observations.
5. Always start recording the new practical on a fresh page.

The purposes of any scientific investigation are to construct and propose new knowledge claims and validate those claims based on empirically obtained evidence, including evidence gathered by others or through experimentation. Therefore, it is crucial to communicate the procedures of investigation to others in detail using appropriate scientific language, so that they can conduct similar investigations to validate the new knowledge claims. The proposed theory is then either accepted or rejected based on scientific, logical, or mathematical reasoning using empirical data. The details of an investigation, the data obtained, result analysis procedure, and the conclusions drawn are communicated, through publications, in a standard format which consists of all the above essential components as follows.

I. *Title of the Experiment*

This section should contain the name of the experiment and the date the experiment was conducted.

II. Aim of the Experiment

The aim of the experiment consists of one or two sentences indicating the goal(s) of the practical work.

III. Theory

This section includes a brief description about the concept and mathematical relations regarding the experiment.

IV. Question

This section should contain the hypothesis question.

V. Hypothesis

In this section, the student(s) should include his/her own hypothesis of what is the expected outcome of the experiment. S/he should explain, in one or two sentences, why s/he thinks the stated hypothesis is correct.
Example: In an experiment to determine the combined focal length of two coaxially placed converging lens, the hypothesis would state: the combined focal length of the combination of two converging lenses would be smaller than either of the lenses. Explanation: Since the two lenses are placed co-axially the new radii of curvature increases, therefore the focal length of the combined lenses will become smaller.

VI. Variables

This section should allow students to identify the variables in the experiment.

VII. Materials and Apparatus Required

This section should contain the list of all the materials in a set, including the numbers of devices, to conduct the practical individually or in a group.

VIII. Procedure

This is one of the most important sections in the laboratory report. The procedures to be followed to conduct the practical should be written in the chronological order.

IX. *Observation*

In this section, students need to record their observations. Typically, an observation table is drawn before the experiment where you record all the data. Always be cautious that the observed values are not the final data to be entered into the observation table. The data should be the corrected reading, with all the errors and least count of the instrument accounted for. These data which will be used for all the computations. There may be cases where two or more than two observation tables are required. Irrespective of the number of observation tables required, they should be labelled and contain appropriate units.

X. *Result*

It consists of all the findings of the experiment

XI. *Conclusion/Verification of Hypothesis*
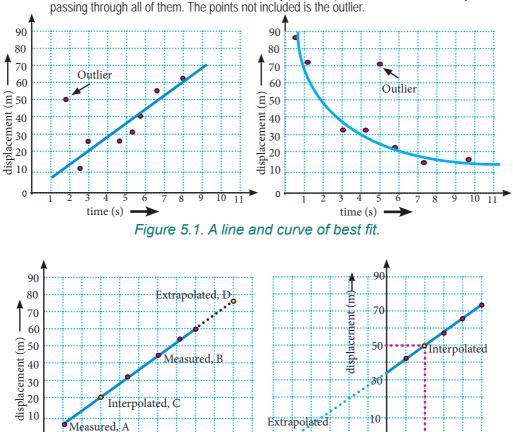
In this section, the entire results of the experiment is generalised into general theory, law or phenomenon.

5.2. Plotting a Graph

Graph is a two dimensional drawing which represents relationship of two quantities in visual form. There are different types of graphs but all the graphs consist of components of x-axis and y-axis to represent the variables with values.

1. **Axis:** Axes are the lines perpendicular to each other. The vertical line is known as y-axis and the horizontal is called x-axis. The intersection point on the axes is called origin of the graph, usually represented by the ordered pair (0, 0), but it may have other ordered pair according to the reading. This origin divides each of these axes into two halves (four quadrants), a positive and a negative semi axis.

2. **Plotting of Variables:** Out of the two variables, one is independent and the other is dependent variables. Independent variables do not change or vary with other variables and should be taken along the x-axis as well as should be the first set of data in a data table. Dependent variables vary according to the value of the independent variables; hence, it should be taken along the y-axis.

3. **Choosing of Scale:** From the data, calculate the range of each variable by subtracting minimum reading from the maximum reading, then divide the range and the number of squares on the axis. Round the answer to a number that is easy to count by such as 1, 2, 5, 10, 20, etc. The scale chosen for both the axes may be different, but it should be easily subdivided for the divisions on the graph paper. Axes should be marked at regular intervals according to the chosen scale and should cover more than half of the area of graph.

4. **Plotting the Points:** Plot each ordered pair on the graph with a small dot and encircle it with a small circle or with a cross (x).

5. **Plotting of Graph Line or Curve:** Join all the points with a thin and sharp straight line with the help of ruler for line graph and for curve, draw perfect curve with free hand.

6. **Line of Best Fit:** It is a straight line that passes through either maximum number of points or closer to maximum number of points, on the either sides of the line. They can either be straight lined, or a smooth curve. The Figure 6.1 is example of the graph with the best fit line and curve.

7. **Extrapolations and Interpolations:** If required to extrapolate (extend the graph, along the same slope, above or below measured data), use dotted line. It is used to predict the value of the dependent variable for an independent variable that is outside the range of our data. Interpolation is used to predict the value of the dependent variable for an independent variable that is in the midst of our data. Interpolation and extrapolations are shown in Figure 6.1. Interpolation is preferred because we have a greater likelihood of obtaining a valid estimate. When we use extrapolation, we make the assumption that our observed trend continues for values outside the range we used.

A line or curve of best fit comes close to as many points as possible without necessarily passing through all of them. The points not included is the outlier.

Figure 5.1. A line and curve of best fit.

Figure 5.2. Extrapolation and Interpolation.

$$\text{Slope} = \frac{\Delta d}{\Delta t} = \frac{(70 - 30)\,\text{m}}{(8.5 - 4)\,\text{s}} = \frac{40}{4.5}\,\text{m/s}$$

$$= 8.89 \text{ m/s}$$

Figure 5.3. Slope.
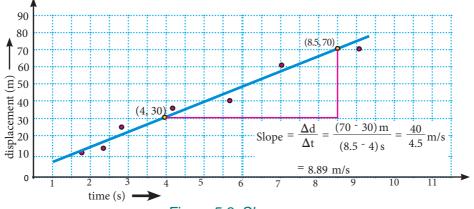
8. **Calculating Slope:** The steps for calculating the slope of graph are given below.

   (a) *Mark two points on the line, as far apart as possible.*

   (b) *Connect the two points with one horizontal line and one vertical line to form a triangle.*

   (c) *Measure the run - how far the line has gone to the right on the horizontal line.*

   (d) *Measure the rise - how far the line has gone up (or down) on the vertical line.*

   (e) *Divide the rise by the run to get the slope.*

5.3. Measurement in Chemistry

5.3.1. Measurement Error(s)

Error is the difference between the actual value of a quantity and the value obtained by a measurement. Repeating the measurement will reduce the random error but not the systematic error.

Accuracy : Accuracy in measurement is how close measured values are to the actual value or true value on multiple observations.

Precision : Precision in measurement is how close the measured values are to each other.

(a) Classification of Errors
Errors can be broadly classified into two categories namely, systematic error and random error.

1. **Systematic Error:** Systematic errors are those errors which tend to shift all measurements in a systematic way so their mean value is displaced. This may be due to incorrect calibration of equipment, consistently improper use of equipment or failure to properly account for some effect.

2. **Random Errors:** Random errors are those errors which fluctuate from one measurement to the next. They yield results distributed about the mean value. They can occur due to various reasons.

   • They may occur due to lack of sensitivity. For a sufficiently small change, an instrument may not be able to respond to it or to indicate it or the observer may not be able to discern it.

- They may occur due to noise. There may be extraneous disturbances which cannot be taken into account.
- They may be due to imprecise definition.

Random errors displace measurements in an arbitrary direction whereas systematic errors displace measurements in a single direction. Some systematic error can be substantially eliminated (or properly taken into account). Random errors are unavoidable and must be lived with.

3. **Absolute Error:** The absolute error is the difference between the actual and the measured value.

4. **Relative Error:** Relative error is the absolute error divided by the actual measurement.
$$Relative\ error = \frac{Absolute\ error}{Actual\ value}$$

5. **Percentage Error:** The percentage error is the relative error shown in terms of percentage.

5.3.2. Significant Figures and Rounding Off

(a) Significant Figures:
Significant figures of a measurement are the digits reliably known plus one last digit that is uncertain.

Following points should be kept in mind while determining the significant figures of a measurement:

i. All the non-zero digits are significant figures.

ii. The number of significant figures in a number is equal to the number of digits counted from the first non-zero digit on the left to last digit on the right. For instance, in a number 12.6 there are three significant figures.

iii. All zeros occurring between two non-zero digits are significant figures. In a number 10003, there are 5 significant figures.

iv. All zeros lying in between a decimal point and the first non-zero digit on its right side are not significant. A number 0.000345 has 3 significant figures.

v. All zeros appearing on the right side of a decimal point are significant. A number 12.000 has 5 significant figures.

vi. Where there is no decimal, final zeros are not significant. A number 3340000 has 3 significant figures.

vii. The last digit in significant figures of a number is its uncertain digit. In a number 45.6, 6 is uncertain digit.

(a) *Rounding off to the Required Number of Significant Figures*

The following are the rules to be followed for rounding off:

i. If a digit to be dropped is less than 5, then the digit immediately preceding it remain unchanged. For example, if the result 134.627 m is rounded off to 4 significant figures, then the digits 2 and 7 are dropped and the result is 134.6 m.

ii. If the digit to be dropped is more than 5, then the digit immediately preceding it is raised by one. For example, if the result 12.376 m is to be rounded off to 4 significant figures, then digit 6 is dropped, the preceding digit 7 is raised by one and the result is 12.38 m.

iii. If the digit to be dropped is 5, then preceding digit is made even by:
a. *increasing it by one, if it is odd.*

b. *keeping it unchanged, if it is even.*

For example, if the result 3.75 m is rounded off to two significant figures, the result is 3.8 m and if the measurement is 3.85 m, the result is 3.8 m.

The accuracy of the measurement depends upon the number of significant figures. Greater the number of significant figures, greater is the accuracy of the measurement.

5.3.3. Measurement of Volume
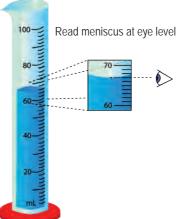
Figure 5.2. Volume measurement using measuring cylinder.

(a) *Measuring Cylinder*

It is an 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. There are various types of measuring cylinder (150 mL, 100 mL, 50mL,etc.) based upon the calibrations on it.

(b) Volumetric Flask

It is a flat bottomed spherical glass vessel having a long and narrow neck with a glass stopper. There is an etched mark on the neck of the flask. The capacity of the flask is also marked on it. Volumetric flask of 250 mL capacity is usually used in volumetric analysis.

Figure 5.3. Volumetric flask.

5.3.4. Measurement of Mass and Weight

A digital balance is a measuring device used to measure the mass of an object or substances. It is more compact, durable, and precise than other kinds of balances which often wear out and give different readings over time. Digital balance requires a power source. It is generally accurate and consistent even when used over extended periods of time. A digital balance may be used for different

Figure 5.4. (a) Digital balance (b) Spring balance.

purposes ranging from the measurement of ingredients in the kitchen to the precise measurement of substances in a laboratory. A picture of a digital balance is shown in Figure 6.4 (a).

Spring balance is an instrument used to measure the weight of an object. It works upon the principle of Hooke's law, which states that load applied is directly proportional to the length of the spring stretched by the load.

5.3.5. Measurement of Temperature

1. Laboratory Thermometer

It is used to measure the temperature of substances with high level of accuracy, and it is designed to hold mercury or coloured alcohol in a graduated tube, which either expands or contracts as the temperature changes. The temperature of the body is read where the liquid column coincides with a calibrated scale on the tube or frame of the thermometer. The general laboratory thermometer has the graduation ranging from -20°C to 110°C.

Clinical thermometer is used to measure human body temperature. It has a constriction in the capillary tube above the bulb to prevent the downward movement of the liquid once it has reached its maximum temperature. This helps to continue to indicate the maximum temperature until the liquid reaches to its original position by shaking the thermometer.

Relation of Temperature in Degree Celsius and Fahrenheit Scale
There are different temperature scales used to record the temperature of the patients. Our normal body temperature is 37°C or 98.6°F respectively. The relation between temperature in celsius scale and fahrenheit scale is:

$$C = \frac{5}{9}(F - 32)$$

$$or\ F = \frac{9}{5}C + 32$$

5.3.6. Measurement of Length

Metre Scale
The length of an object is measured with a metre scale that contains 100 divisions in centimetre (cm). A centimetre is further divided into ten divisions called millimetre (mm). The following methods are used to minimise errors in measurement using a metre scale.

1. Place the object horizontally against the metre scale in such a way that one end of the object coincides with any calibration on the scale other than zero.

2. While taking the reading, the eye must be horizontal or perpendicular to the marking and not at an angle.

3. Sometimes, it may happen that the other end does not coincide with any of the markings exactly. In such cases, correct measurements are obtained by noting the marking near to the end of the object.

(b)

(a)

Figure 5.5.
(a) Clinical thermometer
(b) Laboratory thermometer.
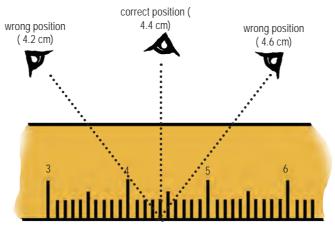
Figure 5.6. Position of eye while measuring.

4. The correct length is obtained by subtracting the two values corresponding to the two coinciding calibrations.

5.3.7. Measurement of Voltage

Voltmeter

Figure 5.7 Voltmeter.

A voltmeter, as shown in Figure 6.7, is an instrument used for measuring electrical potential difference between two points in an electric circuit. Potential difference is commonly measured in volt (V) or millivolt (mV = 10^{-3} V). The potential difference between any two points in a circuit can be measured by connecting the terminals of the voltmeter between these points in parallel without breaking the circuit. This is necessary because electrical devices in parallel experience the same potential difference. The positive terminal of the voltmeter must be connected to the end of the resistor that is at the higher potential, and the negative terminal to the end of the resistor at the lower potential.

a. Least Count of Voltmeter

Least count of voltmeter is the least measurement that the instrument can make accurately. It is the value of one division on the scale of the instrument.

$$\text{Least count of voltmeter(L.C.)} = \frac{\text{Range of voltmeter}}{\text{Total number of divisions}}$$

The reading given by voltmeter is determined by multiplying the number of divisions shown by the deflection of the pointer with the least count of the instrument.

For example,

if the range of a voltmeter = 0 to 3 V

the total number of divisions on its scale = 60

Least count of voltmeter $= \dfrac{\text{Range of voltmeter}}{\text{Total number of divisions}} = \dfrac{3 \text{ V}}{60} = 0.05 \text{ V}$

Suppose the number of divisions shown by the pointer = 8

Then, obtained voltmeter reading = least count × number of divisions

= 0.05 V × 8

= 0.4 V

b. Precaution While Using Voltmeter:

1. Do not connect the voltmeter in series with the circuit element, because the resistance of the voltmeter is very high that a negligible current will be drawn from the power supply.

6.   Equipment, Apparatus and their Operation

6.1.1. Water Bath

A water bath is a device that maintains water at a constant temperature. Water baths should be filled with distilled water. If you are using the water bath for an experiment you should check the temperature frequently to make sure that the water bath is maintaining the proper temperature.

Figure 6.1. Water bath.

6.1.2. Electric Oven

An oven is a useful drying cabinet in a school science laboratory. It can be used for drying glassware, for slow evaporation of solutions, for the drying of chromatograms or as an incubator.

Figure 6.2. Electric oven.

6.1.3. Titration Flask

It is a conical flask with a short neck, sloping sides and flat bottom. It allows thorough shaking of the contents without spilling and can be heated when required. Before using titration flask, thoroughly wash it with water. It must never be rinsed with the liquid to be titrated.

Figure 6.3. Titration flask.

6.1.4. Boiling Tube

A boiling tube is a small cylindrical vessel used to strongly heat substances in the flame of a Bunsen burner. They are designed to be wide enough to allow substances to boil violently. Boiling tubes are made from borosilicate glass that can withstand high temperatures.

Figure 6.4. Boiling tube.

6.1.5. Kjeldahl Flask

A glass flask with a round bottom and a long wide neck. It is used to find the melting point of derivatives of organic compounds.

Figure 6.5. Kjeldahl.

6.1.6. Centrifuge

A **centrifuge** is an equipment that puts an object in rotation around a fixed axis(spins it in a circle), applying a potentially strong force perpendicular to the axis of spin (outward). The centrifuge works using the sedimentation principle, where the centripetal acceleration causes denser substances and particles to move outward in the radial direction. At the same time, objects that are less dense are displaced and move to the center. In a laboratory centrifuge that uses sample tubes, the radial acceleration causes denser particles to settle to the bottom of the tube, while low-density substances rise to the top.

Figure 6.6. Centrifuge.

6.1.7. Gas Jar

A container used for collecting gas from experiments. It looks like a tube with a broad base and a broad opening. The jar can also be used as chromatography jar.

Figure 6.7. Gas jar.

6.1.8. Calorimeter

Calorimeter is a device used to measure the heat evolved or absorbed during any physical or chemical processes. It consists of a container placed in a heat insulating compartment which prevents the heat exchange between the system and its surrounding. The physical change or the chemical reaction is carried out by taking the substances into the calorimeter. The heat changes is determined by recording the initial and the final temperature of the system in the calorimeter.

Figure 6.8. Calorimeter.

6.1.9. Stopclock

A **stopclock** is an instrument designed to measure accurate small time interval between two events. The device is used when time periods must be measured precisely and with a minimum of complications.

Figure 6.9. Stop clock.

6.1.10. Digital Multimeter

A digital multimeter is a device used for measuring various electrical measurements, such as AC and DC voltage, AC and DC current, and resistance. In electrochemistry a digital multimeter is used to measure the e.m.f of an electrochemical cell.

Figure 6.10. Multimeter.

6.1.11. Bunsen Burner

Bunsen burners are the main source of heat in all the laboratories in the schools. For this reason, both the teacher and the laboratory assistant should know the maintenance and repair of major damages.

Figure 6.11.Bunsen burner.

a. Working of Bunsen Burner

The gas enters the burner at the base and its supply is externally regulated by the gas cock. As the gas streams upward through a jet like nozzle inside the base it mixes with the air. The amount of air can be regulated by rotating the metal ring that fits over the hole in the barrel of the burner. Maximum air enters when the holes in the sleeve match with those of the barrel.

b. Instruction for Use

- The proper method of lighting the burner is, close off the air supply, turn on the gas and spark the light.

- The flame will be large and yellow. Gradually, open the air intake until the flame becomes blue in colour.

Clear blue flame (Hot)

Dark blue flame (Warm)

Barrel

Air ports

Gas inlet

Needle valve

Base
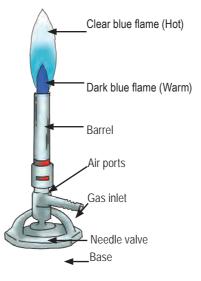
Figure 6.12. Parts of bunsen burner.

c. Maintenance and Precautions

- Bunsen burner should be used very carefully. There should not be any gas leakage from the pipeline.

- Sometimes the carbon particles or any materials that happen to fall inside the barrel block the jet. Unscrew the barrel and with the help of the fine needle, remove the obstacle.

- One should try to get non-luminous flame. Luminous flame is not only associated with less heat but it also blackens any materials heated over it. Non-luminous flame can be obtained by adjusting the air hole with the help of metal ring.

- In dealing with Bunsen burner, one is dealing with something dangerous. Therefore, one should not keep gas turning on without lighting it.

6.1.12. Desiccator

Desiccator is an airtight glass vessel, which is used to dry the content during analysis in the laboratory. Suitable drying agent is kept at the lower compartment

Figure 6.13. Desiccator.

of the vessel. The drying agent used can be any one of the following; phosphorous pentaoxide, quick lime, magnesium sulphate, dry sodium sulphate, anhydrous calcium chloride or anhydrous zinc chloride, depending upon the material to be dried inside the desiccators. It is used for drying materials. The glass rim of the desiccators is sealed with a thin film of petroleum jelly or grease. This helps the vessel to keep airtight. Avoid use of excess grease.

a. *How to Use the esiccator*

- Place the desiccator on a safe stable place.

- Do not pull or lift the lid of the desiccator, open the lid by sliding the lid over the ground glass rim of the desiccator.

- Place a drying agent at the base of the lower compartment.

- The drying agent should not be put more than the level of the lower compartment.

- If a hot object is placed in desiccator, the air should be allowed to expand for a few seconds before closing the lid.

- Replace the drying agent after every 5-6 months.

- Never leave the desiccator without covering it with the lid.

6.1.13. Kipp's Apparatus

Kipp's apparatus is used for producing hydrogen sulphide gas by the action of dilute sulphuric acid and ferrous sulphide. The reaction occurs in the bulb as shown in the Figure 7.14. The gas gets stored in the middle bulb and comes out through the nozzle when the tap is opened. Thus, it is used for storing the gas for a short duration.

Figure 6.14. Kipp's apparatus.

Procedure for Using Kipp's Apparatus

- Add lumps of iron sulphide to the middle bulb.

- Add dilute sulphuric acid down the top bulb, with the tap open, until the acid just covers the iron sulphide.

- Close the tap. The pressure of the gas forces the acid out of the middle bulb and up into the top bulb.

- As the acid and sulphide no longer mix, there would be no reaction. The reaction resumes when the tap is opened.

- Always keep the side tube dipped in a beaker of water to avoid rotten egg smell.

Acid reservoir contains H_2SO_4

Gas reservoir contains H_2S and FeS sticks

Base contains $FeSO_4$
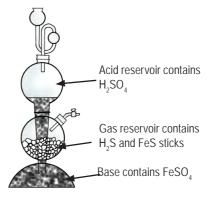
Figure 6.15. Internal structure of Kipp's apparatus.

6.1.14. Burette

A burette is a graduated tube with a tap to deliver any quantity of liquid accurately. The graduation is in mL or cm^3 with zero at the top. The stopper tap may be made of glass, plastic or may be replaced by a spring clip or pinch valve. The glass tap is given the finest smear of petroleum jelly or silicon burette grease after cleaning and held in a position by a rubber band looped across the barrel of the tap. Plastic tap do not require burette grease.

Figure 6.16. Burette.

How to Use Burette

- Pour about 5 mL of distilled water in the burette and rinse by inverting it several times with the thumb over the end.

- Drain the water through the tap and repeat the process once or twice.

- Repeat the procedure (1) and (2) using the given solution.

Figure 6.17. Burette handling.
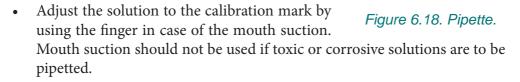
- Fill the burette with the solution just above the zero mark.

- Open the tap to allow the tip to be filled with and the meniscus to touch the zero mark.

- Check that the burette is vertical in its stand by viewing it from two vertical corners of the table. The best technique to use the tap is to curl the left hand around the stem of the burette, twining the tap with the thumb and index finger. This method automatically presses the stopcock into the barrel to prevent leaks and also leaves the right hand free for mixing the solution in the receiving vessel as shown in the figure 7.17.

- The meniscus should be read with the eye on exact level to avoid parallax error or use burette card to minimise error while reading the burette.

6.1.15. Pipette

The pipette is used to measure accurate volume of the liquid.

a. *How to Use Pipette*

- Clean the pipette first with water and then with the solution to be pipetted.

- Fill the pipette using the pipette filler or by mouth suction.

- Adjust the solution to the calibration mark by using the finger in case of the mouth suction. Mouth suction should not be used if toxic or corrosive solutions are to be pipetted.

Figure 6.18. Pipette.

- Deliver the liquid by releasing the finger. Do not blow out the last drop from the pipette.

b. *Pipette Filler*

- Pipette filler is a rubber bulb designed to fill pipettes with solutions. Whenever a procedure calls for pipetting toxic or corrosive liquids, pipette fillers should always be utilised - never pipette by mouth.

6.1.16. Salt Bridge

A salt bridge is a U-shaped device containing concentrated solution of an inert electrolyte like KCl, KNO_3, etc. or a solidified solution of those electrolytes in agar-agar solution and gelatin. It connects the two half cells of a galvanic cell. It has two main functions:

- To allow the flow of ions from one solution to another without mixing of the two solutions and completing the electrical circuit.

- To maintain the electrical neutrality of the solutions in the two half cells.

How to Construct a Salt Bridge

- Prepare an agar or gelatin solution by heating a mixture of agar or gelatin in the aqueous solution of KCl, or KNO_3.

- Heat the mixture gently with stirring until the agar is completely dissolved (solution becomes clear).

- Fill the agar solution into the U-tube and plug both ends with cotton.

- Keep it untouched for sometime to allow it to set.
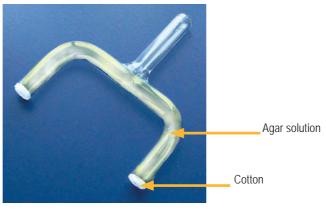
Figure 6.19. Salt bridge.

6.1.17. Preparation of TLC plate

Preparation of TLC plate

1. Add 5g of silica into a clean dry flask and add 12.5mL of distilled water. (ratio of 1: 2.5)

2. Shake the mixture thoroughly until no lumps of silica is seen.

3. Using a dropper pour the slurry on the glass slide and spread it uniformly.

4. Keep the plate undisturbed for around 30 minutes to let it dry.

Figure 6.20. Preparation of TLC Plate.

5. Gently heat the slides coated with the slurry in the oven to remove any traces of water.

6.1.18. Glass Tubes and Rods

Glass apparatuses of different shapes and sizes are necessary for various experiments in Chemistry. However, many of them must be customised construction. The following techniques help students to construct some of them.

1. Cutting a Delivery Tube

Step 1. Hold the glass tube or glass rod on a soft flat surface.

Step 2. Using a file make straight scratch at the place of the measured length and scratch around the glass tube with minimum force or pressure.

Figure 6.21. Making scratch using a triangular file.

Step 3. Hold the tube with both hands between the thumbs and the first fingers in such a way that the thumbs lie adjacent to the scratch.

Figure 6.22.Cutting glass-tube and rod (step 3 & 4).
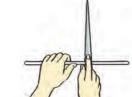
Step 4. To break the tube at the marked place, apply an outward force on the tube with thumbs.

Step 5. If the tube doesn't break, repeat the steps 1 to 4.

2. Bending Delivery Tubes

Step 1. Hold the tube in horizontal position with hands.

Step 2. Place the portion tube to be bent in the non-luminous flame and keep on rotating gently till it softens.

Step 3. Remove it from the flame and bend it as a desired shape.
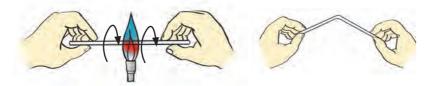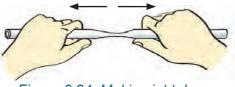
Figure 6.23. Bending glass-tube in non-luminous flame.

3. Making a Dropper or Jet Tube

Step 1. Heat the glass tube at the middle in non-luminous flame.

Step 2. Rotate the tube gently to ensure even heating.

Figure 6.24. Making jet tube.

Step 3. When the tube softens take out the hot tube from the flame. Do not touch the hot section with the bare hands.

Step 4. Slowly pull apart the two ends of the tube till a narrow tube of required diameter as shown in figure 7.23 is obtained.

Step 5. Hold the tube in the same position till it cools down and stiffens.

Step 6. Place the cooled tube on top of the soft surface and cut into desired length.

4. Boring hole in the Cork.

Step 1. Select the cork borer whose diameter is slightly less than that of the glass tube to be fitted into the cork.

Step 2. Soften the cork by dipping in water for sometimes and gently rolling it under your shoe.
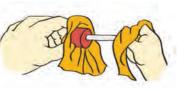
Figure 6.25. Boring hole using a cork borer.

Step 3. Mark the position of the hole on both sides of the cork in the middle for a single hole. In case of double holes, mark the position of holes on each side of the cork, which are parallel and vertical. They should not be too near to the center nor be too near to the periphery.

Step 4. Dip the sharp end of cork borer in water and place the wet borer vertically on the position of the mark with your right hand.

Step 5. Drive the cork borer half way into the cork. Then pull out the cork borer and remove the cork pieces from inside the borer with the help of a probe.

Step 6. Turn the cork upside down and bore hole through the mark from the opposite side.

5. Fitting Delivery Tube in the Bored Cork

Step 1. Dip the delivery tube in water and hold it partly wrapped in cloth with right hand.

Step 2. Hold the cork with your left hand.

Step 3. Insert the delivery tube into the hole with a gentle twist.

Figure 6.26. Inserting delivery tube in the bored cork.

PRECAUTION

Do not push the delivery tube forcefully, it may break and cause accidents. The hole should be slightly narrower than the tube to be inserted..

7. Preparation of reagents and solutions

7.1.1. Preparation of Water Extract

- Dissolve the given salt mixture in cold water.

- If the salt does not dissolve in cold water, heat it.

- If the salt mixture does not dissolve in hot water, sodium carbonate extract is prepared.

7.1.2. Preparation of Sodium Carbonate Extract

- Mix 1 part of salt mixture + 4 parts of Sodium Carbonate + 10 mL of distilled water

- Boil the content for 5 minutes.

- Filter the content.

- The filtrate is called sodium carbonate extract/ soda extract and it is used for confirmatory test of anions.

7.1.3. Making solution of Solid Chemical Substance

- Weigh the solid accurately.

- Transfer the solid into a beaker. Add the required amount of water and stir it till all the solid particles are dissolved. Some solids dissolve faster when temperature of the water is increased.

- Transfer the solution into the reagent bottle and put glass stopper on it. Label the reagent bottle with the name of the dissolved substance and the date of preparation.

7.1.4. Making Solution of Liquid Chemical Substance

- Measure the required volume of liquid in a measuring cylinder.

- Transfer the liquid into a beaker.

- Rinse the measuring cylinder with distilled water and pour it into the same beaker.

- Add distilled water into the beaker up to the mark required.

- Stir the solution thoroughly using a glass rod to ensure that the concentration is same throughout the solution.

- Transfer the solution into the reagent bottle and put a glass stopper on it.

- Label the reagent bottle with the name of the liquid and the date of preparation.

7.1.5. Preparation of Bench Solutions

Table 7.1 Procedure for Preparation of Solution

Substance	To make 1 litre solution	Precaution
Iodine solution	i. Weigh 20 g of potassium iodide crystals ii. Dissolve it in 600 mL water iii. Add 12.7 g of iodine crystals to the solution. iv. Make it up to 1 litre by adding water.	
Lime water	i. Weigh 75 g of calcium oxide. ii. Dissolve it in 1 litre of water and iii. Filter the solution obtained. The filtrate is the limewater.	To protect from atmospheric carbon dioxide, the lime water bottle should be kept airtight.
Starch solution	i. Weigh 10 g of soluble starch. ii. Make a paste with cold water. iii. Pour boiling water with constant stirring and make it upto 1 litre.	Prepare fresh solution as required.
Dilute hydrochloric acid	i. Measure 430 mL of conc. Hydrochloric acid ii. Add it to distilled water and make the volume upto 1 litre.	Always add acid to water. Store in a closed container.
Dilute Sulphuricacid	i. Measure 140 mL of conc. Sulphuricacid. ii. Add it to distilled water and make the volume upto 1 litre.	Always add acid to water
Dilute nitric acid	i. Measure 320 mL of conc. Nitric acid ii. Add it to distilled water and make the volume upto 1 litre.	Do not store nitric acid in plastic containers.
Dilute acetic acid	i. Measure 290 mL of glacial acetic acid ii. Add it to distilled water and make the volume upto 1 litre.	

Substance	To make 1 litre solution	Precaution
Dilute ammonia solution	i. Measure 340 mL of conc. Ammonia solution. ii. Add it to distilled water and make the volume upto 1 litre.	Avoid breathing the fumes and any risk of ammonia getting into the eyes.
Potassium hydroxide solution	i. Weigh 224 g of potassium hydroxide pellets ii. Add it to distilled water and make the volume upto 1 litre.	Potassium hydroxide is highly corrosive substance
Sodium hydroxide (5 M)	i. Weigh 200 g of Sodium hydroxide pellets. ii. Add it to distilled water and make the volume upto 1 litre.	Use rubber stopper or polythene stopper bottles.
Aquaregia	iii. Add one part of concentrated nitric acid to three parts of concentrated hydrochloric acid.	Prepare wheneverrequired. DO NOT STORE!
Silver nitrate solution	i. Weigh 17 g of Silver nitrate. ii. Add it to distilled water and make the volume upto 1 litre.	Silver nitrate is sensitive to light. Store in dark bottles.
Ammonium chloride (5M)	i. Weigh 270 g of Ammonium chloride ii. Add it to distilled water and make the volume upto 1 litre.	
Ammonuim nitrate (1M)	i. Weigh 80 g of Ammonium nitrate. ii. Add it to distilled water and make the volume upto 1 litre.	
Barium chloride (0.5M)	i. Weigh 61 g of Barium chloride. ii. Add it to distilled water and make the volume upto 1 litre.	
Ferric chloride (0.5M)	i. Weigh 125 g of Ferric chloride ii. Add it to distilled water and make the volume upto 1 litre.	

CLASSES XI & XII

Substance	To make 1 litre solution	Precaution
Biuret reagent	i. Measure 95 mL of 3% copper sulphate solution ii. Dissolve it in 10% potassium hydroxide solution and make the volume upto 1 litre.	
Methyl orange	i. Weigh 2 g of methyl orange ii. Add it to distilled water and make the volume upto 1 litre.	
Phenolphthalein	i. Weigh 1.75 g of phenolphthalein ii. Add it to distilled water/ethanol and make the volume upto 1 litre.	

7.1.6. Preparation of Common Reagents

Table 7.2 Procedure for Preparation of Reagents

Reagents	Preparation of 1 litre solution
Ammonium Acetate (3 M)	i. Weigh 231 g of Ammonium acetate ii. Add it to distilled water and make the volume upto 1 litre.
Ammonium carbonate (2 M)	i. Measure 140 mL of conc. ammonia and 860 mL of water. ii. Make a mixture of the two. iii. Weigh 160 g of Ammonium carbonate iv. Dissolve it in the mixture.
Ammonium oxalate (0.5 M)	i. Weigh 35 g of Ammonium oxalate ii. Add it to distilled water and make the volume upto 1 litre.
Ammonium sulphate (1 M)	i. Weigh 132 g of Ammonium sulphate ii. Add it to distilled water and make the volume upto 1 litre..

Reagents	Preparation of 1 litre solution
Ammonium sulphide (yellow) (3M)	i. Measure 150 mL of conc. ammonia solution. ii. Pass H_2S in cold till it is saturated. iii. Add 10 g of sulphur and 250 mL of conc. Ammonia solution. iv. Shake the mixture until the sulphur is dissolved and finally dilute with water to make the volume upto 1 litre.
Calcium chloride (0.5M)	i. Weigh 55 g of calcium chloride. ii. Add it to distilled water and make the volume upto 1 litre.
Cobalt nitrate (0.3M)	i. Weigh 44 g of cobalt nitrate. ii. Add it to distilled water and make the volume upto 1 litre..
Copper (II) sulphate (0.5M)	i. Weigh 125 g of copper sulphate. ii. Add it to distilled water containing 3 mL of conc. H_2SO_4 and make the volume upto 1 litre.
Lead acetate (0.5M)	i. Weigh 180g of Lead acetate ii. Add it to distilled water and make the volume upto 1 litre..
Mercuric chloride (0.2M)	i. Weigh 54 g of mercuric chloride ii. Add it to distilled water and make the volume upto 1 litre
Potassium chromate 0.5M	i. Weigh 98 g of potassium chromate. ii. Add it to distilled water and make the volume upto 1 litre..
Potassium ferricyanide (0.5M)	i. Weigh 75 g of potassium ferricyanide ii. Add it to distilled water and make the volume upto 1 litre.
Potassium ferrocyanide (0.2 M)	i. Weigh 68 g of potassium ferrocyanide ii. Add it to distilled water and make the volume upto 1 litre.
Potassium iodide (0.5M)	i. Weigh 83 g of potassium iodide. ii. Add it to distilled water and make the volume upto 1 litre.

Reagents	Preparation of 1 litre solution
Potassium permanganate (0.1 M)	i. Weigh 16 g of Potassium permanganate. ii. Add it to distilled water and make the volume upto 1 litre
Potassium thiocyanate (0.5 M)	i. Weigh 49 g of potassium thiocyanate. ii. Add it to distilled water and make the volume upto 1 litre..
Sodium di-hydrogen phosphate (1.0 M)	i. Weigh 120 g of sodium di-hydrogen phosphate ii. Add it to distilled water and make the volume upto 1 litre..
Stannous chloride (0.1 M)	i. Weigh 95 g of stannous chloride. ii. Dissolve it in 100 mL of conc. HCl and then iii. Add it to distilled water and make the volume upto 1 litre.. iv. Add a few pieces of tin metal.

7.1.7. Preparation of Reagents for Organic Analysis

Table 7.3 Procedure for Preparation of Reagents

Reagent	Preparation
Alcoholic silver nitrate	i. Prepare 10% solution of $AgNO_3$ in alcohol
Braford's reagent	i. Weigh 6.5 g of copper acetate crystals ii. Dissolve it in 100 mL of 1% acetic acid.
Benedict's solution	i. Weigh 1.73 g of crystals of copper sulphate. ii. Dissolve it in 100 mL of water and iii. Add 17.3 g of sodium citrate and 10g of anhydrous Na_2CO_3 in 80 mL of water. iv. Dilute the solution to 500 mL with water.

Reagent	Preparation
2,4-dinitrophenyl hydrazine	i. Weigh 0.25 g of 2,4-dinitrophenyl hydrazine. ii. Add it to a mixture containing 40 mL of conc. HCl and 50 mL of water by warming on a water bath. iii. Cool and dilute the solution to 250 mL with distilled water. *** This reagent is more suitable for water soluble aldehydes and ketones, such as acetaldehyde, acetone, ethyl methyl ketone etc.
Fehling's solution	i. Weigh 33 g of copper sulphate ii. Dissolve it in 500 mL of water (Fehling's solution A). iii. Weigh 175 g of Rochelle salt (sodium potassium tartarate) and 70 g of solid Ammonium chloride. iv. Dissolve it in water and dilute to 500 mL (Fehling's solution B). v. Mix solution A and B in equal volume, whenever required. OR vi. Mix Fehling's A and Fehling's B available in the laboratory
Molisch's reagent	i. Weigh 10 g of α-naphthol. ii. Dissolve it in 100 mL of rectified spirit.
Neutral $FeCl_3$ solution	i. Add Na_2CO_3 drop-by-drop to 10% Ferric chloride solution till a slight ppt. persists on shaking. ii. Filter and use the filtrate.
Nessler's reagent	i. Weigh 23 g of mercuric iodide and 16 g of potassium iodide. ii. Dissolve it in 1000 mL distilled water (free of NH_3). iii. Add 100 mL of 6 M NaOH solutions.
Schiff's reagent	i. Pass SO_2 gas in 1% solution of Fuschine (rosaniline) till its colour is discharged. ii. Filter and store the solution.
Sodium bisulphite solution	i. Prepare a saturated solution of the salt in distilled water.

Reagent	Preparation
Tollen's reagent	i. Mix 2 mL of 10% NaOH with 2 mL of 10% $AgNO_3$ solution. ii. Add NH_4OH in drops till the solution is colourless.
Lucas reagent	i. Weigh135 g of anhydrous Zinc chloride. ii. Dissolve it in 100 mL of conc.HCl.

8. Fundamental Concepts for Practical Works

8.1.1. Terms and Relations for Qualitative and Quantitative Analysis.

Volume: The units of volume commonly used in this manual are cm^3 and dm^3. The conversion between cm^3 and dm^3 is 1 dm^3 = 1000 cm^3. Note that a cm^3 is same as millilitre (mL) and dm^3 is same as litre (L). 1 cm^3 = 1 mL and 1 dm^3 = 1 L.

Concentration: Concentration is a measure of amount per volume. The amount can be grams, kilograms, number of moles, or any other unit of amount. Volume can be cm^3, dm^3, or any other units of volume. The two types of concentration units used commonly are mol/L and g/L.

The Mole Concept: A mole (mol) is a unit of amount. 1 mol of any substance contains particles equal to 6.022×10^{23} .

The formula for determining the number of moles of a compound is:

$$\text{number of moles (n)} = \frac{\text{weight of substances in gram (w)}}{\text{molecular mass (M)}}$$

Standard Solution: A solution containing a known weight of the solute dissolved in a known volume of solvent (a solution whose strength is exactly known). Strength is often expressed in g/litre.

Normal Solution (N): The normality of a solution may be defined as the number of gram equivalents of the solute per litre of the solution. The gram equivalent of substance is its equivalent weight expressed in grams. Thus, a solution, which contains one gram equivalent weight of the solute per litre of the solution, is called a normal solution.

Eg. A normal solution of sodium hydroxide contains 40 g of it in one litre of solution, therefore strength of the solution is 1N (Where N = Normality of the solution)

$$\text{Normality (N)} = \frac{\text{number of gram equivalents}}{\text{volume of solution in litre}}$$

Equivalent Weight: Equivalent weight is defined as the number of parts by mass of any substance which can combine or displace one part by mass of hydrogen, 8 parts by mass of oxygen, 35.5 parts by mass of chlorine or 108 parts by mass of silver.

- Equivalent weight of an acid is defined as the amount of acid that furnishes one mole of H^+ ions in a given reaction.

$$\text{Equivalent weight of acid} = \frac{\text{Molecular weight of acid}}{\text{Number of replaceable } H^+ \text{ions}}$$

$$= \frac{\text{Molecular weight of acid}}{\text{Basicity}}$$

$$\text{Equivalent weight of base} = \frac{\text{Molecular weight of base}}{\text{Number of replaceable } OH^- \text{ions}}$$

$$= \frac{\text{Molecular weight of base}}{\text{Acidity}}$$

$$\text{Equivalent weight of salt} = \frac{\text{Molecular weight of salt}}{\text{Total number of positive charge}}$$

- The equivalent weight of oxidising and reducing agents

$$\text{Equivalent weight of oxidising agent} = \frac{\text{Molecular weight}}{\text{Total number of electrons lost or gained}}$$

Molar Solution (M): The molarity of a solution may be defined as the number of moles of solute contained in one litre of the solution.

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litre}}$$

Calculation of Normality and Molarity of concentrated acids:

$$\text{Molarity} = \frac{\text{Approximate percentage by weight}}{\text{Molecular mass}} \times \text{Specific gravity} \times 10$$

$$\text{Normality} = \frac{\text{Approximate percentage by weight}}{\text{Equivalent weight}} \times \text{Specific gravity} \times 10$$

a. **Relation between Molarity and Normality**

Molarity = normality X Z, where *Z*= acidity or basicity

Example : Calculation of molarity of concentrated sulphuric acid:

$$\text{Molarity} = \frac{\text{Approximate percentage by weight}}{\text{Molecular mass}} \times \text{Specific gravity} \times 10$$

$$\text{Molarity} = \frac{97}{98} \times 1.84 \times 10 = 18.21 \text{ molar}$$

$$\text{Normality} = \frac{97}{49} \times 1.84 \times 10 = 36.42 \text{ normal}$$

Note: *The approximate percentage by weight and specific gravity are given on the label of the container in which the acid is supplied.*

b. **Preparation of Solution of Acid and Base of Required Concentration**.

Molarity equation:

$$M_1 V_1 = M_2 V_2$$

Example: to prepare 250 mL of 0.1 M solution of sulphuric acid.

$$18.21 \text{ x } V_1 = 0.1 \text{ x } 250$$

$$V_1 = \frac{0.1 \times 250}{18.21} = 1.37 = 1.4 \text{ mL}$$

Take about 1.4 mL of concentrated sulphuric and make 250 mL volume by adding water.

c. **Preparation of Solution of Salt of Required Concentration:**

$$\text{Molarity} = \frac{\text{weight}}{\text{molecular weight}} \times \frac{1000}{V}, \text{ where V = required volume in mL or cm}^3$$

8.1.2. Volumetric Analysis

Volumetric analysis is a type of analysis which involves the measurement of volumes of reacting substances. Some of the important terms used in the volumetric analysis are:

- *Titration:* The process of completely reacting a known volume of one substance with a solution of another substance is called titration.

- *Titrant:* The solution of known concentration which is usually taken in the titration flask is called titrant.

- *Titre or analyte:* The solution whose strength or concentration is determined by titration is called titre.

- *End point:* It is a point at which the chemical reaction involved in the titration is just complete.

- *Indicator:* It is a substance which shows the completion of the reaction by change in colour in the solution.

- *Rinsing:* It is the process of washing a burette or pipette with distilled water followed by a liquid to be filled in it.

- *Standard solution:* It is a solution of known weight of a solute dissolved in a known volume of a solvent.

- *Concordant reading:* It is any two readings which do not differ by more than 0.1 mL (1 drop).

8.1.3. Volumetric Calculations

a. Normality

Volumetric calculations are based upon the law of equivalents, which states that at the end point, the number of the equivalents of the titrant is equal to the number of equivalents of titre used.

Thus, if V_1 mL of solution A of normality N_1 requires V_2 mL of solution B of normality N_2 for the completion of reaction, then

No. of gram equivalents in V_1 mL of solution $A = \dfrac{N_1 V_1}{1000}$

and, No. of gram equivalents in V_2 mL of solution $B = \dfrac{N_2 V_2}{1000}$

$\therefore$ By the law of equivalents, we have;

$$\frac{N_1 V_1}{1000} = \frac{N_2 V_2}{1000}$$

$$\boldsymbol{N_1 V_1 = N_2 V_2}$$

This relation is known as *Normality equation.*

b. Molarity:

Let n_1 moles of substance A reacts with n_2 moles of substance B. The volumes of A and B are taken as V_1 and V_2 respectively. The molarity equation is . $\frac{M_1 V_1}{n_1} = \frac{M_2 V_2}{n_2}$

Calculation of Strength of Solution: The strength in grams per litre of the substance is calculated by making use of the relation;

Strength in gL^{-1} = Normality $\times$ Equivalent weight

Strength in gL^{-1} = Molarity $\times$ Molecular mass

Calculation of Percentage Purity

Percentage purity of substance $= \dfrac{\text{Normality} \times \text{Equivalent weight}}{\text{Weight of substance}} \times 100$

Percentage purity of substance $= \dfrac{\text{Molarity} \times \text{Molecuar mass}}{\text{Weight of substance}} \times 100$

Percentage purity of substance $= \dfrac{\text{Amount of pure sample (calculated strenght)}}{\text{Amount of impure sample (given strength)}} \times 100$

8.1.3. Indicators

Indicators are those substances, which change colour depending on the medium (acidic or alkaline) on which it comes in contact. Some of the common indicators used in determination of end point are phenolphthalein, methyl orange and starch solution. For acid base titration, the choice of the indicators for a particular titration depends upon the nature of the acid and the alkali to be titrated.

Table 7.1 Nature of Acid and Base and the Choice of Indicators.

Acid	Base	Indicators
Strong	Strong	Phenolphthalein or Methyl orange
Weak	Strong	Phenolphthalein
Strong	Weak	Methyl orange

Table 7.2. Colour change of indicators in acid and alkalis.

Indicator	Alkali	Acid
Methyl orange	Yellow	Orange red (or Reddish pink)
Phenolphthalein	Pink	Colourless

a. Universal Indicator

Universal indicators are usually mixtures of several indicators. A universal indicator is a solution that undergoes several colour changes over a wide range of pH. The colour corresponds to the pH values.
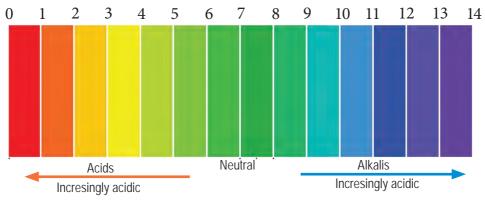
Figure 9.1. Colour change in universal indicator.

PART A
Experiments for Class XI

1

Chemical Equilibrium

Experiment 1a

Aim   To study the chemical equilibrium between dichromate (VI) and chromate (VI) ions in potassium dichromate solution.

Theory:

The chromate and dichromate are salts of chromic acid and dichromic acid. These salts have an intense yellow and orange colour respectively.

When solid potassium dichromate ($K_2Cr_2O_7$) is dissolved in water, it dissociates to give dichromate ions and chromate ions. In solution, the dichromate ions and the chromate ions are inter -convertible and exist in dynamic equilibrium which is indicated by the following equation:

$$Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$$

       dichromate ion   chromate ion

         (Orange)   (Yellow)

However, at equilibrium, the concentration of dichromate ions is comparatively higher than chromate ions because of which the solution is predominantly orange. The dynamic equilibrium between dichromate and chromate ions is sensitive to the pH of the solution. When acid is added to the orange solution, the colour of the solution remains same but when base is added, the colour of the solution changes to yellow.

Question:

Does the chemical equilibrium of dichromate (VI) ions and chromate (VI) ions in potassium dichromate solution change on adding an acid or an alkali? Investigate .

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

Materials Required

Chemicals	Apparatus
• 0.1 M potassium dichromate solution • Dil. H_2SO_4 • NaOH solution	• Eye protection • Dropper - 1 No • Test-tubes - 3 No

Procedure:

Step 1. Take 5 mL of freshly prepared 0.1 M potassium dichromate solution in test-tube A and B.

Step 2. Add NaOH solution in test tube B dropwise and compare your observations with test tube A.

Step 3. Add dilute H_2SO_4 dropwise to the same solution of test tube B and observe the change.

Step 4. Record your observation in Table 1.1.

STAY SAFE

- Sodium hydroxide and acid are corrosive.
- Potassium dichromate is poisonous.

Observation:

Table 1.1 *Change in Colour of Solution*

Sl. No.	State	Colour of Solution B
1	Before the experiment	
2	After adding NaOH solution	
3	After adding dil. H_2SO_4	

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 1b

Using materials provided in Table 1.2, design and carry out an experiment to study the equilibrium between copper (II) ions and tetra- ammonium copper (II) ions.

Materials Required

Chemical	Apparatus
• 0.5 M copper (II) sulphate solution	• Test-tubes – 3 No
• 0.1 M Ammonia solution	• Dropper – 1 No
• 0.1 M Dil. H_2SO_4	• Test tube rack – 1 No

*Note: This experiment is very sensitive **therefore, add only 1- 2** drops of ammonia solution.*

Question:

1. With the help of mathematical calculation, prove that the oxidation state of chromium in dichromate ion and chromate ion is six.

2. Why does the orange colour of dichromate solution remain unchanged when acid is added to it but changes to yellow chromate solution when base is added to it?

3. List down some of the day to day life applications of chemical equilibrium.

Concentration and Rate of Chemical Reaction

Experiment 2a

Aim	To study the effect of concentration of reactant(s) on the rate of chemical reaction.

Theory:

The concentration of a reactant affects the rate of chemical reaction. The rate of chemical reaction is the change in concentration of reactant or the product per unit time.

Mathematically:

$$\text{rate} = \frac{\text{change in concentration of reactant}}{\text{change in time}} = \frac{\text{change in concentration of product}}{\text{change in time}}$$

At a given temperature, the rate is directly proportional to the product of the active masses (molar concentration) of the reactants.

for an elementary reaction: $nA + mB \longrightarrow xC$

$$r = k[A]^n [B]^m$$

where 'k' is the rate constant

The rate constant (k) for a particular reaction at a given temperature is constant.

Sodium thiosulphate reacts with hydrochloric acid to produce colloidal sulphur that turns solution turbid.

$$Na_2S_2O_{3\,(aq)} + 2HCl\,(aq) \longrightarrow 2NaCl_{\,(aq)} + S_{\,(s)} + SO_{2\,(g)} + H_2O_{(l)}$$

Question:

Does the change in concentration of a reactant affect the rate of a chemical reaction? Investigate.

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

Materials Required

Chemical	Apparatus
• 0.05 M $Na_2S_2O_3$ • 1.0 M HCl	• Stop clock / Digital watch – 1 No • Boiling tubes (50 mL) – 4 No • Measuring cylinder (25 mL) – 1 No • Test tube rack – 1 No

Procedure:

Step 1. Add 20 mL, 15 mL, 10 mL and 5 mL of hydrochloric acid solution to 50 mL boiling tubes which are marked as A, B, C and D respectively.

> **STAY SAFE**
> • Mineral acids are corrosive.
> • Always add acid to water when you prepare dilute acid.

Step 2. Add 5 mL, 10 mL, 15 mL of distilled water to boiling tubes B, C and D containing the above solution.

Step 3. Add 10 mL of 0.05 M hypo in boiling tube A and record the time immediately (initial time).

Step 4. Shake the content thoroughly and leave it till the appearance of turbidity in the solution and record the time (final time).

Step 5. Repeat steps (3) and (4) with boiling tubes B, C and D and record the time in Table 2.1.

Step 6. Using data from Table 2.1, plot a graph for concentration of HCl acid versus time taken using Excel/graph paper.

Observation:

Table 2.1 *Concentration vs Time Taken*

SL.No	Volume of HCl acid (mL)	Volume of distilled water (mL)	Concentration of HCl (Molar)	Time taken (sec)
1	20	0	1.0	
2	15	05	0.75	
3	10	10	0.5	
4	5	15	0.25	

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

Experiment 2b

Aim To study the effect of concentration of reactant(s) on the rate of chemical reaction.

Theory:

The "Iodine Clock" reaction is an oxidation reduction reaction. In this reaction, two different colourless solutions of known concentration are mixed together in the presence of starch and after a short duration, the resulting solution rapidly turns dark blue. The following oxidation reduction reactions take place in the solution, which can be described as follows:

Hydrogen peroxide oxidizes iodide ions to molecular iodine:

$$H_2O_{2\ (aq)} + 2I^-_{\ (aq)} + 2H^+_{\ (aq)} \longrightarrow I_{2\ (aq)} + 2H_2O_{\ (l)}$$

The solution remains clear for a short duration because the forming iodine reacts with sodium thiosulphate:

$$2S_2O_3^{2-}_{\ (aq)} + I_{2\ (aq)} \longrightarrow S_4O_6^{2-}_{\ (aq)} + 2I^-_{\ (aq)}$$

When the forming iodine has already reacted with all of the available sodium thiosulphate, it begins to react with starch, forming a dark-blue starch iodine complex.

$$Starch + I_{2\ (aq)} \rightarrow starch\text{-}iodine\ complex\ (dark\ blue)$$

The time for the appearance of dark blue colour can be adjusted by varying the concentration of thiosulphate in solution, so a 'clock' of any desired time interval can be produced.

Question:

Does the change in concentration of reactant affect the rate of a chemical reaction? Investigate.

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

Materials Required

Chemical	Apparatus
• Hydrogen peroxide solution • 1.0 M HCl • 0.01 M KI / NaI • 0.03 M $Na_2S_2O_3$ • Starch solution	• Digital balance • Measuring cylinder (25 mL) – 2 No • Beaker (50 mL) – 4 No • Volumetric flask (100 mL) – 2 No • Conical flask (250 mL) – 1 No • Test tube – 1 No • Dropper • Spatula • Wash bottle • Stop clock / Digital watch • Eye protection – 1 No

Procedure:

STAY SAFE

- Mineral acids are corrosive.
- Always add acid to water when you prepare dilute acid.
- H_2O_2 is corrosive to the eyes, skin and respiratory system

Step 1. Take 25 mL of 0.01 M potassium iodide solution in a conical flask.

Step 2. Add 5 mL of 0.03 M sodium thiosulphate solution in the above conical flask. Shake the content well and add a few drops of starch solution.

Step 3. Take 25 mL of 10 % H_2O_2 solution in a test tube and acidify it by adding a few drops of 1.0 M HCl solution. Add this solution into the above conical flask and shake the content well. Record the time immediately (initial time).

Step 4. Allow the mixture to stand and note down the time when dark blue colouration first appears (final time).

Step 5. Repeat steps (1) to (4) using H_2O_2 concentration of 8 %, 6 %, and 4 % respectively.

Step 6. Record the data in Table 2.4

Step 7. Plot a graph of concentration of H_2O_2 Vs. time.

Observation

Table 2. *2 Concentration vs Time Taken*

SL.No	Concentration of H_2O_2 (%)	Time taken (sec)
1	10	
2	8	
3	6	
4	4	

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

Question:

1. Table 2.3 provides data on the decomposition of hydrogen peroxide into water and oxygen.

    Complete the table and plot a graph of concentration versus rate of decomposition. Deduce the conclusion based on the graph.

Table 2.3

Time (hour)	Concentration of hydrogen peroxide (mol L⁻¹)	Change in concentration of hydrogen peroxide (mol L⁻¹)	Change in time (hr)	Rate of decomposition (mol L⁻¹hr⁻¹)
0.00	1.000			
2.00	0.600			
4.00	0.400			
6.00	0.250			
8.00	0.150			

2. Does increase in concentration always increase the rate of reaction? Explore.

Temperature and Rate of Chemical Reaction

Experiment

Aim — To study the effect of temperature on the rate of a chemical reaction.

The rate of a chemical reaction is affected by temperature. Increase in temperature increases the kinetic energy of the reacting molecules resulting in the effective collision between the reacting molecules. Thus, the rate of reaction generally increases with rise in temperature.

Sodium thiosulphate reacts with hydrochloric acid to produce colloidal sulphur which turns solution turbid as given below in the equation.

$$Na_2S_2O_{3\ (aq)} + 2HCl_{\ (aq)} \longrightarrow 2NaCl_{\ (aq)} + SO_{2\ (g)} + H_2O_{\ (aq)} + S\downarrow$$

(Colloidal)

The rate of the reaction may be studied by recording the time for appearance of turbidity of the solution at different temperatures.

Question:

Does the change in temperature affect the rate of a chemical reaction? Investigate

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:
Independent variables:
Dependent variables:
Controlled variables:

Materials Required

Chemical	Apparatus
• 0.05 M sodium thiosulphate solution • 0.5 M HCl solution	• Boiling tube – 6 No • Measuring cylinder – 2 No • Thermometer – 1 No • Glass rod – 1 No • Water bath –1 No

Procedure:

Step 1. Take 10 mL of 0.05 M sodium thiosulphate and 10 mL of 0.5 M HCl solution in two different boiling tubes. Record their temperature.

Step 2. Mix the above two solutions and record the time immediately (initial time).

Step 3. Now, stir the mixture constantly and record the time as soon as the turbidity appears (final time).

Step 4. Take 10 mL of 0.05 M sodium thiosulphate and 10 mL of 0.5 M HCl solution in two different boiling tubes. Place them in the water bath maintained at 30^0C until the solutions are at the same temperature as the water bath.

Step 5. Mix the solution immediately after taking out from water bath and record the time (initial time). Stir the mixture constantly and record the time as soon as the turbidity appears (final time).

Step 6. Repeat steps (4) and (5) maintaining the temperature of solutions at 45^0C, 60^0C and 75^0C respectively.

Step 7. Record your data in Table 3.1

Step 8. Using the data in Table 3.1, plot a graph of temperature against time taken for appearance of turbidity.

STAY SAFE
- Mineral acids are corrosive.
- Always add acid to water when you prepare dilute acid.
- Handle hot water carefully.

Observation

Table 3.1 *Temperature vs Time Taken*

Sl. No.	Volume of 0.05 M $Na_2S_2O_3$ (mL)	Volume of 0.5 M HCl (mL)	Temperature of the solution (^{0}C)	Time Taken for the appearance of turbidity (sec)
1	10	10	Room temperature	
2	10	10	30	
3	10	10	45	
4	10	10	60	
5	10	10	75	

Result:

Write the result based on the observation

Conclusion:
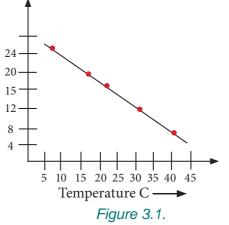
Draw a conclusion based on the result.

Question:

1. Tshogay conducted an experiment by mixing equal volume of 0.1 M potassium iodide and 0.2 M sodium bisulphite solution at different temperatures and obtained the relationship as shown in Figure 3.1.

Figure 3.1.

    Answer the following questions.

    (i) Draw the table of observation based on Figure 3.1.

    (ii) Formulate a hypothesis based on the experimental data.

2. Open the link given below to study the factors affecting the rate of a chemical reaction.

    Based on the study, write the relationship between the rate of reaction and factors.

    https://teachchemistry.org/classroom-resources/reaction-rates-simulation

Primary, Secondary and Tertiary Alcohol

Experiment

Aim To differentiate primary, secondary and tertiary alcohol.

Theory:
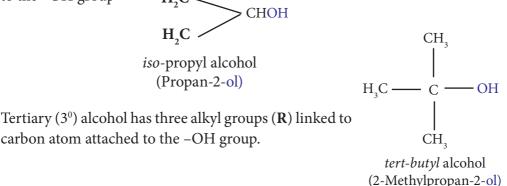
Alcohols are group of organic compounds containing –OH as the functional group. Monohydric alcohols contain one –OH group. Depending on the number of alkyl groups bonded to the carbon where the –OH group is attached, monohydric alcohol is classified as primary, secondary and tertiary alcohol.

Primary (1^0) alcohol has one alkyl group (**R**) linked to carbon atom attached to the –OH group.

$$\textbf{CH}_3\textbf{CH}_2\textbf{OH.}$$

Ethyl Alcohol

Secondary (2^0) alcohol has **two** alkyl groups (**R**) linked to carbon atom attached to the –OH group

$$\textbf{H}_2\textbf{C}$$
$$\textbf{H}_2\textbf{C}$$ $$\text{CHOH}$$

iso-propyl alcohol
(Propan-2-ol)

Tertiary (3^0) alcohol has three alkyl groups (**R**) linked to carbon atom attached to the –OH group.

$$H_3C \underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}} OH$$

tert-butyl alcohol
(2-Methylpropan-2-ol)

Lucas test is used to differentiate primary, secondary and tertiary alcohols.

This test is based on the difference in reactivity of the three classes of alcohols with hydrogen halides in Lucas reagent.

Question:

How are primary, secondary and tertiary alcohols different? Investigate.

Hypothesis:

Formulate your own hypothesis

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

Materials Required

Chemical	Apparatus
• Ethanol • 2-propanol (isopropyl alcohol) • 2-methylpropan-2-ol (tertiary butyl alcohol) • Lucas reagent	• Test tubes – 3 No • Dropper – 3 No

Procedure:

Step 1. Add 0.5 mL of three given samples of alcohol in test tube A, B and C.

Step 2. Add 3 mL of Lucas reagent in test tube A, shake vigorously and observe the change. If there is no change, wait for five minutes. Heat the solution if no change is observed within 5 minutes.

STAY SAFE

• Lucas reagent contains conc. HCl, handle carefully.

Step 3. Repeat step 2 for other two samples.

Step 4. Record your observation in Table 5.1.

Observation

Table 4.1 *Lucas Test for Alcohols*

SL.No.	Sample	Observation	Inference
1	A		
2	B		
3	C		

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Questions:

1. Suppose a laboratory assistant has mistakenly stored methanol and butan-2-ol in containers without labeling. Suggest a chemical test to identify the alcohol?

2. Use the suggested link to distinguish primary, secondary and tertiary alcohols.

   https://amrita.olabs.edu.in/?sub=73&brch=8&sim=141&cnt=4

3. Explore the applications of different forms of alcohol in daily life.

5 Phenol

Experiment
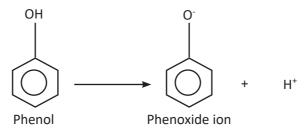
Aim To investigate the chemical properties of phenol.

Theory:

Phenol is an aromatic organic compound containing at least one -OH group directly attached to the benzene ring. Phenol is acidic in nature as it undergoes ionization in aqueous solution to form phenoxide ion which is stabilised due to resonance.

The common chemical properties of phenol is basically due to the -OH group on the benzene ring. Due to formation of phenoxide ion in the solution, phenol generally undergoes electrophilic substitution reaction. It also undergoes nucleophilic reactions such as halogenation involving benzene ring.

Question:

How is the nature of -OH group in phenol different from that of -OH group in alcohol?

Hypothesis

Formulate your own hypothesis

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Materials Required

Table 5.1

Chemical	Apparatus
• Litmus solution/paper • NaOH • Concentrated H_2SO_4 • $FeCl_3$ solution • Phenol • Phthalic anhydride	• Test tubes • Beakers • Testtube racks • Dropper

Compound	Test
Phenol OH	When phenol is treated with a blue litmus solution, the litmus solution turns red indicating its acidic nature.
	Phenol on treatment with neutral ferric chloride solution forms a blue, violet, or purple solution.
	When Phenol is treated with phthalic anhydride and conc.H_2SO_4 followed by cooling the mixture and then adding NaOH solution and finally pouring the content into the water forms red colour solution.

Procedure :

1. Carry out the relevant test for phenol by using the information given in table

2. Record your experimental procedure, observation and inference in the tabular form.

Result:

Write the results based on the observation.

Conclusion:

Draw a conclusion based on the result.

Question:

1. Design an experiment to distinguish phenol from primary alcohol.

Acid-Base Titration

Experiment 6a

| **Aim** | To determine the molarity and the strength of a given acid. |

Theory:

Acid-base titration is used to calculate the molarity or normality of either acidic or basic solution by titrating it against a standard solution of known concentration. The standard solution is the solution whose exact concentration is known. The solutions are made to react and the end point of the titration is indicated by change in colour using suitable indicators. By measuring the volume of solutions accurately, the quantitative composition of the solution is determined. The molarity and the strength of the solution is calculated using the expression given below.

$$\frac{\text{Molarity X Volume of base}}{\text{Molarity X Volume of acid}} = \frac{n_b}{n_a}$$

Where: n_a = no. of moles of acid

n_b = no. of moles of base

Strength of acid/base = molarity X molecular weight of acid/base

When hydrochloric acid is titrated against a known concentration of sodium carbonate, the neutralization reaction occurs between acid and base generally to form salt and water as given below.

$$2HCl + Na_2CO_3 \longrightarrow 2NaCl + CO_2 + H_2O$$

This is the titration of strong acid with strong base. The end point of titration can be determined by using the indicator methyl orange which changes the colour of the solution from yellow to pink or red.

Question:

How is the strength related to molarity of an acid? Investigate.

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

Materials Required

Chemical	Apparatus
• 0.05 M HCl • 0.05 M Na_2CO_3 • Methyl orange indicator	• Burette (50 mL) – 1 No • Conical flask (50mL) – 1 No • Burette stand with clamp – 1 No • Pipette (20 / 25 mL) – 1 No • Beaker (100 mL) – 2 No

Procedure:

Step 1. Prepare 0.05 M solution of sodium carbonate by dissolving anhydrous sodium carbonate in water.

> **STAY SAFE**
> • HCl is corrosive. Handle with care.

Step 2. Prepare 0.05 M solution of HCl.

Step 3. Rinse and fill the burette with HCl solution

Step 4. Pipette out any volume (not exceeding 25 mL) of sodium carbonate solution in a clean conical flask and add 2 to 3 drops of methyl orange.

Step 5. Run down the HCl solution from the burette into the conical flask shaking constantly until a permanent light pink or red colour is obtained.

Step 6. Repeat the titration to obtain at least two concordant readings.

Step 7. Record your observation in Table 6.1.

Step 8. Using the data recorded in Table 6.1, calculate the following:

    i.   Volume of sodium carbonate solution used =

    ii.   Titre value =

    iii. Molarity of HCl solution =

    iv. Strength of HCl solution =

    v.   Percentage purity of the HCl =

Set up:

Pull the stopcork against the taper each time you turn it

Swril the flask continuously until one drop of titrant causes the colour change throughout the entire solution

White tile
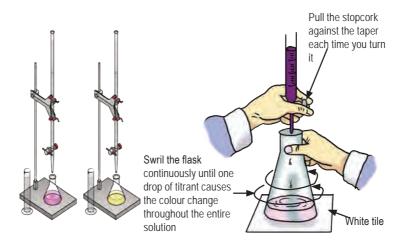
Fig. 6.1. Titration.

Observation:

Table 6.1 Acid-Base Titration

Sl. No.	Volume of Na$_2$CO$_3$ solution taken (mL)	Burette reading (mL)		Volume of HCl consumed (mL)
		Initial reading (mL)	Final reading (mL)	
1				
2				
3				

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

Experiment 6b

Design and conduct an experiment to determine the molarity and strength of secondary standard NaOH solution by titrating against oxalic acid using suitable acid – base indicator.

Question :

1. Why is it necessary to use suitable indicator for a particular type of acid – base titration?

2. Write the chemical equation for the reaction between HCl and NaOH.

3.   Write some of the applications of neutralization reaction in our daily life.

7 Oxidation number

Experiment

| **Aim** | To investigate the change in oxidation number of an atom during redox reaction. |

Theory:

Oxidation number is the net positive or negative charge that the atom carries in its free state or in a compound. A redox reaction involves change in oxidation number of the interacting atoms. The oxidation number decreases when an atom or ion undergoes reduction and increases when it undergoes oxidation. The atom of an element in different oxidation number exhibits different colour in the solution. Therefore, the change in oxidation number of certain atom during the redox reaction can be inferred by observing the change in colour of the solution.

Question:

How do you determine whether a particular atom of an element has undergone oxidation or reduction during the redox reaction?

Hypothesis:

Formulate your own hypothesis..

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables

Materials Required

Chemicals	Apparatus
• Copper sulphate • Copper plate / copper strip / copper turnings • Zinc strip / zinc granules	• Beakers

Procedure:

Step 1: Prepare aqueous solution of copper sulphate such that the solution is visibly blue.

Step 2: Take two beakers and label them as A and B.

Step 3: Take copper sulphate solution in beaker A and B.

Step 4: Place zinc strip or few zinc granules into the copper sulphate solution in beaker A.

Step 5: Place copper strip or copper turnings into the copper sulphate solution in beaker B.

Step 6: Keep the setups for few hours or a day.

Step 7: Record your observation.

Observation:

Table 7.1:

Beaker	Observable change
A	
B	

Result:

Write the result based on the observation.

Conclusion:

Draw the conclusion based on the result.

Questions:

1. Which set-up represents controlled experiment?

2. Write the equation for the redox reaction that has taken place in the Beaker(s).

3. Determine the change in the oxidation number of the atoms due to redox reaction.

4. Based on your observation compare the reactivity of zinc and copper.

5. Suggest one real life application of redox reaction.

The Solubility of Salt

Experiment 8a

Aim To determine the molarity and the strength of a given solution of HCl by titrating it against standard solution of sodium carbonate solution.

Theory:

Solubility of a substance is defined as the maximum amount of solute dissolved in a fixed quantity of solvent at a given temperature.

A solution that can dissolve more solute at a given temperature is called unsaturated solution and the solution that cannot dissolve any more solute is called saturated solution. A solution that contains more solute than the solvent can dissolve under normal conditions is known as a supersaturated solution.

Binary salt:

Consider AB as a binary salt and its solubility 's' $molL^{-1}$. After complete dissociation, 's' moles of AB gives 's' moles each of A^+ and B^- ions.

$$AB_{(s)} \longrightarrow A^+_{(aq)} + B^-_{(aq)}$$

Ternary salt:

Consider AB_2 as ternary salt and its solubility 's' $molL^{-1}$ at a particular temperature. After complete dissociation, 's' moles of AB_2 will give 's' moles of A^{2+} ions and 2 's' moles of B^- ions.

$$AB_{2(s)} \longrightarrow A2^+_{(aq)} + 2B^-_{(aq)}$$

Question:

How do you calculate the solubility of a salt? Investigate.

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:
Independent variables:
Dependent variables:
Controlled variables:

Materials Required

Computer having PhET simulation software installed.

Procedure:

Activity 1. Estimate the number of NaCl molecules dissolved in a fixed volume of solvent.

Step 1.   Run PhET simulation on salt and solubility or use the link

      https://phet.colorado.edu/en/simulation/soluble-salts.

Step 2.   Select 'table salt' tab and maintain the water level in the container at 5.0 x 10^{-23}L.

Step 3.   Add NaCl till sodium and chloride ions reach a level of 140. Record the changes in Table 7.1
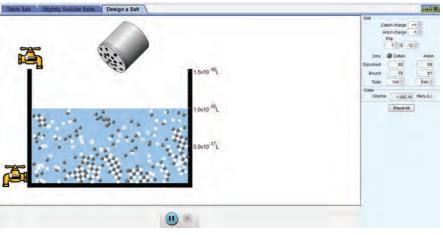
Figure 8.1.

Step 4. Increase the number of NaCl molecules by 20 and observe the molecules in the container and record the values.
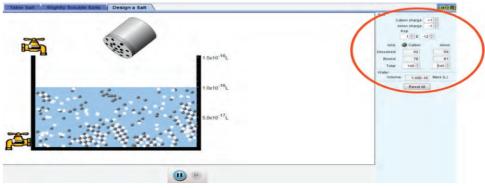
Figure 7.2.

Step 5. Repeat step (4) three more times and record the corresponding values.

Table 8.1 *Solubility of NaCl*

Number of NaCl molecules added	Total number of salt ions dissolved	Total number of salt ions bound	Types of solution
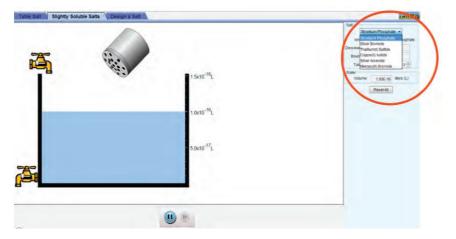
Figure 8.3.

Procedure:

Step 1. From the 'table salt' tab, take any volume of water and dissolve salt till the solution becomes saturated, i.e. bound values fluctuate between zero and one.

Step 2. Note down the number of dissolved cations and anions in the solution and record in the observation Table 8.2.

Step 3. From the 'Slightly soluble salt' tab, select AgBr and dissolve it into any volume of water until the solution becomes saturated.

Step 4. Record the dissolved number of cations and anions in the observation Table 8.2

Step 5. Repeat step (3) and (4) for HgBr₂.

Step 6. Calculate solubility from the data.

    1. No. of molecules = (No. of cations + No. of anions dissolved) / sum of the ratio of the ions

    2. No. of moles = No. of molecules / Avogadro's number

    3. Solubility = No. of moles / Volume of solvent in litres

Table 8.2 *Solubility of Different Salts*

Compound	From simulation		Volume of solvent	No. of molecules	No. of moles	Solubility
	Cations at saturation	Anions at saturation				
NaCl	182	182				
AgBr	44	44				
HgBr$_2$	15	30				

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

Experiment 8b

Select 'Molarity' from Chemistry section in PhET simulations. Dissolve different types of solute in a fixed amount of solvent to form a saturated solution. Record the amount of solute dissolved to get saturated solution and the molarity of the solution in a tabular form.

Questions:

1. Does solubility of different salts increase with rise in temperature. Explore.

2. Write every day applications of solubility.

PART B
Experiments for Class XII

Enthalpy of Neutralisation

Experiment

Aim — To determine the calorimeter constant (W) of a calorimeter.

Theory:

Enthalpy is the total heat content of the system. A chemical reaction is associated with either absorption or evolution of heat energy. The heat evolved or absorbed during a chemical reaction is determined by a calorimeter. A calorimeter works by insulating a system from its surrounding. Glass calorimeter is used instead of metallic calorimeter because glass normally does not react with chemicals. During the measurement of heat change, some amount of heat is absorbed by the container of the calorimeter, thermometer and the stirrer. This absorbed amount of heat is calculated as calorimeter constant (W).

Heat lost by hot water = heat gained by cold water + heat gained by calorimeter

$$m_h \times C_p \times \Delta T = m_c \times C_p \times \Delta T + W \times \Delta T$$

$$m_h \times C_p \times (T_h - T_m) = m_c \times C_p \times (T_m - T_c) + W \times (T_m - T_c)$$

where:

m_h	-	mass of hot water
m_c	-	mass of cold water
m_m	-	mass of mixture water
C_p	-	specific heat capacity of water (4.18 J/g^{0}C)
T_h	-	temperature of hot water
T_c	-	temperature of cold water
T_m	-	temperature of mixture water
W	=	calorimeter constant

As the density of water is considered as 1.0g/cm3, the mass of water is considered as its volume.

$$V_h \times 4.18 \times (T_h - T_m) = V_c \times 4.18 \times (T_m - T_c) + W \times (T_m - T_c)$$

$$W = \frac{[V_h (T_h - T_m) - V_c (T_m - T_c)] \times 4.18)}{T_m - T_c}$$

Question:

How do you determine the calorimetry constant (W) of a calorimeter? Investigate.

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:
Independent variables:
Dependent variables:
Controlled variables

Materials Required

Chemical	Apparatus
Distilled water	Glass calorimeter with stirrer (copper calorimeter can be replaced by a 100 mL beaker) –1 No 250 mL beaker – 4 No 100 mL beaker – 2 No Thermometer – 2 No Burette stand with clamps.

Procedure:

Step 1. Place a beaker (100 mL) in insulating compartment which serves as the calorimeter.

Step 2. Add 40 mL cold distilled water in the calorimeter and record the temperature of the water ($T_c{}^0C$).

Step 3. Heat 40 mL distilled water to a temperature of 50^0C to 60^0C in another 100 mL beaker.

Step 4. Note down the temperature of the hot distilled water ($T_h{}^0C$) and immediately transfer it to the calorimeter containing cold distilled water.

Step 5. Stir after mixing hot and cold water and note down the final temperature ($T_m{}^0C$).

Step 6. Calculate the calorimeter constant (W) of the beaker.

<div>

NOTES

- Use the thermometer of 0.1oC gradation.
- While determining the calorimeter constant, measure the temperature of hot water just before mixing.
- Avoid too much stirring of the mixture solution as it produces heat due to friction.
- Prepare the solutions in advance so that the solutions are brought to room temperature.

</div>

Observation:

Table 1.1 *Calorimeter Constant*

	Volume (mL)	Temperature (°C)
Cold distilled water	40	
Hot distilled water	40	
Cold water + hot water	80	

Result:

Write the result based on the observation.

Experiment 1b

Aim To determination the enthalpy of neutralisation using strong acid and strong base.

Theory:

Theory: During neutralisation reaction, H^+ ions from the acid react with OH^- ions from the base to form water. During this process, heat is released and therefore the reaction is exothermic.

$$H^+_{(aq)} + OH^-(aq) \longrightarrow H_2O_{(l)} \; \Delta H_{neu} \text{ is negative}$$

ΔH_{neu} is the enthalpy of neutralization.

The enthalpy of neutralisation is defined as the amount of heat liberated when one mole of H^+ ions reacts with one mole of OH^- ions to form one mole of water.

The neutralizsation reaction between 1 mole of any strong acid and 1mole of any strong base producing 1 mole of water, liberates constant heat which is equal to -57.3 kJ (-13.7 kcal).

$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)} \; \Delta H = -57.3 \text{ kJ}$$

The heat evolved during the neutralisation reaction is calculated using the following expression.

Heat released by neutralization = heat gained by solution mixture + heat gained by calorimeter

$$q_{neu} = m_{sol} \; X \; C_p \; ✗ \; \Delta T + W$$
$$q_{neu} = (V_a + V_b) \; ✗ \; 4.18 \; ✗ \; (T_1 - T_2) + W$$

Where:

V_a - volume of acid

V_b - volume of base

T_2 - Final temperature of mixure solution

T_1 - Temperature of acid or base

W - calorimetry constant

Enthalpy of neutralization (ΔH_{neu}) is the heat released or absorbed per mole of formation of water.

$$\Delta H_{neu} = \frac{q}{n}$$

$$\Delta H_{neu} = \frac{(V_a + V_b) \times 4.18 \times (T_1 - T_2) + W}{n}$$

Question:

How do you determine enthalpy of neutralisation using strong acid and strong base? Investigate.

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

STAY SAFE

- HCl and NaOH are corrosive. Handle carefully.
- Be careful while handling the flame.

Materials Required

Chemical	Apparatus
Distilled water 1.0 M NaOH 1.0 M HCl	Glass calorimeter with stirrer (copper calorimeter can be replaced by a 100 mL beaker) –1 No 250 mL beaker – 4 No 100 mL beaker – 2 No Thermometer – 2 No Burette stand with clamps.

Set up:
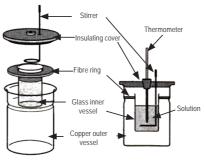
Figure 1.1. Calorimeter.

Procedure:

Step 2. Take 40 mL of 1.0 M HCl in a calorimeter.

Step 3. Take 40 mL of 1.0 M NaOH solution in a 100 mL beaker.

Step 4. Record the temperature of the above solutions (T_1 ^{0}C) kept at room temperature.

Step 5. Add 40 mL of 1.0 M NaOH solution into the calorimeter containing 1.0 M HCl solution. Stir the mixture constantly and record the maximum temperature attained (T_2 ^{0}C).

Step 6. Calculate the enthalpy of neutralisation for the formation of 1.0 mole of water. Express the enthalpy in terms of kJ mol-1.

Table 1.3 *Neutralization Reactions between Strong Acid and Strong Base*

Solution	Volume (mL)	Temperature (°C)
1.0M NaOH	40	
1.0M HCl	40	
NaOH + HCl	80	

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

Experiment 1c

Design and carryout an experiment using 1.0 M acetic acid and 1.0 M NaOH solutions to determine the heat used up for dissociation of acetic acid. Use Table 1.4 to record your observation.

Table 1.4

Solution	Volume (mL)	Temperature (°C)
1.0M NaOH	30	
1.0M CH_3COOH	30	
NaOH + CH_3COOH	60	

Question:

1. Calculate the enthalpy of neutralisation when 0.5M of HNO_3 solution is mixed with 0. 2 M of NaOH solution, if the enthalpy of neutralisation for the formation of 1 mole of water -57.1 kJ.

2. Write the chemical equation for the reaction between NaOH and CH_3COOH.

3. When certain volume of acid solution is added to certain volume of base solution, the temperature of the solution increases and reaches maximum. Why does the temperature not increase on further addition of base solution?

Enthalpy of Dissolution

Experiment

Aim To compare the enthalpy of dissolution of anhydrous copper sulphate and potassium nitrate.

Theory:

The enthalpy of dissolution is defined as the heat change (ΔH) of the system when one mole of a salt is dissolved in a given volume of solvent.

The heat absorbed or evolved during the dissolution of a salt in water is due to either dissociation of molecules into ions or due to hydrate formation. If a salt dissolves by ion formation, heat is absorbed and if it dissolves by formation of hydrate, heat is evolved. Salt which dissolves by hydrate formation has negative ΔH and the one which dissolves by dissociating into ions has positive ΔH.

The heat of dissolution of a given salt is calculated by the following expression:

Heat of dissolution = heat change of calorimeter +heat change of solution mixture

$$q = W(T_w - T_m) + (V + W_1) \times 4.18 (T_w - T_m)$$

where ,   W   : calorimeter constant

T_m : temperature of solution mixture

T_w : temperature of water

V   : volume of water

W_1 : weight of salt

Heat liberated by 1g of salt $= \dfrac{\text{Total enthalpy of dissolution}}{W_1}$ J

Heat liberated by 1mole of salt = $\dfrac{\text{Total enthalpy of dissolution}}{W_1}$ x molar mass of salt J mol^{-1}

Question:

Is the enthalpy of dissolution of anhydrous $CuSO_4$ different from enthalpy of KNO_3? Investigate.

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

> **STAY SAFE**
>
> - HCl and NaOH are corrosive. Handle carefully.
> - Copper sulphate is harmful. Avoid inhaling its dust and contact with skin.
> - Practice safe disposal of Copper sulphate solution.

Materials required:

Chemicals	Apparatus
• Anhydrous $CuSO_4$ • KNO_3	• Calorimeter - 1 No • Thermometer - 2 No • Digital Balance – 1 No • Beaker (100 ml) - 2 No

Procedure:

Step 1. Take 50 mL distilled water in a calorimeter whose calorimeter constant is known. Record the temperature of the water (T_w ^{0}C

Step 2. Take 4g (W_1) of powdered anhydrous $CuSO_4$ and add it to the distilled water in the calorimeter. Stir the solution thoroughly using a glass rod and place the thermometer in the solution.

Step 3. Record the maximum temperature of the solution attained (T_m ^{0}C).

Step 4. Calculate the enthalpy of dissolution in kJ mo^l-1

Step 5. Repeat the experiment with anhydrous potassium nitrate and calculate its enthalpy of dissolution.

Observation

Table 2.1 *Enthalpy of Dissolution*

Salt	Weight of salt (g)	Temperature of water, T_w (°C)	Temperature of salt solution, T_m (°C)
$CuSO_4$			
KNO_3			

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

Question:

1. A student performed the experiment on dissolution of salt in water using calorimeter (calorimeter constant: 10.5 joules per degree celcius) and obtained the result given in Table 2.2.

Table 2.2

Salt	Weight of salt (g)	Volume of water (mL)	Temperature of water, T_w (°C)	Temperature of salt solution, T_m (°C)
KCl	5	60	23.5	19.5
Anhydrous $MgSO_4$	5	60	23.5	28.0

Using the data from Table 2.2

a. calculate the enthalpy of dissolution of each salt.

b. suggest a mechanism by which the dissolution of each salt takes place.

2. Will the enthalpies of dissolution of chloride salts group I elements differ? Explore.

3

Variation of Cell Potential

Experiment

Aim To study the variation of cell potential with change in concentration of $CuSO_4$ solution.

Theory:

Electrochemical cell (galvanic cell) is a device in which electric current is generated as a result of chemical reaction. It consists of two half cells called oxidation half cell and reduction half cell connected by a salt bridge. The potential difference between two electrodes when no current is drawn from the cell is known as electromotive force (e.m.f). The cell potential is the difference between reduction potential of cathode and anode.

$$E_{cell} = E_{cathode} - E_{anode}$$

Redox reaction takes place in galvanic cell. Oxidation takes place at the anode where as reduction takes place at cathode.

Oxidation (loss of electron): $M_{(s)} \longrightarrow M^{n+}_{(aq)} + ne^-$

Reduction (gain of electron): $M^{n+}_{(aq)} + ne^- \longrightarrow M_{(s)}$

The representation of galvanic cell/Daniel Cell:

$$Zn_{(s)} / Zn^{2+}_{(aq)} \parallel Cu^{2+}_{(aq)} / Cu_{(s)}$$

The standard reduction potentials of zinc and copper electrodes are given as -0.76 V and 0.34 V respectively.

At the anode: $\qquad$ $Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2e$

At the cathode : $\qquad$ $Cu^{2+}_{(aq)} + 2e \longrightarrow Cu_{(s)}$

The cell reaction (redox reaction) is represented as:

$$Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$$

The electrode potential of a given electrode under non-standard conditions (the concentration of ions other than one mole per litre) is calculated using the Nernst Equation.

$$E_{M^{n+}/M} = E^0_{M^{n+}/M} + \frac{2.303\ RT}{nF}\ \log \frac{[M^{n+}_{(aq)}]}{[M_{(s)}]}$$

where,

$E_{M^{n+}/M}$: standard reduction potential of the electrode.

R : is the gas constant ($8.314\ J\ K^{-1}Mol^{-1}$)

n : no. of electrons gained or lost during the redox reaction.

F : no. of faraday of electricity (96500 coulombs)

T : absolute temperature (298 K)

The $[M_{(s)}]$ is taken as unity

The cell potential of a galvanic cell under non-standard condition is determined by the equation given below:

$$E_{cell} = E^0_{cell} + \frac{2.303\ RT}{nF}\ \log \frac{[M^{n+}(anode)]}{[M^{n+}(cathode)]}$$

$$E^0_{cell} = E^0_{cathode} - E^0_{anode}$$

Question:

Does the cell potential vary with change in concentration of $CuSO_4$ solution?

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variable:

Controlled variables:

STAY SAFE

- Copper sulphate is harmful. Avoid inhaling its dust and contact with skin.

Materials Required

Chemicals	Apparatus
• (10^{-1}M, 10^{-2}M, 10^{-3}M, 10^{-4}M, 10^{-5}M) $CuSO_4$ solution • 0.1 M $ZnSO_4$ solution	• Voltmeter (0 to 1volt) / digital multimeter. • Beaker 100 mL - 2 No • Beaker 250 mL – 5 No • Copper electrode. • Zinc electrode. • Connecting wire. • Salt bridge

Set up:

TIPS

- Use fresh ZnSO4 solution after every measurement of e.m.f.
- Place the salt bridge in distilled water or KCl solution immediately after use.
- Clean the zinc and copper electrodes with sand paper.

Figure 3.1. Electrochemical cell.

Instruction:

Observe Figure 3.1 and set up the electrochemical cell using the following information:

1. Use 40 mL 0.1 M $ZnSO_4$ solution and 40 mL 0.1 M $CuSO_4$ solution in two different 100 mL beakers. Measure the cell potential and record its value in Table 3.1.
2. Use 40 mL $CuSO_4$ solution in the following order 0.01M, 0.001M, 0.0001M and 0.00001M and measure the cell potential. Record the values of cell potential in Table 3.1.
3. Plot a graph of variation of cell potential versus concentration of copper sulphate solution.

Observation

Table 3.1 *Concentration of Copper Sulphate Solution vs Cell Potential*

SL.No	$Cu^{2+}_{(aq)}$ [molL^{-1}]	E cell (volt)
1	10^{-1}	
2	10^{-2}	
3	10^{-3}	
4	10^{-4}	
5	10^{-5}	

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 3b

Conduct a similar experiment by varying the concentration of $ZnSO_4$ solution (0.1M, 0.01M, 0.001 M, 0.0001M and 0.0000M) and keeping the concentration of $CuSO_4$ constant (0.1 M). Compare your result with that of the above experiment and draw the conclusion.

Question:

1. Following are the four half cells to be used for construction of a galvanic cell. Which two half cells would be used to construct an electrochemical cell that will give the highest cell potential?

    (a) Cu^{2+}/Cu $E° = +0.34$ V   (c) Ag^+ / Ag $E° = +0.80$ V

    (b) Al^{3+}/ Al $E° = -1.67$ V   (d) Zn^{2+} / Zn $E° = -0.76$ V

2. Explain the function and the composition of salt bridge.

3. How will the weights of anode and cathode vary over time in the functional electrochemical cell?

Paper Chromatography

Experiment

Aim To determine the retention factor (R_f) values of leaf pigments using paper chromatography.

Theory:

Chromatography is a technique used for the separation of mixtures. It is based on the principle of adsorption or partition between mobile and stationary phase. There are many chromatographic techniques used for the separation of mixtures.

Paper chromatography is based on the principle of partition between two liquid phases. In paper chromatography, water in the pores of the chromatography paper (Whatman paper) acts as a stationary phase and the solvent which moves over the stationary phase as mobile phase. The separation of mixture is achieved by partition between two liquid phases.

The mixtures move under the capillary action of pores in the cellulose paper to different distances depending upon their solubility in the mobile phase. The mobile phase on the chromatographic paper carries the mixtures along with it. The component which is more soluble in the solvent moves faster and farther than the one that is less soluble. The differential solubility of components in the mixture and their rates of mobility in the given solvents are used to separate components from the mixture. The mobility of the components is represented by their Rf values. The components have their own R_f values in a given solvent.

The R_f values are calculated using the following equation.

$$R_f = \frac{\text{Distance travelled by the component from the reference line (cm)}}{\text{Distance travelled by the solvent from the reference line (cm)}}$$

Since the solvent travels faster than the components, the R_f values are always less than one. It has no unit.

There are many uses and applications of paper chromatography. It is used as an analytical technique to separate mixtures having polar and non-polar compounds, separation of amino acids, determine biochemistry of urine, and identification of inorganic compounds and complexes.

Question:

1. Do the R_f values of different pigments in a leaf extract differ? Investigate.
2. What is the relation between R_f value and solubility of leaf pigment?

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

STAY SAFE
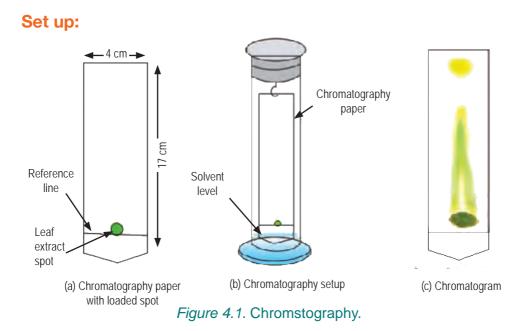
- Avoid inhalation of acetone; it causes irritation of the eyes and respiratory tract.
- Diethyl Ether poses an inhalation hazard, and can cause irritation of the eyes and skin.

Materials Required

Chemicals	Apparatus
• Plant leaves • Acetone • Diethyl ether	• Grade 1 Whatman chromatography paper (2 X 20 cm) - 1 No • Chromatography jar - 1 No • Beaker (100 mL) – 2 No • Muslin cloth piece – 1 No • Mortar and pestle- 1 No • Capillary tube – 5 No • Scissors – 1 No

TIPS

- Ensure that the chromatography paper is suspended freely in the chromatography jar.

Set up:

4 cm

17 cm

Reference
line

Leaf
extract
spot

(a) Chromatography paper
with loaded spot

Chromatography
paper

Solvent
level

(b) Chromatography setup

(c) Chromatogram

Figure 4.1. Chromstography.

Procedure:

Step 1. Cut the leaves and transfer them into a mortar. Add a pinch of sand, 1 to 2 mL of acetone and grind the leaves thoroughly.

Step 2. Filter the leaf extract using muslin cloth.

Step 3. Cut a strip of Whatman chromatography paper into the size that can fit into the chromatography jar.

Step 4. Draw a line with a sharp pencil about 2 cm above the lower end of the chromatography paper and mark the spot on the centre of the line.

Step 5. Load the leaf extract on the spot (less than 2 mm in diameter) using capillary tube and dry it.

Step 6. Prepare a solution of ether and acetone in the ratio 4:1 respectively.

Step 7. Pour about 3 to 5 mL of this solvent mixture into a chromatography jar and suspend the loaded paper in the jar so that the loaded spot is just above the solvent mixture.

Step 8. Allow the solvent to move up to two-third of the length of the paper. Remove the chromatography paper as soon as pigments are separated and dry the paper. Mark and measure the distance travelled by the solvent front and the pigments from the reference line.

Step 9. Calculate the R_f value of each pigment using the given formula

$$R_f = \frac{\text{Distance travelled by the component from the reference line (cm)}}{\text{Distance travelled by the solvent from the reference line (cm)}}$$

Table 4.2

Leaf pigment	Colour	Distance travelled by the solvent. (cm)	Distance travelled by the pigment. (cm)	R_f value
Carotene	Yellow			
Chlorophyll a	Bluish green			
Chlorophyll b	Greenish yellow			
Xanthophyll	Orange			

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the theory and result.

Experiment 4b

You will work in four groups. Each group will prepare 0.1 M standard salt solution of each salt. Take equal volume of each of the standard solution and mix them to obtain salt solution of the combination given below and carry out the following analysis using paper chromatography.

Group 1: $AgNO_3$, $Cu(NO_3)_2$ and $Fe(NO_3)_3$

Group 2: $Co(NO_3)_2$, $Fe(NO_3)_3$ and $Cu(NO_3)_2$

Group 3: $AgNO_3$, $Cu(NO_3)_2$ and $Fe(NO_3)_3$

GROUP 4: $AgNO_3$, $Cu(NO_3)_2$ and $Cu(NO_3)_3$

Spot the standard solution of each salt and the solution mixture on the

chromatography paper as given in Figure 4.1.

To run the chromatographic separation, use mobile phase (mixture of 5 mL of 6 M HCl, 4 mL ethanol and 4 mL n-butanol). After the separation of the mixture, place the chromatography paper in the developing solution (mixture of 2.0 g of $K_4[Fe(CN)_6]$ and 0.8 g KI in 250 mL solution).
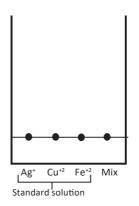
Fig 4.2. Sample loading on chromatography paper.

Using the paper chromatogram obtained, note down your observation in Table 4.3.

Table 4.3

Solution	Colour (after drying)	Colour (after staining)	Distance travelled by the solvent front (cm)	Distance travelled by the cation (cm)	R_f value
Ag^+					
Co^{2+}					
Cu^{2+}					
Fe^{3+}					
Mixture					

Using the above data:
(a) compare the R_f value of the standards and components in the salt mixture.

(b) identify metal ions present in the salt mixture based on the R_f values obtained.

Thin Layer Chromatography

Experiment

Aim	To separate the mixture of amino acids using Thin Layer Chromatography.

Theory:

Thin Layer Chromatography is a technique used for the separation of components present in a compound. It is based on the principle of adsorption between mobile and stationary phase.

A TLC plate is a glass slide with its surface coated with a thin layer of adsorbent materials such as silica gel or alumina. A tiny drop of the solution to be analysed is placed near the bottom of the plate onto the silica gel (stationary phase), and then organic solvents (mobile phase) are allowed to move over the surface by capillary action.

As the stationary and mobile phases interact, the components of the mixture will partition between the two phases. Based on the relative affinities towards mobile phase and the stationary phase, the components in the mixture travel at different rates and get separated at different distances from the reference line on the plate. The mobility of the component is represented by their R_f values. The R_f values are calculated using the following equation.

$$\text{Retention factor } (R_f) = \frac{(\text{Distance travelled by the amino acid})}{(\text{Distance travelled by the solvent})}$$

Since the solvent travels faster than the components, R_f values are always less than 1

Question:

Why is adsorption rate different for different type of amino acids?

Hypothesis

Formulate your own hypothesis

Materials Required

Chemicals	Apparatus
• Butanol • Acetic acid • Silica • Distilled water • Ninhydrin	• TLC chamber/jar • Glass slides • Tong • Capillary tube • Oven • Measuring cylinder

Procedure:

Precaution:
• Draw the reference line gently to avoid dam-age to the thin layer coating.
• Acetone and ethanol are highly inflammable.

Step 1.   Draw a line 1cm above the lower end of the TLC plate and mark a spot on the centre of the line.

Step 2.   Load the mixture of amino acids on the spot using a capillary tube.

Step 3.   Allow the spot to dry.

Step 4.   Mix butanol, acetic acid and water in the ratio of 2:1:1 and pour the mixture into the TLC chamber.

Step 5.   Close the TLC chamber to develop solvent vapour pressure in the chamber.

Step 6.   Place the TLC plate in the TLC chamber evenly. Position the plate such that the spot

is not fully immersed in the solvent mixture.

Step 7.   Close the chamber and allow the capillary action to draw the solvent up the TLC plate until it is approximately 1cm from the upper end of the TLC plate.

Step 8.   Quickly mark the position of the solvent front with a pencil.

Step 9.   Dry the plate in a hot air oven and spray Ninhydrin to make the spots visible.

Step 10. Mark the spots with a pencil and measure the distance travelled by each spot from the reference line.

Step 11. Calculate the Rf of each amino acids from the chromatogram.

Step 12. Determine the number of amino acids present in the mixture.

Result

Write the results based on the observation.

Conclusion

Draw a conclusion based on the result.

Question

1.   What would be the consequences if the reference line on the plate is drawn with pen?

2.   Why is the solvent spot marked immediately after taking out the TLC plate from the chamber, while the other spots are marked only after drying?

Functional Group in an Organic Compound

Experiment 6a

Aim To detect the functional group present in an organic compound.

Theory:

Organic compounds are derivatives of parent hydrocarbons formed by replacing one or more hydrogen atoms with other atoms or group of atoms. The chemical property of an organic compound is determined by the presence of functional group. The detection of functional group depends on the type of elements present in it.

Table 6.1 *Functional Group Test*

Compound	Functional group	Test
Carboxylic acid $\text{R}-\overset{\displaystyle O}{\overset{\displaystyle \|}{\text{C}}}-\text{O}-\text{H}$	$-\overset{\displaystyle O}{\overset{\displaystyle \|}{\text{C}}}-\text{O}-\text{H}$	• When an aqueous or alcoholic solution of carboxylic acid is treated with blue litmus, it turns red. • Compound having carboxyl group in solid or liquid form produces brisk effervescence of CO_2 on adding a solution of sodium carbonate. • Carboxylic acid when treated with ethanol and concentrated H_2SO_4 gives ester having fruity/pleasant odour.

Compound	Functional group	Test
Alcohol R—O—H	—O—H	• When the filtrate obtained by mixing alcohol and anhydrous $CaCl_2$ is reacted with metallic sodium, effervescence forms due to evolution of hydrogen. • The mixture of alcohol and solid KOH when warmed, cooled and then treated with CS_2 results in the formation of yellow precipitate (xanthate). • Dilute solution of alcohol turns red when treated with ceric ammonium nitrate.
Aldehyde $$\begin{array}{c} O \\ \| \\ R-C-H \end{array}$$ Ketone $$\begin{array}{c} O \\ \| \\ R-C-R \end{array}$$	$$\begin{array}{c} O \\ \| \\ -C-H \end{array}$$ $$\begin{array}{c} O \\ \| \\ -C- \end{array}$$	• Carbonyl group in aldehydes and ketones can be detected by warming it with 2, 4-dinitrophenyl hydrazine as it forms yellow, orange or red precipitate. This is also called 2,4-dinitrophenyl hydrazine or Brady's Test. • Aldehydes and ketones form crystalline white precipitate when mixed thoroughly with sodium bisulphite solution. • When aldehydes and ketones are treated with Schiff's reagent, there is an appearance of pink/purple colour in the solution. (Acetone is an exception which restores the pink colour but very slowly). • Aldehydes give silver mirror/greyish black precipitate, when warmed with Tollen's reagent, while ketones do not give positive test.

Question:

How do you identify the functional group present in the given organic compound? Investigate.

Materials Required

Chemicals	Apparatus
• Ethanol • Acetaldehyde • Acetone • Acetic Acid • Red litmus • Blue litmus • Sodium carbonate • Sodium metal • Carbon disulphide • Ceric ammonium nitrate solution • Calcium chloride • Potassium hydroxide • Sodium bisulphate • Ethyl alcohol • Conc. H_2SO_4 • Tollen's reagent • Schiff's reagent	• Test tubes • Water bath • Test tube holder

Instruction:

1. Carry out the relevant tests for the given organic compound using the information provided above in Table 5.1.

2. Write down the experimental procedure, observation and inference in the tabular form.

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

STAY SAFE

- Avoid inhalation of acetone, it causes irritation of the eyes and respiratory tract.
- H_2SO_4 and KOH are corrosive in nature. Handle with care.
- Sodium metal is explosive in water.
- Ethyl alcohol is inflammable.

Result:

Write the result based on the observation.

Conclusion:

1. Lemon contains citric acid. Design an experiment to confirm the presence of functional group in the acid.

2. A laboratory assistant has placed two test tubes containing acetaldehyde and acetone without labels on them. Perform appropriate chemical tests to identify them.

Experiment 6b

Lemon contains citric acid. Using the information from Table 5.1 design and carry out an experiment to confirm the presence of functional group in the acid.

Questions:

1. A student is given two test tubes containing acetaldehyde and acetone without any label on them. Write appropriate chemical tests to identify them.

2. An organic compound 'A' on warming with ethanol and concentrated sulphuric acid produce a compound 'B' having a smell of banana. To which class of organic compound does 'A' and 'B' belong respectively? What generalization can be drawn from this reaction?

Colligative properties

Experiment 7a

Aim To investigate the effect of addition of non-volatile solute on the boiling point of a solvent.

Theory:

Elevation of boiling point is the increase in the boiling point of a solvent when a non-volatile solute is added to it. The elevation of boiling point is the colligative property as it depends on the number of solute particles in the solution and not on the nature of the solute.

Elevation of boiling point (ΔT_b) = boiling point of solution – boiling point of solvent.

Elevation of boiling point is calculated using the following expression.

$$\Delta T_b = K_b \times i \times m$$

Where:

K_b = boiling point elevation constant/ ebullioscopic constant

i = Van't Hoff factor

m = molality of the solution.

Question:

How does the concentration of a solution affect its boiling point?

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

Materials Required

Chemicals	Apparatus
• Distilled water • Sodium Choloride	• Beakers (250 mL) • Thermometer • Glass rod • Digital weighing balance • Measuring cylinder • Tongs • Bunsen burner/ heating plate

Procedure:

Step 1:   Take 100 gram or 100 mL of distilled water in a 250 mL beaker.

Step 2:   Dip the thermometer into the distilled water in a beaker such that it does not touch the   base of the beaker.

Step 3:   Heat the distilled water in beaker constantly to boiling.

Step 4:   Record the final constant temperature of the boiling water.

Step 5:   Take 100 grams or 100 mL distilled water in another 250 mL beaker and label it as 'A'

Step 6:   Weigh 5.85 gram of NaCl and dissolve it in distilled in beaker A.

Step 7 :   Dip the thermometer into the solution in beaker A.

Step 8 :   Heat the solution in beaker A constantly to boiling.

Step 9:   Record the final constant temperature of the boiling solution.

Step10 :   Repeat step 5,7 - 9 by taking 11.7 grams, 17.55 grams and 23.4 gram of NaCl respectively and determine the elevation of boiling point of each solution.

Step 11: Use Microsoft excel to plot a graph of molality of solution versus elevation of boiling point or plot the graph manually.

Observation:

Table 7.1

Weight of water (grams)	Weight of NaCl (gram)	Molality of solution(mol per kg)	Boiling point	Elevation of boiling point

Result:

Write the result based on the observation.

Conclusion:

Draw conclusion based on the result.

Question.

1. Determine the average value of ebullioscopic constant / boiling point elevation constant of water based on your data.

2. List down some of the real life application of elevation of boiling point.

3. Design an experiment to determine the depression in freezing point.

8 Qualitative Analysis of Salt

Experiment 8a

Aim	To identify anions in salt mixture.
	(This practical can be done virtually or may be demonstrated by the teacher)

Theory:

Qualitative analysis is a method to find out elemental composition in a compound. Ions are usually identified by the characteristic reaction they show upon the addition of a certain reagent. The reaction forms a precipitate or a coloured solution. The separation of ions is done by the addition of a precipitating reagent, which selectively reacts with an ion in the solution.

The anions can be identified by performing the following tests:

Dil. H_2SO_4 Group (CO_3^{2-}, S^{2-}, HCO_3^-, NO_2^-)

1. Dil. H_2SO_4 test

   When salts are treated with dilute H_2SO_4, they decompose with evolution of gas. The evolution of gas indicates the presence of a particular acid radical.

   (a) Carbonate: Carbonates react with dil. H_2SO_4, evolving colourless and odourless gas (CO_2) with brisk effervescence.

   $$CO_3^{2-} + H_2SO_4 \longrightarrow CO_2 \uparrow + H_2O + SO_4^{2-}$$

   The gas can be identified by passing it through lime water which turns turbid due to formation of calcium carbonate.

   $$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 \downarrow + H_2O$$
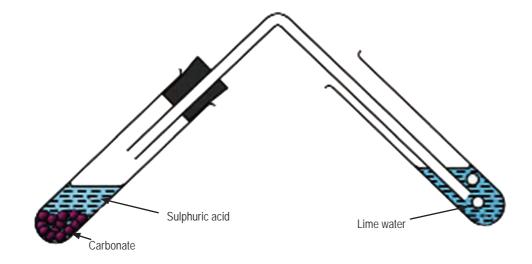
Figure. 8.1. Lime water test.

The soluble carbonates react with the magnesium sulphate solution and form a white precipitate of insoluble magnesium carbonate.

$$CO_3^{2-} + MgSO_4 \longrightarrow MgCO_3 \downarrow + SO_4^{2-}$$

(b) Sulphide: Sulphides reacts with dil. H_2SO_4, evolving colourless gas (H_2S) with rotten egg smell.

$$S^{2-} + H_2SO_4 \longrightarrow H_2S \uparrow + SO_4^{2-}$$

- The soda extract of sulphide salt with solution of sodium nitroprusside, forms purple or violet colour.

$$2Na + S^{2-} + Na_2 [Fe (CN)_5 NO] \longrightarrow Na_4 [Fe (CN)_5 NOS]$$

- The soda extract of sulphide salt with solution of lead acetate, forms black precipitate.

$$S^{2-} + (CH3COO)_2 Pb \longrightarrow PbS \downarrow + 2 CH_3COO^-$$

Conc. H_2SO_4 group (NO_3^-, Cl^-, Br^-, I^-, CH_3COO^-)

2. Conc. H_2SO_4 Test

    When salts are heated with conc. H_2SO_4, evolution of a characteristic gas depends upon the nature of acid radical.

    (a) Chloride: Chloride salts react with conc. H_2SO_4, evolving colourless gas (HCl) with pungent odour, which increases on addition of a pinch of MnO_2. The gas forms dense white fumes of NH_4Cl when glass rod dipped in NH_4OH solution is brought near the mouth of the test tube.

    $$Cl^- + H_2SO_4 \longrightarrow HCl\uparrow + HSO_4^-$$

    The acidified soda extract or water extract of chlorides with $AgNO_3$ solution forms white precipitate, which is soluble in excess of NH4OH.

    $$Cl^- + AgNO_3 \longrightarrow AgCl\downarrow + NO_3^-$$

    $$AgCl + 2NH_4OH \longrightarrow [Ag(NH_3)_2]Cl + 2H_2O$$

    Soluble complex

    (b) Bromide: Bromide salts react with conc. H_2SO_4, evolving reddish brown gas (Bromine), which intensifies on addition of a pinch of MnO_2. The gas turns starch paper yellow.

> **STAY SAFE**
> - Chlorine, bromine and iodine are toxic. Perfrom the experiment in a fume cupboard and avoid direct inhalation of evolved gases.
> - Avoid facing the mouth of the test tube towards self and others.nto the hot test tube.

    $$2Br^- + MnO_2 + 3H_2SO_4 \longrightarrow 2HSO_4^- + MnSO_4 + 2H_2O + Br_2\uparrow$$

    The soda extract or water extract of bromides with $AgNO_3$ solution forms pale yellow precipitate, which is soluble in excess of NH_4OH.

    $$Br^- + AgNO_3 \longrightarrow AgBr\downarrow + NO_3^-$$

    (c) Iodide: Iodide salts react with conc. H_2SO_4, gives out violet vapour of iodine. The vapour turns starch paper deep blue.

    $$I^- + H_2SO_4 \longrightarrow HI + HSO_4$$

    $$2HI + H_2SO_4 \longrightarrow I_2\uparrow + SO_2 + 2H_2O$$

The soda extract or water extract of iodides with $AgNO_3$ solution forms curdy yellow precipitate, which is insoluble in excess of NH_4OH.

$$I^- + AgNO_3 \longrightarrow AgI \downarrow + NO_3^-$$

(d) Nitrate: Nitrate salts react with conc. H2SO4, gives out light brown fumes (NO_2) with irritating odour that intensifies on addition of copper turnings. The gas turns the KI paper yellow. The nitrate can be confirmed by brown ring test.

$$4NO_3^- + 2H_2SO_4 \longrightarrow 4NO_2 \uparrow + O_2 \uparrow + 2SO_4^{2-} + 2H_2O$$

Brown Ring test:

Soda extract or aqueous solution of salt and freshly prepared solution of ferrous sulphate are mixed and cooled, and a few drops of conc. H_2SO_4 are added gently along the side of the test tube. A brown ring appears at the junction of two liquids.

$$2HNO_3 + 6FeSO_4 + 3H_2SO_4 \longrightarrow 3Fe (SO_4)_3 + 2NO + 4H_2O$$

$$FeSO_4 + NO \longrightarrow FeSO_4.NO$$
$$\text{Nitroso ferrous sulphate}$$

Figure 8.2. Brown ring test.

Anions not identified by dilute or conc. H_2SO_4: ($SO4^{2-}$, PO_4^{3-})

- The soda extract or water extract of sulphate salts with dil. HCl and $BaCl_2$ solutions forms white precipitate.

$$SO_4^{2-} + Ba^{2+} \longrightarrow BaSO_4 \downarrow$$

- The soda extract or water extract of sulphate with acetic acid and lead acetate solutions forms white precipitate, which is soluble in ammonium acetate solution.

$$SO_4^{2-} + Pb^{2+} \longrightarrow PbSO_4 \downarrow$$

$$PbSO_4 + 2CH_3COONH_4 \longrightarrow (CH_3COO)_2Pb + (NH_4)_2SO_4$$

Materials Required

Chemical	Apparatus
• Dil. H_2SO_4	• Test tube
• Lime water.	• Delivery tube
• Magnesium sulphate solution	• Watch glass
• $KMnO_4$ solution	• Glass rod
• Sodium nitroprusside solution	• Test-tube holder
• Dil. acetic acid	• Tongs
• Lead acetate	• Evaporating Dish
• Barium chloride	• Spatula
• Ammonium acetate	
• $AgNO_3$	
• NH_4OH	
• $K_2Cr_2O_7$	
• Dil.HNO_3	
• MnO_2	
• Noah	
• KI paper	
• Starch paper	
• $FeSO_4$	
• Conc.H_2SO_4	
• Dil. HCl	

Instructions:

1. Carry out dil. H_2SO_4 test with the given salt mixture. If anion of this group is present, carry out relevant confirmatory tests.

2. Carry out conc. H_2SO_4 test with the given salt mixture. If anion of this group is present, carry out relevant confirmatory tests.

3. Carry out analysis of anions not identified by dilute or conc. H_2SO_4. If anion of this group is present, carry out relevant confirmatory tests.

4. Record all your experimental procedure, observation and inference in a tabular form.

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

Experiment 8b

Design and carry out the test to detect the anion present in the table salt.

Questions:

1. Why is it necessary to prepare and use sodium carbonate extract for the confirmatory test of anions?

2. Why is soda extract not used for confirmatory test of carbonate ion?

3. Write the chemical test to distinguish between potassium chloride and potassium bromide.

Experiment 8c

| **Aim** | To identify cations in the given salt mixture. |
| | *(This practical can be done virtually or may be demonstrated by the teacher)* |

Theory:

Qualitative analysis is used to detect, identify and separate cations and anions in a salt mixture. Ions are identified by the characteristic reaction they undergo on adding certain reagent. The cations are analysed depending on the differences in the solubility products of chlorides, sulphides, hydroxides and carbonates in acidic and alkaline medium.

For qualitative analysis, cations are divided into seven groups, including zero group. The reagent used to test the presence of ions in a particular group is known as group precipitating reagent. The separation of ions is done by adding a precipitating reagent, which selectively reacts with ions of that particular group in the solution.

Group zero (NH_4^+)

Salt mixture on warming with NaOH solution evolves NH3 gas. When a glass rod dipped in HCl solution is brought near the gas, a dense white fumes of NH4Cl is formed.

$NH_4Cl + NaOH \longrightarrow NaCl + H_2O + NH_3\uparrow$

$NH_3 + HCl \longrightarrow NH_4Cl$

dense white fumes

On passing the gas through Nessler reagent, a brown precipitate is formed.

$2K_2HgI_4 + NH_3 + 3KOH \longrightarrow HgO.Hg(NH_2)I\downarrow + 7KI + 2H_2O$

Basic mercury (II) amido-iodine (Brown precipitate)

Preparation of the original solution (OS)

The cations of group I to group VI are detected by preparing original solution. The original solution may be coloured in the case of coloured salts. Solubility of salt mixture is tested by taking a pinch of it in the following order:

a) Cold distilled water

b) Hot distilled water

c) Cold dilute HCl

d) Hot dilute HCl

e) Cold conc. HCl

f) Hot conc. HCl

g) Aquaregia (conc. HNO_3 + conc. HCl in 1:3 ratio)

Once a suitable solvent is found, OS is prepared by dissolving about 1 gm of the mixture in about 10 mL of solvent.
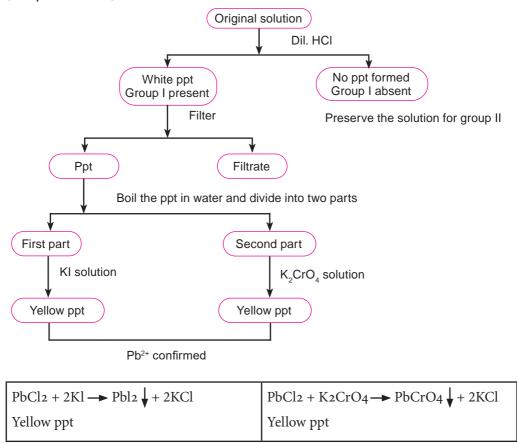
Table: 8.1 *Solubility of Salt*

Sl. No.	Salt	Solubility of salt in	
		Water	**HCl**
1	Carbonates and bicarbonates	All bicarbonates and alkali metal carbonates.	All
2	Nitrates and nitrites	All	All
3	Sulphides and sulphites	Na^+, K^+, NH_4^+	All except HgS, NiS, CoS
4	Sulphates	All except Pb^{2+}, Ba^{2+}, Sr^{2+}	All except Pb^{2+}, Ba^{2+}, Sr^{2+}
5	Chlorides, bromides, iodides	All except Ag^+, Hg_2^{2+}, Pb^{2+}	All except Ag^+, Hg_2^{2+}, Pb^{2+}

Test for Cations
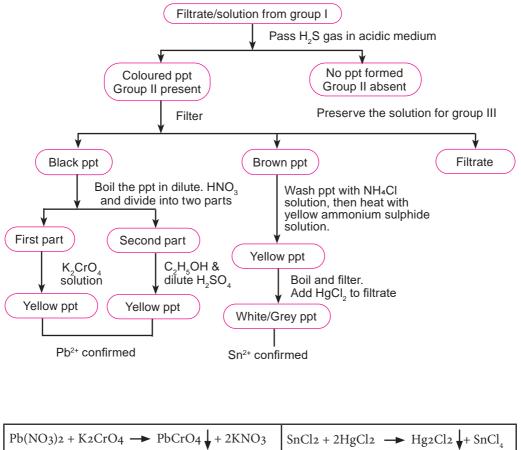
Groups I Cations (Ag^+, Pb^{2+})

[In Syllabus Pb^{2+}]

Original solution

Dil. HCl

White ppt
Group I present

No ppt formed
Group I absent

Filter

Preserve the solution for group II

Ppt

Filtrate

Boil the ppt in water and divide into two parts

First part

Second part

KI solution

K_2CrO_4 solution

Yellow ppt

Yellow ppt

Pb^{2+} confirmed

$PbCl_2 + 2Kl \longrightarrow Pbl_2 \downarrow + 2KCl$	$PbCl_2 + K_2CrO_4 \longrightarrow PbCrO_4 \downarrow + 2KCl$
Yellow ppt	Yellow ppt

Groups II Cations (Pb²⁺ Sn²⁺, Cu²⁺, Hg²⁺)

Groups II Cations (Pb^{2+} Sn^{2+}, Cu^{2+}, Hg^{2+})

[In Syllabus Pb^{2+} Sn^{2+}]

Filtrate/solution from group I

Pass H_2S gas in acidic medium

Coloured ppt
Group II present

No ppt formed
Group II absent

Preserve the solution for group III

Filter

Black ppt

Brown ppt

Filtrate

Boil the ppt in dilute. HNO_3 and divide into two parts

Wash ppt with NH_4Cl solution, then heat with yellow ammonium sulphide solution.

First part

Second part

Yellow ppt

K_2CrO_4 solution

C_2H_5OH & dilute H_2SO_4

Boil and filter. Add $HgCl_2$ to filtrate

Yellow ppt

Yellow ppt

White/Grey ppt

Pb²⁺ confirmed

Pb^{2+} confirmed

Sn²⁺ confirmed

Sn^{2+} confirmed

$Pb(NO_3)_2 + K_2CrO_4 \rightarrow PbCrO_4 \downarrow + 2KNO_3$ Yellow ppt $Pb(NO_3)_2 + H_2SO_4 \rightarrow PbSO_4 \downarrow + 2HNO_3$ White ppt	$SnCl_2 + 2HgCl_2 \rightarrow Hg_2Cl_2 \downarrow + SnCl_4$ White ppt $Hg_2Cl_2 + SnCl_2 \rightarrow 2Hg \downarrow + SnCl_4$ Grey ppt

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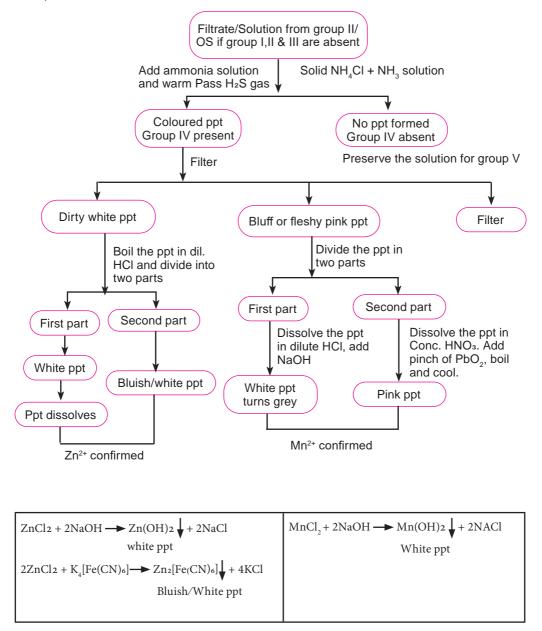
Group III cations (Al³⁺, Cr³⁺, Fe³⁺, Fe²⁺)

(In syllabus Al³⁺, Cr³⁺)

Filtrate/Solution from group II/
OS if group I & II are absent

Boil off H_2S gas+solution pinch
of NH_4Cl warm + Ammonia

Solid NH_4Cl + NH_3 solution

Coloured ppt
Group III present

Filter

No ppt formed
Group III absent

Use the filtrate for group IV

Preserve the solution for group IV

Filter

Glatinous
white ppt

Grey green ppt

Boil the ppt in dil. HCl
and divide into two parts

Dissolve the ppt in NaOH
and divide into two parts

First part

Second part

First part

Second part

Ammonia
solution

Blue litmus
solution + NH_4OH

K_2CrO_4
solution

CH_3COOH &
$(CH_3COO)_2$ Pb
solution

White ppt

Blue floating ppt

Greenish
white ppt

Yellow ppt

Al³⁺ confirmed

Cr³⁺ confirmed

$AlCl_3 + 3NH_4 \longrightarrow Al(OH)_3 \downarrow + 3NH_4Cl$	$Na_2 + CrO_4 + (CH_3COO)_2Pb \longrightarrow PbCrO_4 \downarrow + CH_3COONa$
Gelatinous white ppt	Yellow ppt

Group IV cations (Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+})

(In syllabus Zn^{2+}, Mn^{2+})

$ZnCl_2 + 2NaOH \longrightarrow Zn(OH)_2 \downarrow + 2NaCl$ white ppt $2ZnCl_2 + K_4[Fe(CN)_6] \longrightarrow Zn_2[Fe(CN)_6] \downarrow + 4KCl$ Bluish/White ppt	$MnCl_2 + 2NaOH \longrightarrow Mn(OH)_2 \downarrow + 2NACl$ White ppt

Group V Cation (Ba^{2+}, Ca^{2+}, Sr^{2+})

(In syllabus Ba^{2+}, Ca^{2+})

Filtrate/Solution from group IV/OS if Group I, II, III & IV are absent

Boil off H_2S gas, add a pinch of NH_4Cl + ammonia solution. Add $(NH_4)_2CO_3$ and warm

White ppt
Group V present

No ppt formed
Group V absent

Filter

Preserve the solution for group V

White ppt

Filter

Filter

Use the filtrate for group VI

Dissolve the ppt in CH_3COOH and divide into two parts

First part

Second part

$(NH_4)_2C_2O_4$ solution, warm

K_2CrO_4 solution

White ppt

Yellow ppt

Ca^{2+} confirmed

Ba^{2+} confirmed

$(CH_3COO)_2Ca + (NH_4)_2C_2O_4 \longrightarrow CaC_2O_4 \downarrow + 2CH_3COONH_4$ white ppt	$K_2CrO_4 + (CH_3COO)_2Ba \longrightarrow BaCrO_4 \downarrow + 2CH_3COOK$ Yellow ppt

Group VI cations (Na+, K+, Mg^{2+})

(In syllabus Mg2+)

If cations of other groups are absent, then on adding NH_4Cl and NH_4OH to the filtrate from group V or original solution followed by ammonium phosphate solution, a white precipitate is formed. Mg^{2+} is confirmed.

$$Mg^2+ + (NH_4)_3PO_4 \longrightarrow MgNH_4PO_4 \downarrow + 2NH^{4+}$$
$$\text{White ppt}$$

Question:

How do you detect cations in a salt mixture?

Materials Required

Chemicals	Apparatus
• Dil. HCl, dil. H_2SO_4, dil. HNO_3 • Conc. HCl, conc.H_2SO_4, conc. HNO_3 • Solid NH_4Cl • NH_4OH solution • NaOH Solution • Solid Na_2CO_3 • H_2S gas	• Test tubes • Test tube holders • Bunsen burner / spirit lamp • Water bath • Droppers • Spatula • Water bottle • Kipps apparatus

Instruction:

1. Perform the relevant test for group zero with the given salt mixture. If cations of this group are present, carry out relevant confirmatory test.

2. Perform systematic analysis for cations with a given salt mixture. If the cation of particular group is present, confirm it by conducting relevant confirmatory test.

3. Write the experimental procedure, observation and inference in a tabular form.

STAY SAFE

- Acids and alkalis are corrosive
- Handle chemicals with care.
- Avoid direct inhalation of gas
- Handle flame carefully.

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Question:

1. Write the steps for preparing the original solution of the given salt mixture.

2. Sonam noticed that the wheat plants in her field had poor root growth and wilted easily. She guessed that it might be due to high gypsum content in the soil. Outline the chemical analysis she would need to conduct to confirm the presence of cation in gypsum.

3. A health worker suspects that drinking water has been contaminated with lead. Design an experiment for the qualitative analysis of the water to confirm the presence of contaminants. Support your findings with relevant chemical equations.

Permanganometry

Experiment 9a

Aim To estimate the amount of ferrous ion present in an iron tablet using potassium permanganate solution.

Theory:

Quantitative analysis is used to determine the amount or concentration of substances present in a sample. It involves measurement of either mass or volume of reacting substances. Permanganometry is a technique used for quantitative analysis to determine the concentration of unknown chemical samples using potassium permanganate solution. It is based on the principle of redox reaction between potassium permanganate and unknown solution. Permanganate ions undergo reduction into manganese (II) ions and oxidize iron (II) into iron (III) as given in the equation.

$$MnO_4^- + 8H^+ + 5Fe^{2+} \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

Question:

How do you estimate the amount of ferrous ion in an iron tablet using potassium permanganate solution?

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:
Independent variables:
Dependent variables:
Controlled variables:

Materials Required

Chemicals	Apparatus
• 0.005 M $KMnO_4$ solution • 1.5 M H_2SO_4 • 5 Iron tablets	• Burette -1 No • Pipette/ graduated pipette -1 No • Conical flask (250 mL) - 1 No • Beaker (150 mL) - 3 No • Measuring cylinder (25 mL) -1 No • Volumetric flask (250 mL) - 2 No • Volumetric flask (100 mL) - 1 No • Mortar and pestle – 1 No • Pipette filler – 1 No

Procedure:

STAY SAFE

• H_2SO_4 is corrosive. Handle with care.
• Use pipette filler to fill pipette.

Step 1. Prepare 0.005 M $KMnO_4$ solution in a volumetric flask.

Step 2. Weigh 5 iron tablets and crush them using mortar and pestle.

Step 3. Transfer the powdered iron tablets into a beaker and dissolve in 100 mL of dilute sulphuric acid.

Step 4. Transfer the above solution into a 250 mL volumetric flask and add distilled water up to the etched mark.

Step 5. Pipette out any volume (not exceeding 25mL) of iron (II) solution into the conical flask and add 10 mL of dilute sulphuric acid to it.

Step 6. Fill the burette with potassium permanganate solution.

Step 7. Run down the solution from the burette to the conical flask and shake the content continuously till a permanent light pink colour appears. Note the burette reading.

Step 8. Tabulate the reading in Table 8.1 and repeat the titration to obtain at least two concordant readings.

Observation

Table 9.1 *Volume of Solutions*

Sl. No.	Volume of iron tablet solution (mL)	Burette Reading (mL)		Volume of KMnO$_4$ used (mL)
		Initial reading	Final reading	
1				
2				
3				

Calculation:

i.   Mass of five iron tablets = …..g

ii.   Titre value = …… mL

iii.   Volume of iron tablet solution used = ……….mL

iv.   Molarity of iron (II) solution = ………………..

v.   Total volume of iron (II) solution = 250 mL

vi.   Number of moles of iron in 250 mL solution =……………

vii.   Mass of iron in 250 mL of solution = ……….…..

viii. Mass of iron in each tablet = …………………….

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 9b

C-1 is a solution prepared by dissolving 0.45 g of an impure sample of potassium permanganate in 250 mL of solution. The solution C-2 is prepared by dissolving 20.5 g of pure crystalline hydrated ammonium iron (II) sulphate per litre. The redox reaction takes place as given below:

$2KMnO_4 + 3H_2SO_4 \longrightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5[O]$

$[2FeSO_4. (NH_4)_2 SO_4 .6H_2O + H_2SO_4 + [O] \longrightarrow Fe_2 (SO_4)_3 + 2(NH_4)_2 SO_4 + 13H_2O]$ x 5

a. Write the standard procedure and carry out the volumetric analysis.
b. Calculate the following:
i.   The molarity of the hydrated ammonium iron (II) sulphate solution, (C-2).
ii.   The molarity of the potassium permanganate solution, (C-1)
iii. The concentration of potassium permanganate solution, (C-1)
iv. The percentage purity of the impure sample of potassium permanganate that was used in the preparation of solution, C-1

Questions:

1.   Write the ionic equation for the above redox reaction.
2.   Why is dilute sulphuric acid added to iron solution?
3.   Why is determination of percentage purity in chemical product important in quantitative analysis?

10 Iodometry

Experiment 10a

Aim To estimate iodine content in table salt.

Theory:

Iodine titration is a volumetric analysis based on the redox reaction. Iodine titrations are of two types,Iodimetric titration and Iodometric titration.

In iodimetric titration, the standard solution of iodine is prepared by dissolving I_2 in KI solution which is titrated against reducing agents such as sodium thiosulphate, sodium arsenite etc. This method of titration is called direct method.

$$KI + I_2 \longrightarrow KI_3$$

$$2Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6 + 2NaI$$

In iodometric titration, iodine liberated by the oxidation of iodide ion is titrated against a standard sodium thiosulphate solution. This method is also known as an indirect method.

$$K_2Cr_2O_7 + 7H_2SO_4 + 6KI \longrightarrow 4K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3I_2$$

$$6Na_2S_2O_3 + 3I_2 \longrightarrow 3Na_2S_4O_6 + 6NaI$$

Iodine titration can be practically applied in analyzing the iodine content of salt samples. It involves the reaction of iodine in the salt sample with a strong reducing agent such as sodium thiosulphate. The chemical equation for the redox reaction is

$$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$$

Iodine is essential for proper functioning of thyroid gland. The determination of iodine content in edible salt samples is important because when the physiological

requirements for iodine are insufficient, it results in functional and developmental abnormalities in the body including thyroid disorder. Daily requirement of iodine for the body is 150-200 micrograms (μg) in adults, 90- 120 μg in children and 250 μg for pregnant & lactating mothers.

Question:

How do you estimate iodine content in table salt?

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

Materials Required

Chemicals	Apparatus
• 0.005 M $Na_2S_2O_3$ • 1 M H_2SO_4 • 10% KI • Starch solution • Iodised salt	• Burette – 1 No • Pipette/graduated pipette – 1 No • Conical flask (250 mL) -1 No • Beaker (250 mL) – 3 No • Measuring cylinder (50 mL) - 1 No • Black paper • Pipette filler - 1 No

Procedure:

Step 1. Weigh 50g of salt sample and transfer it to 250 mL volumetric flask. Dissolve the salt in water making volume up to the etched mark.

Step 2. Measure 50 mL of the salt solution and transfer it into a 250 mL conical flask.

STAY SAFE

• H_2SO_4 is corrosive. Handle with care.
• Use pipette filler to fill pipette.

Step 3. To the above content, add 5 mL of 1.0 M H_2SO_4 and 5 mL of 10% KI solution. Cover the flask with a black paper and allow it to stand for 10 minutes.

Step 4. Rinse and fill the burette with 0.005 M Na2S2O3 solution.

Step 5. Run $Na_2S_2O_3$ solution from the burette into the conical flask slowly until the colour turns pale yellow.

Step 6. Add about 2 mL of freshly prepared starch solution to the conical flask (the solution should turn dark blue).

Step 7. Continue titration until the solution finally becomes colourless. This is the end point.

Step 8. Record the burette reading in Table 10.1.

Step 9. Repeat the titration to get at least two concordant readings.

Observation

Table 10.1 *Burette reading*

Sl. No.	Volume of salt solution (mL)	Burette Reading (mL)		Volume of $Na_2S_2O_3$ used (mL)
		Initial reading	Final reading	
1				
2				
3				

Calculations:

1. The molarity of salt solution
2. Strength of iodine in the salt solution
3. The amount of iodine present in 50 g of table salt

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 10b

Carry out the following iodometric titration between A-1 and A-2. A-1 is a solution containing 15.0 g of impure sample of hydrated sodium thiosulphate($Na_2S_2O_3.5H_2O$) (hypo) per litre of the solution and A-2 is a solution of potassium dichromate ($K_2Cr_2O_7$) containing 2.8 gm per litre of the solution.

The redox reaction between A-1 and A-2 is given below.

$$K_2Cr_2O_7 + 7H_2SO_4 + 6KI \rightarrow 4K_2SO_4 + Cr_2(SO_4)_3 + 7H2O + 3I_2$$

$$6Na_2S_2O_3 + 3I_2 \rightarrow 3Na_2S_4O_6 + 6NaI$$

Procedure

1. Rinse and fill the burette with the given solution A-1. Take any volume (not exceeding 25mL) of solution A-2 into a clean conical flask. To it add about equal of A-3 (dilutesulphuric acid) and about equal volume of A - 4 (potassium iodide solution).
2. To the content in the conical flask, add about same volume of distilled water followed by a pinch of sodium bicarbonate.
3. Shake the content of the flask by covering with a piece of paper. Allow the solution to stand for about 5 minutes until the solution becomes dark reddish brown.
4. Run down the solution of A-1 from the burette until the solution turns yellowish green. To it add about 2-3 cm3 of freshly prepared starch solution till it turns dark blue.
5. Continue adding A-1 solution dropwise until the colour changes from dark blue to light green. Tabulate at least three readings.

Calculate the following:

(a) The molarity of the potassium dichromate solution (A-2).
(b) The molarity of sodium thiosulphate solution (A-1).
(c) The strength of sodium thiosulphate solution (A-1) in gram per litre.
(d) The percentage purity of impure sample of sodium thiosulphate (A-1).

Question:

1. Chimi performed iodimetric titration between 12.5 g of $Na_2S_2O_3$. x H_2O and iodine solution and obtained the following observations as recorded in Table 10.2.

Table 10.2

Sl. No.	Volume of iodine solution (mL)	Burette Reading (mL)		Volume of $Na_2S_2O_3$ x H_2O solution used (mL)
		Initial reading	Final reading	
1	20	0	19.5	19.5
2	20	0	19.3	19.3
3	20	0	19.3	19.3

Using the data, calculate:

    i.   The molarity of sodium thiosulphate solution.

    ii.   The molecular mass of sodium thiosulphate

    iii. Find the value of x in $Na_2S_2O_3$. xH_2O.

2. Why is starch solution need to be freshly prepared to be used as an indicator?

3. If the daily salt intake of a person is about 5g per day, using the information in experiment 9a, calculate the amount of iodine consumed by the person.

11

pH Curve of Neutralisation Reaction

Experiment

| Aim | To generate the pH curve for neutralisation reaction. |

Theory:

When a solution of strong acid is added to a solution of strong base or vice versa, the pH of the solution changes considerably. During neutralisation reaction, H+ ions liberated by acid combine with the OH- ions liberated by base to form water. As the titration proceeds, initially there is gradual change in the pH but close to the equivalence point, sharp change in the pH of the solution occurs. This sharp change in pH indicates the end point of the titration. At this point only a small fraction of H+ ions or OH- ions remain unconsumed in the solution.

Titration is often represented on the graph called pH curve or titration curve. pH curve is a plot that shows the change in pH of the titrated solution (analyte) and the volume of the added solution (titrant). A titration curve is used to determine:

1. The equivalence point of an acid-base reaction.
2. The pH of the solution at the equivalence point.

Equivalence point of a neutralisation reaction is the point at which equivalent quantities of acid and base are mixed. At this point, the concentration of H^+ ions in the solution becomes equal to the concentration of OH^- ions.

Figure 11.1 to Figure 11.3 represent the typical titration curve for three different acid base pairs.
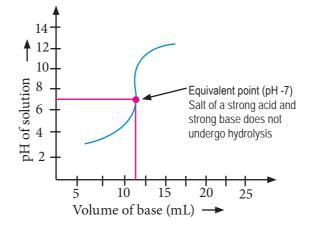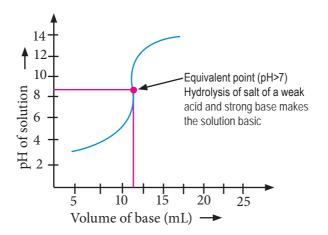
Figure 11.1. pH curve for strong acid vs strong base.

Figure 11.2. pH curve for weak acid vs strong base.

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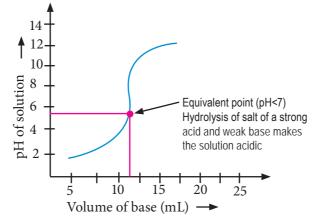
Figure 11.3. pH curve for strong acid vs weak base.

Question:

How is the pH curve generated from neutralisation reaction between a strong acid and strong base?

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables:

> **STAY SAFE**
>
> - Acid and alkali are corrosive. Handle with care.
> - Use pipette filler to fill pipette.

Materials Required

Chemicals	Apparatus
• 0.1 M HCl • 0.1 M NaOH solution • Digital pH mtre/universal indicator	• Burette -1 No • Conical flask (250 mL) - 1 No • Pipette - 1 No • Beaker (250 mL) - 2 No • Dropper - 1 No • pH chart - 1 No • Burette stand - 1 No • Glazed tile -1 No • Funnel (small) -1 No • Pipette filler - 1 No

Procedure:

If Universal indicator is used:

Step 1. Fill the burette with 0.1 M NaOH solution.

Step 2. Take any volume (not exceeding 25mL) of 0.1 M HCl solution into a conical flask and add five drops of universal indicator.

Step 3. Run 0.1 M NaOH solution in lots from the burette as given in Table 10.1.

Step 4. Shake the content of the conal flask after adding each lot of NaOH solution and observe the colour change.

Step 5. Match the colour of solution with that of colour given in pH chart and note the pH value.

Step 6. Tabulate your data in Table 11.1.

Step 7. Plot a graph of pH value versus total volume of NaOH added.

If pH metre is used:

Step 1. Fill the burette with 0.1 M NaOH solution.

Step 2. Take any volume (not exceeding 25mL) of 0.1 M HCl solution in 250 mL beaker.

Step 3. Run 0.1 M NaOH solution in lots from the burette as given in Table 10.1.

Step 4. Shake the content of the beaker after adding each lot of NaOH solution and record the pH.

Step 5. Tabulate your data in Table 11.1.

Step 6. Plot a graph of pH value versus total volume of NaOH added.

Observation

Table 11.1 *pH of Solution Vs. Volume of NaOH*

Sl. No.		Volume of NaOH added in lots (mL)	Total volume of NaOH added to the solution in flask/beaker (mL)
1		0	0
2		12.0	12.0
3		10.0	22.0
4		2.0	24.0
5		0.5	24.5
6		0.3	24.8
7		0.2	25.0
8		0.2	25.2
9		0.3	25.5
10		0.5	26
11		2.0	28
12		10	38

Result:

Write the result based on the observation. Represent your data in the form of graph.

Conclusion:

Draw a conclusion based on the result.

Experiment 11b

Following the above procedure, perform the experiment using strong acid and weak base.

Question:

1. 200 mL 0.15 M HCl solution is mixed with 500 mL of 0.2 M NaOH solution. Determine the pH of the resulting solution.
2. The pH curve for the titration between different acids and bases are different. Predict the type of pH curve which can be obtained from the titration between weak acid and weak base.
3. The volume of base added in lots to the acid solution is decreased drastically after certain stage in titration in 10a. Explain.

Primary, Secondary and Tertiary amines

Experiment
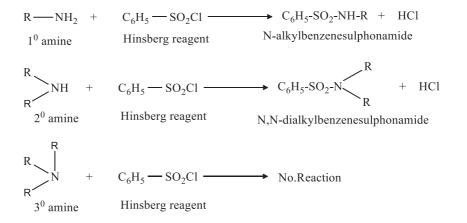
| Aim | To identify different types of amines. |

Theory:

Amines are organic compounds consisting of alkyl group attached to amine group (–NH2) and are referred to as derivatives of ammonia. There are three types of amines namely primary amines secondary amines and tertiary amines. Primary amines have two hydrogen atoms attached to nitrogen atom. Secondary amines have one hydrogen atom attached to nitrogen atom and tertiary amines do not have any hydrogen atom attached to nitrogen atom. These amines can be identified by using benzene sulphonyl chloride (also called Hinsberg reagent) in the presence of an excess of aqueous base. Primary amine gives a precipitate of N-alkylbenzenesulphonamide which is soluble in excess base. Secondary amine gives precipitate of

N,N-dialkylbenzenesulphonamide which is insoluble in base. Tertiary amine does not react with Hinsberg reagent.

$$R-NH_2 \quad + \quad C_6H_5-SO_2Cl \longrightarrow C_6H_5\text{-}SO_2\text{-}NH\text{-}R \quad + \quad HCl$$

1^0 amine   Hinsberg reagent   N-alkylbenzenesulphonamide

$$\begin{array}{c} R \\ \diagdown \\ \diagup \\ R \end{array}NH \quad + \quad C_6H_5-SO_2Cl \longrightarrow C_6H_5\text{-}SO_2\text{-}N \begin{array}{c} R \\ \diagup \\ \diagdown \\ R \end{array} \quad + \quad HCl$$

2^0 amine   Hinsberg reagent   N,N-dialkylbenzenesulphonamide

$$\begin{array}{c} R \\ | \\ R \diagdown \\ N \\ R \diagup \end{array} \quad + \quad C_6H_5-SO_2Cl \longrightarrow \text{No.Reaction}$$

3^0 amine   Hinsberg reagent

Question:

How do you identify different types of amines?

Hypothesis:

Formulate your own hypothesis.

Variables:

Identify the following:

Independent variables:

Dependent variables:

Controlled variables

Materials Required

Chemicals	Apparatus
• Distilled water • Benzene sulphonyl chloride (Hinsberg reagent) • 25 % aqueous NaOH solution • Aniline • N-methyl aniline • N,N - dimethylaniline	• Beakers • Test tubes • Droppers

Procedure:

Precaution:
Benzene sulphonyl chloride and NaOH solution are corrosive in nature.

Step 1: Take three test tubes labelled A, B and C containing samples of three different types of amines.

Step 2: Add 5 mL of distilled water to each samples of amines taken in test tubes A, B and C.

Step 3: Add few drops of Hinsberg reagent to test tube A and shake the mixture carefully. Note down the observation in the given table.

Step 4: Add excess NaOH solution to the product obtained in Step 3. Note down the observation in the given table.

Step 5: Repeat Steps 3 and 4 for amines taken in test tubes B and C

Observation

Table 12.1 *Test to identify type of amines*

Test tube	Observation after adding Hinsberg reagent	Observation after adding NaOH solution
A		
B		
C		

Result:

Write the result based on the observation.

Conclusion:

Draw the conclusion based on the result.

Questions:
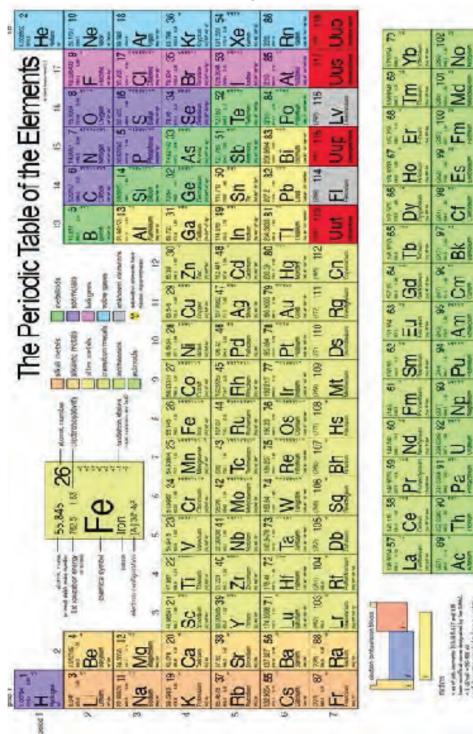
1. Design an experiment to distinguish primary, secondary and tertiary amines using other relevant reagents.

ANNEXURE A

Physical quantities and units of measurement

Sl No.	Quantity	Name of the unit	Symbol
1	Mass	Kilogram	kg
2	Length	Metre	m
3	Time	Seconds	S
4	Electric current	Ampere	A
5	Thermodynamic Temperature	Kelvin	K
6	Amount of substance	Mole	mol
7	Luminous Intensity	Candela	cd
8	Area	Square meter	m^2
9	Density	Kilogram per meter cube	Kgm^{-3}
10	Heat	Joule	J
11	Pressure	Pascal	Pa
12	Speed	Meter per second	ms^{-1}
13	Temperature (T)	Kelvin	K
14	Velocity	Meters per second	ms^{-1}
15	Voltage	Volt	V
16	Volume	Cubic meter	m^3
17	Work or energy	Joule	J

ANNEXURE B

The Periodic Table of the Elements

ANNEXURE C

Physical constants

Sl.No	Name	Symbols	Values
1	Speed of light	C	2.99792458×10^8 m^{-2}
3	Planck's constant	h	$6.6260755 \times 10^{-34}$ Js
4	Gravitation constant	G	6.67259×10^{-11} m^3 kg^{-1} s^{-2}
5	Molar gas constant	R	8.314510 mol^{-1}K^{-1}
6	Avogadro's number	N_A	6.0221×10^{23} mol^{-1}
7	Charge of electron	e	$1.60217733 \times 10^{-19}$ C
8	Permeability of vacuum	μ_0	$4\pi \times 10^{-7}$ NA^{-2}
9	Permittivity of vacuum	ε_0	$8.854187817 \times 10^{-12}$ Fm^{-1}
10	Coulomb constant	$1/4\pi\varepsilon_0$=K	8.987552×10^9 Nm^{2}C^{-2}
11	Faraday constant	F	96485.309 C mol^{-1}
12	Mass of electron	m_e	$.1093897 \times 10^{-31}$ kg
13	Mass of electron	m_e	0.51099906 MeC^{-2}
14	Mass of proton	m_p	1.672631×10^{-27} kg
15	Mass of proton	m_p	938.27231 MeVC^{-2}
16	Mass of neutron	m_n	$1.6749286 \times 10^{-27}$ kg
17	Mass of neutron	m_n	939.56563 MeVC^{-2}
18	Atomic mass unit	u	$1.6605402 \times 1 0^{-27}$
19	Rydberg constant	R_∞	10973731.534 m^{-1}
20	Standard atmosphere	atm	101325 pa

ANNEXURE D

Assessment in Science Practical Works

Educational assessment is the process of documenting, usually in measurable terms, outcomes of knowledge, skills, attitudes and beliefs of the learners. This includes the processes of gathering and interpreting information about the progress of their learning. In order for the assessment to be valuable to individuals and organizations, the assessment must be accurate and objective. The learners should be well informed about what will be assessed and how it will be assessed. This makes the teacher's expectations clear to the learners to set appropriate learning outcomes. The teachers can play an important role in the learners' achievement by effectively monitoring their learning and giving them constructive feedback on how they can improve, and provide the necessary scaffolding for the needy learners as identified through the reliable assessment techniques and tools.

Purpose of Assessment

One of the first things to consider when planning for assessment is its purpose. Who will use the results? For what will they use them?

Assessment is used to:

1. *inform and guide teaching and learning*: A good classroom assessment plan gathers evidence of student learning that informs teachers' instructional decisions. It provides teachers with information about what students know and can do. To plan effective instruction, teachers also need to know what the student misunderstands and where the misconceptions lie. In addition to helping teachers formulate the next teaching steps, a good classroom assessment plan provides a road map for students. Students should, at all times, have access to the assessment so they can use it to inform and guide their learning.

2. *help students set learning goals*: Students need frequent opportunities to reflect on where their learning is at and what needs to be done to achieve

their learning goals. When students are actively involved in assessing their own next learning steps and creating goals to accomplish them, they make major advances in directing their learning, and what they understand about themselves as learners.

3. *assign report card grades:* Grades provide parents, employers, other schools, governments, post-secondary institutions and others with summary information about student learning.

4. *motivate students*: Research (Davies 2004; Stiggins et al. 2004) has shown that students will be motivated and confident learners when they experience progress and achievement, rather than the failure and defeat associated with being compared to peers that are more successful. The achievements and performances of the learners in science are assessed on three domains (Work scientifically, scientific knowledge and scientific values and attitudes).

Areas of Assessment

Assessment in science involves detailed process of measuring students' achievement in terms of knowledge, skills, and attitude. The progress of learning is inferred through analysis of information collected.

The achievements and performances of the learners in Chemistry are assessed on the following three domains:

Scientific Knowledge

Advanced knowledge and understanding of atoms and molecules, chemical kinetics, thermochemistry, chemical equilibrium, electrochemistry, mechanism of organic reactions, analytic techniques and their relevance to the world; inter-relationship of chemistry with other branches of science, and their applications.

Working Scientifically

Advanced, logical and abstract thinking; exploration, experimentation and investigation, and comprehension of complex situation, including exploration of how technological advancement are related to the scientific ideas that underpins them. Compare, contrast, synthesise, question and critique the different sources of information, and communicate their ideas clearly and precisely in a variety of ways, including the use of ICT.
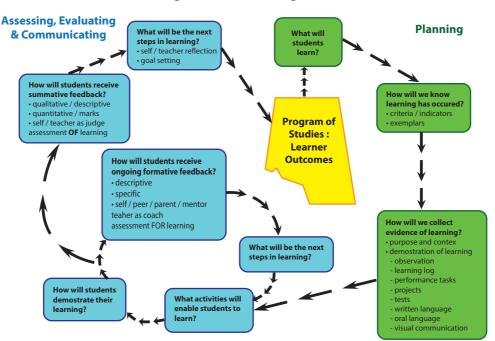
Scientific Values and Attitudes

Consider the power and limitations of science in addressing social, industrial, ethical and environmental issues, and how different groups in the community and beyond may have different views about the role of science. They make informed judgments on statements and debates that have a scientific basis, and use their learning in science for planning positive action for their own welfare as well as of others in their community and the environment.

Assessment Process

Effective classroom assessment in Science may entail the following processes:

1. addresses specific outcomes in the program of studies

2. shares intended outcomes and assessment criteria with students prior to the assessment activity

3. assesses before, during and after instruction

4. employs a variety of assessment strategies to provide evidence of student learning

5. provides frequent and descriptive feedback to students

6. ensures students can describe their progress and achievement and articulate what comes next in their learning

7. informs teachers and provides insight that can be used to modify instruction.

Assessing Student Learning in Classroom

Assessing, Evaluating & Communicating

Planning

What will be the next steps in learning?
• self / teacher reflection
• goal setting

What will students learn?

How will students receive summative feedback?
• qualitative / descriptive
• quantitative / marks
• self / teacher as judge
assessment **OF** learning

Program of Studies : Learner Outcomes

How will we know learning has occured?
• criteria / indicators
• exemplars

How will students receive ongoing formative feedback?
• descriptive
• specific
• self / peer / parent / mentor teaher as coach
assessment FOR learning

What will be the next steps in learning?

How will we collect evidence of learning?
• purpose and contex
• demostration of learning
  - observation
  - learning log
  - performance tasks
  - projects
  - tests
  - written language
  - oral language
  - visual communication

How will students demostrate their learning?

What activities will enable students to learn?

Tools for Assessment of Science Practical works

In order to assess the learners' performance objectively and provide empirical evidences, the following suggested tools are widely used in the assessment processes.

Observation Checklist

Observing students as they solve problems, model skills to others, think aloud during a sequence of activities, or interact with peers in different learning situations provide insight into their learning and growth. The teacher finds out under what conditions success is most likely, what individual students do when they encounter difficulty, how interaction with others affects their learning and concentration, and what students need to learn next. Observations may be informal or highly structured, and incidental or scheduled over different periods of time in different learning contexts.

Observation checklists allow teachers to record information quickly about how students perform in relation to specific outcomes from the program of studies.

Observation checklists, written in a yes or no format can be used to assist in observing student performance relative to specific criteria. They may be directed toward observations of an individual or group. These tools can also include spaces for brief comments, which provide additional information not captured in the checklist.

Before you use an observation checklist, ensure students understand what information will be gathered and how it will be used. Ensure checklists are dated to provide a record of observations over a period of time.

Tips for using observation checklist

1. Determine specific outcomes to observe and assess.

2. Decide what to look for. Write down criteria or evidences that indicate the student is demonstrating the outcome.

3. Ensure students know and understand what the criteria are.

4. Target observations by selecting four to five students per class for one or two specific outcomes to observe.

5. Develop a data gathering system, such as a clipboard for anecdotal notes, a checklist or rubric, or a video or audio recorder.

6. Collect observations over a number of classes during a reporting period and look for patterns of performance.

7. Date all observations.

8. Share observations with students, both individually and in a group. Make the observations specific and describe how this demonstrates or promotes thinking and learning.

9. Use the information gathered from observation to enhance or modify future instruction.

Rating Scale

Rating Scales allow teachers to indicate the degree or frequency of the behaviours, skills and strategies displayed by the learner. Rating scales state the criteria and provide three or four response selections to describe the quality or frequency of student work.

Teachers can use rating scales to record observations which the students can

use as self-assessment tools. Teaching students to use descriptive words, such as always, usually, sometimes and never helps them pinpoint specific strengths and needs. Rating scales also give students information for setting goals and improving performance. In a rating scale, the descriptive word is more important than the related number. The more precise and descriptive the words for each scale point, the more reliable is the tool. Effective rating scales use descriptors with clearly understood measures, such as frequency. Scales that rely on subjective descriptors of quality, such as fair, good or excellent are less effective because the single adjective does not contain enough information on what criteria are indicated at each of these points on the scale.

Rubrics

Rubrics are a set of criteria used to evaluate student's performance. They consist of a fixed measurement scale and detailed description of the characteristics for each level of performance. These descriptions focus on the quality of the product or performance and not the quantity; e.g., not number of paragraphs, examples to support an idea, spelling errors. Rubrics are commonly used to evaluate student performance with the intention of including the result in a grade for reporting purposes. Rubrics can increase the consistency and reliability of scoring. They may be used to assess individuals or groups performances.

Rubrics are increasingly recognised as a way to effectively assess student learning and communicate expectations directly, clearly and concisely to students. The rubrics describe stages in the development and growth of knowledge, understandings and skills. To be most effective, rubrics should allow students to see the progression of mastery in the development of understandings and skills.

Rubrics are constructed with input from students whenever possible. A good start is to define what quality work looks like based on the learning outcomes. Examples of achievement need to be used to demonstrate to students what an excellent or acceptable performance is. This provides a collection of quality work for students to use as reference points. Once the standard is established, it is easy to define what exemplary levels and less-than-satisfactory levels of performance look like. The best rubrics have three to five descriptive levels to allow for discrimination in the evaluation of the product or task. Rubrics may be used for summative purposes to gauge marks by assigning a score to each of the various levels. Begin by developing criteria to describe the acceptable level. Then use Bloom's taxonomy to identify differentiating criteria as you move up the scale. The criteria should not go beyond the original performance task, but reflect higher order thinking skills that students could demonstrate within the

parameters of the initial task.

While developing the scoring criteria and quality levels of a rubric, consider the following guidelines:

1. Level 4 is the **Standard of excellence** level. Descriptions should indicate that all aspects of work exceed grade level expectations and show exemplary performance or understanding. This level is a "Wow!"

2. Level 3 is the **Approaching standard of excellence** level. Descriptions should indicate some aspects of work that exceed grade level expectations and demonstrate solid performance or understanding. This level is a "Yes!"

3. Level 2 is the **Meets acceptable standard**. This level should indicate minimal competencies acceptable to meet grade level expectations. Performance and understanding are emerging or developing but there are some errors and mastery is not thorough. This level is a "On the right track, but …"

4. Level 1 **Does not yet meet acceptable standard**. This level indicates what is not adequate for grade level expectations and indicates that the student has serious errors, omissions or misconceptions. This level is a "No, but …" The teacher needs to make decisions about appropriate intervention to help the student improve.

After a rubric has been created, students can use it to guide their learning. Criteria described in a rubric serve to focus student reflection on their work and facilitate the setting of learning goals for a particular performance assessment. Through self-assessment or peer-assessment by using rubrics, students can assess the quality of work completed to date and guide them in planning steps in learning.

The following provides the format for recording of students' performances in the Chemistry practical classes.

Table 1 Format to Record Chemistry Practical Assessment

Name	Performance Criteria					Total scores (28)
	Hypothesis (4)	Variable (4)	Manipulative (4)	Data Analysis (4)	Conclusion (4)	
Sonam						
Wangmo						
Dorji						

Table 2 Rubrics to Assess Chemistry Practical

Performance Criteria	Performance Rating (Score)			
	4	**3**	**2**	**1**
Question	Clear, testable, relates to aim and shows the variables	Stated but one of the qualifiers is missingfety procedures.	Stated but two qualifiers are missing	Stated but three qualifiers are missing
Hypothesis	Relevant, testable, specific and predicts relationship between variables	Stated but one of the qualifiers is missing	Stated but two qualifiers are missing	Stated but three qualifiers are missing
Variables	Independent, dependent and controlled variables are correctly spelled out	One variable is missing or misattributed to other variable	Two variables are missing or misattributed to other variables	Three variables are misattributed to other variables
Manipulative Skill	Uses appropriate method and obtains relevant and sufficient data	Uses appropriate method, obtains relevant but insufficient data	Uses appropriate method but obtains irrelevant and insufficient data	Uses inappropriate method, and obtains irrelevant and insufficient data
Data analysis	Appropriate mathematical procedures and graphic representation with clear interpretation	Appropriate mathematical procedures and graphic representation but no clarity in interpretation	Appropriate mathematical procedures but lacks graphic representation and clarity in interpretation	Inappropriate mathematical procedures and lack graphic representation and clear interpretation
Conclusion	Relates to hypothesis, shows scientific facts and explains the phenomena, and links to a new context	Relates to hypothesis, shows scientific facts and explains the phenomena	Relates to hypothesis and shows scientific facts	Relates to hypothesis only
Communication	The record is relevant and evidence-based	The record is relevant but lacks evidence	The record lacks both the relevancy and evidence	The record is incomplete

Note:

1) For the prescribed list of experiments, one may come across the research question spelled out beforehand. Therefore, teachers are advised to assess all the phases of inquiry cycle, except the research question. More so, if the experiments organised in the manner of qualitative inquiry/inductive approach/theory development, one is not entailed to test hypothesis as well as identify the variables. Therefore, in such instance, teachers are advised to forgo with the assessment of hypothesis and variable criteria. As a result, the total score many not necessarily be same to the score featured in Table 4.1.

2) If the experiments demand students to design and carry out independently, then teachers are expected to base the assessment on all the phases of inquiry. However, if the experiments are to be devised and carried out based on the principles of qualitative inquiry/ inductive approach /theory development, teachers are advised to forgo with the assessment of hypothesis and variable criteria. Therefore, the total score many not necessarily be same to the score spelled out in table 4.1.

Anecdotal Notes

Anecdotal notes are used to record specific observations of individual student behaviours, skills and attitudes as they relate to the outcomes in their learning. Such notes provide cumulative information on student learning and direction for further instruction. Anecdotal notes are often written as results of ongoing observations during the lessons but may also be written in response to a product or performance the student has completed. They are brief, objective and focused on specific outcomes. Notes taken during or immediately after activity are generally the most accurate. Anecdotal notes for a particular student can be periodically shared with the student or be shared upon the student's request. They can also be shared with students and parents at parent–teacher–student conferences.

1. The purposes of anecdotal notes are to:

    (a) provide information regarding a student's development over a period of time.

    (b) provide ongoing records about individual instructional needs.

    (c) capture observations of significant behaviours or skills that might otherwise be lost.

    (d) provide ongoing documentation of learning that may be shared with students, parents and teachers.

2. Tips for establishing and maintaining anecdotal notes

    (a) Keep a binder with a separate page for each student. Record observations using a clipboard and sticky notes. Write the date and the student's name on each sticky note. Following the note taking, place individual sticky notes on the page reserved for that student in the binder.

    (b) Keep a binder with dividers for each student and blank pages to write notes. The pages may be divided into three columns: Date, Observation and Action Plan.

    (c) Keep a class list in the front of the binder and check off each student's name as anecdotal notes are added to their section of the binder. This provides a quick reference of the students you have observed and how frequently you have observed them.

    (d) Keep notes brief and focused (usually no more than a few sentences or phrases).

(e) Note the context and any comments or questions for follow-up.

(f) Keep comments objective. Make specific comments about student strengths, especially after several observations have been recorded and a pattern has been observed.

(g) Record as the observations are being made, or as soon after as possible, so recollections will be accurate.

(h) Record comments regularly, if possible.

(i) Record at different times and during different activities to develop a balanced profile of student's learning.

(j) Review records frequently to ensure that notes are being made on each student regularly and summarise information related to trends in students' learning.

(k) Share anecdotal notes with students and parents formally and informally.

Scheme of Assessment

The Chemistry practical works of learners are assessed through the following schemes of assessment:

Continuous Formative Assessment (CFA)

Formative assessment is used to provide feedback to teachers and learners, so that teaching and learning can be improved through provision of regular feedback and remedial learning opportunities for the learners when needed. It also enables the teachers to understand what teaching methods and materials work best.

CFA facilitates teachers to diagnose the learning needs of learners and recognise individual differences in learning. Through the constructive feedback provided, learners are able to understand their strengths and weaknesses. It also empowers them to be self-reflective learners who monitor and evaluate their own progress.

CFA should happen daily throughout the teaching-learning processes of the academic year. It is NOT graded, its purpose is to give continuous feedbacks to the learners. The tools identified for CFA are checklists and anecdotal records.

The suggested techniques for CFA for the three domains are:

1. *Work Scientifically*: Class work, observations, immediate interaction with the students, etc.

2. *Scientific Knowledge*: Question and answer, homework, class work, etc.

3. *Scientific Values and Attitudes*: Observations of students' conduct guided by scientific and social values.

Continuous Summative Assessment (CSA)

Continuous Summative Assessment is another form of continuous assessment. It helps in determining the learner's performance and the effectiveness of instructions. The feedback from this assessment helps students improve learning, and guides teachers to incorporate varied teaching strategies and resources to ensure quality teaching and learning in the science classes. It empowers learners to be self-reflective learners who monitor and evaluate their own progress.

In CSA, the learner's performances and achievement are graded. This ensures active participations of learners in the teaching-learning processes. The main tools for CSA are rubrics and paper pencil tests.

The suggested techniques for CSA for the three domains are:

1. *Work scientifically:* Project work, science journal and scrapbook, and practical works.

2. *Scientific knowledge:* Home work, and class tests.

3. *Scientific values and attitudes:* Observation of the learners' conduct in the classroom guided by scientific and social values.

Summative assessment (SA)

Summative assessment (SA) is conducted at the end of the first term and at the end of the year to determine the level of learning outcomes achieved by the learners. The information gathered is used by the teachers to grade learners for promotion and to report to parents and other stakeholders.

The identified techniques for SA are term examinations - first term and annual examinations. The questions for the term examinations should cover all the three domains of science learning objectives using the principles of Bloom's taxonomy.

Assessment Matrix

The assessment types, techniques and tools of assessment, frequency and weighting for each assessment type and domains are summarised in the assessment matrix, Table 3.

Table 3 Assessment Matrix for Classes XI and XII

Assessment Matrix								
Types of assessment	**CFA**			**CSA**			**SA**	
Definition	It is a continuous process of assessing student's problems and learning needs and to identify the remedial measures to improve student's learning. It also enables teachers to understand what teaching methods and materials work best.			It is a continuous process of grading student's performances and achievements. Teachers provide feedbacks for improvement. It also enables teachers to understand what teaching methods and materials work best.			Assesses student's cumulative performances and achievements at the end of each term.	
Domains	Scientific knowledge (SK)	Working scientifically (WS)	Scientific values and attitudes (SV)	Scientific knowledge (SK)	Working scientifically (WS)	Scientific values and attitudes (SV)	SK, WS & SV	SK, WS & SV
Techniques	Quiz & debate,class presentation, homework, class work, immediate interaction with students.	Immediate interaction with students, class work, home work, experiments, exhibition, case studies	Observation of student's conduct, in group work, field trip, excursion, etc.	Class Test	Practical work	Project Work.	Term exam.	Term exam
Assessment Tools	Q&A, checklist and anecdotal records.	Checklist and anecdotal records.	Checklist and anecdotal records.	Paper pencil test	Rubrics (Practical work)	Rubrics (Project work)	Paper pencil test	Paper pencil test
Frequency interval (when &how)	Checklists and anecdotal records must be maintained for each topic throughout the academic year.			Monthly	Twice in each term	Project Work – One PW for Cl 11 & 12 but the work is assessed in parts in each year.	Once in a term.	Once in a year.
Format in Progress Report				SK	WS	SV	Mid-Term	Annual Exam
				T1= 2.5 T2= 2.5	T1=15 T2= 15	T1= 2.5 T2= 2.5	T1=20	T2=40
NB:	Same mode of assessment will be followed in Mid Term and Trial examinations for Class 12. The mark for the Project Work of Class 12 is the sum total of Cl 11 and 12, which is out of 10 (5+5). The Cl 12 Practical Examination (20) is assessed externally.							

Print 2024

ANNEXURE E

Sample Question Paper

Chemistry Practical

Paper -2

(Three hours and quarter)

(The first 15 minutes of the examination are for reading the paper only)

Candidates will NOT be allowed to write or start working on the apparatus during this time).

ALL ANSWERS MUST BE WRITTEN IN THE QUESTION-ANSWER BOOKLET PROVIDED.

Read the questions carefully and follow the given instructions.

Marks are given for clear record of observations actually made and correct significant figures and units wherever applicable.

All workings, including rough work, should be done on the same sheet as, and adjacent to, the rest of the answer.

The intended marks for questions or parts of questions are given in brackets [ ].

Part I [10 Marks]

Question 1

Identify two cations form the given salt mixture by systematic qualitative analysis. Write the hypothesis, aim, short theory on the experiment. Write the procedure, observation and inference in tabular form. Support your confirmatory test with relevant chemical equation. [*Show one confirmatory test of each cation to the visiting examiner*]. [5]

Question 2

Using the leaf extract carry out the paper chromatography. Write the hypothesis, aim, variables and the theory on which paper chromatography is based. Calculate the R_f values from the chromatogram obtained. Attach the dried chromatogram with your answer booklet.

[5]

Part II [10 Marks]

Question 3

You are provided with copper sulphate solution of different known concentrations and another solution -A of copper sulphate with unknown concentration. Write the hypothesis and aim of the experiment. Carry out the experiment by following the given procedure. [5]

Chemical	Apparatus
i. Copper sulphate solutions :40 mL each (0.2M , 0.1M, 0.05M, 0.025M and 0.0125M) ii. Aluminium sulphate solution: 40 mL (1.0M) iii. Solution A	i. Digital multi-meter or digital voltmeter. ii. Beaker 100mL iii. Beaker 250 mL iv. Copper plate. v. Aluminium plate. vi. Connecting wire. vii. Salt bridge

Procedure:

i. Set up the electrochemical cell using the 40mL of 1.0M $Al_2(SO_4)_3$ solution and 40mL 0.2M $CuSO_4$ solutions in 100mL beaker and measure the cell potential.

ii. Repeat the steps from(i) for the other solutions of $CuSO_4$ in decreasing order of concentration 0.05M, 0.025M and 0.0125M.

iii. Measure the cell potential using solution **A** of unknown concentration with respect to $Al_2(SO_4)_3$ solution.

iv. Plot the graph taking concentration of copper sulphate on X- axis and cell potential on Y- axis.

v. From the graph obtained, determine the concentration of solution A provided to you.

Sl no.	$[Cu^{2+} (aq)]molL^{-1}$	$E_{cell} (V)$
1	0.2	
2	0.1	
3	0.05	
4	0.025	
5	Solution A	

Question 4

[5]

Carry out the following iodometric titration between **A-1** and **A-2**.

A-1 is a solution containing 15.0 g of impure sample of hydrated sodium thiosulphate ($Na_2S_2O_3.5H_2O$) (hypo) per litre of the solution and

A-2 is a solution of potassium dichromate ($K_2Cr_2O_7$) containing 2.8 gm per litre of the solution. The redox reaction between A-1 and A-2 is given below.

$$K_2Cr_2O_7 + 7H_2SO_4 + 6KI \rightarrow 4K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3I_2$$

$$6Na_2S_2O_3 + 3I_2 \rightarrow 3Na_2S_4O_6 + 6NaI$$

Write the aim, hypothesis and variables of your experiment.

Follow the procedures given below and solve the following numerical problems.

i. Rinse and fill the burette with the given solution **A-1**. Pipette out 20 mL or 25 mL of solution **A-2** in to a clean conical flask. To it add about 20 mL of **A-3** (dilute sulphuric acid) and about 20 mL of **A-4** (potassium iodide solution).

ii. To the content in the conical flask, add about 20 mL of distilled water followed by a pinch of sodium bicarbonate.

iii. Shake the contents of the flask by covering with a piece of paper. Allow the solution to stand for about 5 minutes till the solution becomes dark reddish brown.

iv. Titrate the solution by running down the solution of **A-1** from the burette till the solution turns yellowish green. To it add about 2-3 mL of freshly prepared starch solution till it turns dark blue.

v. Continue adding **A-1** drop wise till the addition of one drop of **A-1** changes the colour from dark blue to light green.

vi. Repeat the experiment to get two concordant readings.

Calculate the following:

i)   The molarity of the potassium dichromate solution A-2.

ii)   The molarity of sodium thiosulphate solution A-1.

iii)   The strength of A-1 sodium thiosulphate solution in gram per litre.

iv)   The percentage purity of impure sample of sodium thiosulphate.