La-Net

CHM108

GENERAL CHEMISTRY II

Course Code: CHM 108
Course Title: General Chemistry II
Course Unit: 1 Units

Series 1: Laboratory Safety and Rules
Series 2: Scientific Data Collection and Experimentation
Series 3: Glassware and Equipment Identification
Series 4: Organic Compound Testing and Analysis
Series 5: Functional Group and Quantitative Analysis

Series 1: Laboratory Safety and Rules

Series Outline

1.1 General Laboratory Rules

- 1.1.1 Importance of discipline in the laboratory
- 1.1.2 Personal conduct and responsibility
- 1.1.3 Handling of laboratory records

1.2 Safety Procedures and Equipment

- 1.2.1 Identification and use of safety equipment
- 1.2.2 Emergency procedures and first aid basics
- 1.2.3 Safe disposal of chemical waste

1.3 Personal Protective Measures

- 1.3.1 Proper use of protective clothing and gear
- 1.3.2 Hygiene practices in the laboratory
- 1.3.3 Preventing accidents and injuries

Introduction

Working in a chemistry laboratory can be both exciting and rewarding, yet it also presents certain risks if proper rules and safety measures are not followed. Accidents such as chemical spills, fires, or injuries often occur when basic precautions are ignored. Therefore, learning and practising laboratory safety is not only essential for protecting yourself and others, but it also ensures that experiments are conducted effectively and without unnecessary interruptions. This Series will prepare you to approach laboratory work with confidence and responsibility.
The aim of this Series is to equip you with the knowledge and skills required to follow general laboratory rules, apply safety procedures, and adopt personal protective measures that safeguard both individuals and the learning environment.
We shall commence this Series by examining the general rules that govern behaviour and discipline in the laboratory. Next, we will focus on safety procedures and the correct use of safety equipment, including emergency responses and waste disposal. Finally, we will wrap up by exploring personal protective measures such as clothing, hygiene practices, and accident

prevention strategies. Together, these Parts will provide a strong foundation for safe and effective laboratory practice.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **1.1** define the general rules that govern behaviour, discipline, and record keeping in the chemistry laboratory,
- **1.2** explain the importance of personal responsibility and conduct in maintaining a safe laboratory environment,
- **1.3** identify and demonstrate the correct use of safety equipment such as fire extinguishers, eye wash stations, and fume hoods,
- **1.4** outline emergency procedures and apply basic first aid responses to common laboratory incidents,
- **1.5** evaluate safe methods for handling and disposing of chemical waste to prevent hazards,
- **1.6** demonstrate appropriate personal protective measures including the use of clothing, hygiene practices, and accident prevention strategies.

1.1 General Laboratory Rules

1.1.1 Importance of discipline in the laboratory

Discipline in the laboratory is the foundation of safe and effective scientific practice. **Discipline** refers to the consistent adherence to established rules, procedures, and behaviours that ensure order and safety. Without discipline, experiments may be compromised, and hazards such as chemical spills or equipment damage may occur. Learners must cultivate habits of punctuality, attentiveness, and respect for instructions, as these qualities directly influence the success of laboratory work.

Fill in the blank: A lack of __________ in the laboratory often leads to accidents and poor experimental results.

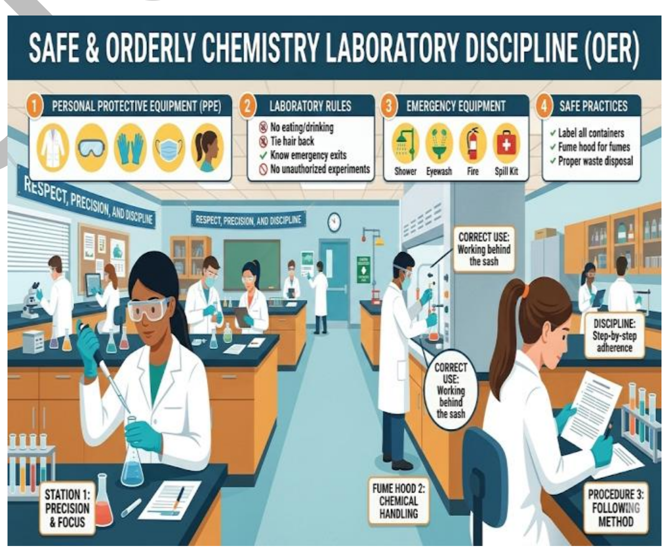


Figure 1.1 A disciplined laboratory environment.

1.1.2 Personal conduct and responsibility

Every learner has a duty to maintain proper **conduct**, which means behaving in a respectful, cautious, and responsible manner while in the laboratory. This includes avoiding horseplay, handling chemicals carefully, and respecting both peers and instructors. **Responsibility** is the obligation to take ownership of one's actions, ensuring that equipment is used correctly and that safety measures are followed. Responsible conduct reduces risks and fosters a collaborative learning environment.

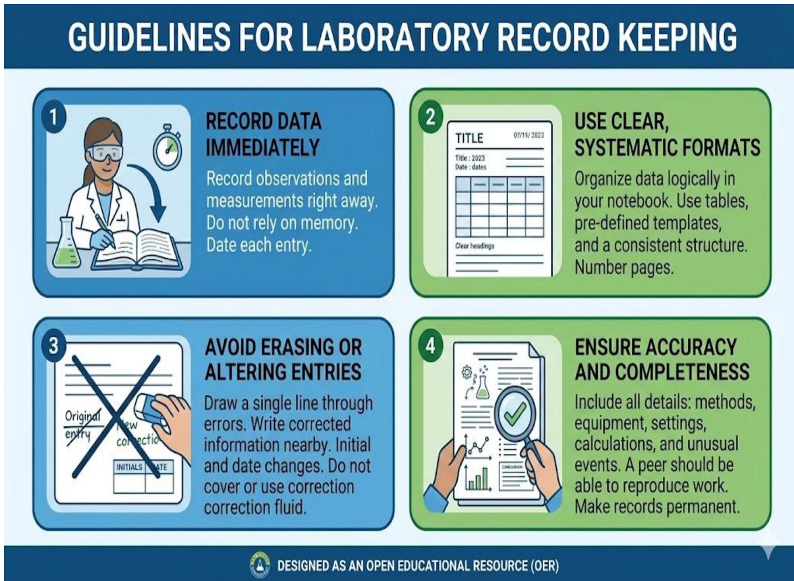
Fill in the blank: Proper laboratory __________ involves respect for peers, careful handling of chemicals, and adherence to safety measures.

Plate 1.1 Demonstrating responsible conduct in the laboratory.

1.1.3 Handling of laboratory records

Accurate and organised **laboratory records** are essential for documenting experiments, observations, and results. Laboratory records refer to written or digital notes that capture the details of procedures, data, and conclusions. They serve as evidence of work done and allow experiments to be repeated or verified. Learners must record data promptly, clearly, and systematically, avoiding alterations or omissions. Proper record keeping also supports academic integrity and scientific reliability.

Fill in the blank: Laboratory __________ provide evidence of experiments and ensure that results can be verified or repeated.



Box 1.1: Key guidelines for laboratory record keeping

Pilot questions 1.1

1. Which term refers to consistent adherence to rules and procedures in the laboratory?
2. What is the main benefit of maintaining discipline in laboratory work?
3. Define personal responsibility in the context of laboratory practice.
4. Why are laboratory records considered essential in scientific work?
5. List two key guidelines for effective laboratory record keeping.

1.2 Safety Procedures and Equipment

1.2.1 Identification and use of safety equipment

In every laboratory, **safety equipment** refers to specialised tools and installations designed to protect individuals from harm and to minimise risks during experiments. Examples include fire extinguishers, eye wash stations, safety showers, fume hoods, and first aid kits. Learners must be able to identify each item, know its location, and demonstrate its correct use. For instance, a fume hood is used to safely handle volatile chemicals by drawing harmful vapours away from the user.

Fill in the blank: A __________ hood is used to safely handle volatile chemicals by drawing harmful vapours away from the user.

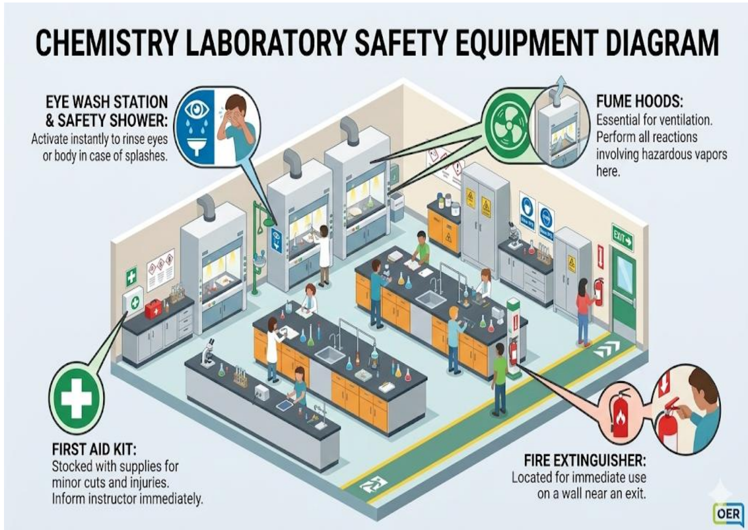


Figure 1.2 Common safety equipment in a chemistry laboratory.

1.2.2 Emergency procedures and first aid basics

Emergency procedures are predefined steps to follow when accidents occur in the laboratory. These include raising alarms, evacuating safely, and using first aid equipment. **First aid** refers to the immediate care given to an injured person before professional medical help arrives. For example, chemical burns should be rinsed with plenty of water, while cuts should be cleaned and covered with sterile bandages. Knowing these basics ensures quick and effective responses that reduce the severity of injuries.

Fill in the blank: Immediate care given to an injured person before medical help arrives is called __________.

Plate 1.2 Applying first aid in a laboratory emergency.

1.2.3 Safe disposal of chemical waste

Chemical waste refers to unwanted or leftover substances produced during laboratory experiments. Improper disposal of chemical waste can cause environmental pollution and health hazards. Safe disposal involves separating waste into categories such as organic solvents, acids, bases, and heavy metals, and then following approved disposal methods. For example, acids and bases may be neutralised before disposal, while organic solvents are collected in labelled containers for specialised treatment.

Fill in the blank: Improper disposal of __________ waste can cause environmental pollution and health hazards.

Box 1.2: Guidelines for safe chemical waste disposal

Pilot questions 1.2

1. Name two examples of safety equipment commonly found in a chemistry laboratory.
2. What is the purpose of a fume hood?
3. Define first aid in the context of laboratory emergencies.
4. Why is it important to separate chemical waste into categories before disposal?
5. List two guidelines for safe disposal of chemical waste.

1.3 Personal Protective Measures

1.3.1 Proper use of protective clothing and gear

Protective clothing refers to specialised garments such as laboratory coats, gloves, and goggles that shield the body from chemical splashes, burns, or contamination. Learners must always wear protective clothing before beginning any experiment, as it serves as the first line of defence against hazards. For example, goggles protect the eyes from harmful vapours or splashes, while gloves prevent direct contact with corrosive substances.

Fill in the blank: Laboratory __________ are worn to protect the body from chemical splashes and contamination.

Plate 1.3 Proper use of protective clothing in the laboratory.

1.3.2 Hygiene practices in the laboratory

Hygiene practices are behaviours that maintain cleanliness and prevent contamination in the laboratory. These include washing hands before and after experiments, avoiding eating or drinking in the laboratory, and keeping work surfaces clean. Good hygiene reduces the risk of chemical ingestion or cross-contamination of samples. Learners should also tie back long hair and avoid loose clothing that may catch fire or spill chemicals.

Fill in the blank: Good laboratory __________ reduces the risk of chemical ingestion and contamination of samples.

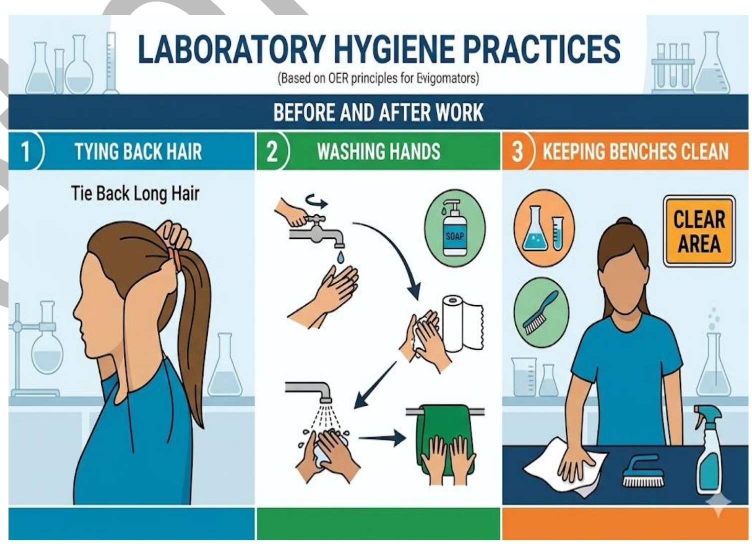


Figure 1.3 Hygiene practices in the laboratory.

1.3.3 Preventing accidents and injuries

Accident prevention refers to proactive measures taken to avoid harm in the laboratory. These include careful handling of glassware, avoiding cluttered workspaces, and following instructions precisely. Learners should never rush experiments, as haste often leads to spills or breakages. Injuries can also be prevented by storing sharp instruments properly and reporting unsafe conditions immediately. Accident prevention is not only about protecting oneself but also about safeguarding peers and the entire laboratory environment.

Fill in the blank: Proactive measures taken to avoid harm in the laboratory are called __________ prevention.

Box 1.3: Key strategies for preventing laboratory accidents

Pilot questions 1.3

1. What is the purpose of wearing protective clothing in the laboratory?
2. Give two examples of hygiene practices that reduce contamination risks.
3. Why should learners avoid rushing experiments?
4. Define accident prevention in the context of laboratory safety.
5. List three strategies for preventing laboratory accidents.

Series Summary

This Series has emphasised the importance of safety and discipline in the chemistry laboratory, highlighting how these practices form the foundation of effective scientific work. We began by exploring general laboratory rules, where discipline, personal conduct, and accurate record keeping were presented as essential habits. We then moved on to safety procedures and equipment, focusing on the identification and correct use of protective installations, emergency responses, and safe disposal of chemical waste. Finally, we examined personal protective measures, including the proper use of clothing and gear, hygiene practices, and strategies for preventing accidents and injuries.

By completing this Series, you should now be able to define laboratory rules and explain their relevance, demonstrate the correct use of safety equipment and emergency procedures, and apply personal protective measures to safeguard yourself and others. These skills directly align with the Series Learning Outcomes, ensuring that you are well prepared to conduct experiments responsibly and confidently in any laboratory setting.

Glossary of Terms

- **Accident prevention**: Proactive measures taken to avoid harm in the laboratory, such as careful handling of equipment, avoiding clutter, and reporting unsafe conditions.
- **Chemical waste**: Unwanted or leftover substances produced during laboratory experiments that must be disposed of safely to prevent hazards and pollution.
- **Conduct**: Behaviour in the laboratory that reflects respect, caution, and responsibility, ensuring a safe and collaborative environment.
- **Discipline**: Consistent adherence to laboratory rules and procedures, which ensures order, safety, and effective scientific practice.
- **Emergency procedures**: Predefined steps to follow when accidents occur, including raising alarms, evacuating safely, and applying first aid.
- **First aid**: Immediate care given to an injured person before professional medical help arrives, aimed at reducing the severity of injuries.
- **Hygiene practices**: Behaviours that maintain cleanliness and prevent contamination in the laboratory, such as hand washing, avoiding food and drink, and keeping work surfaces clean.
- **Laboratory records**: Written or digital notes that document experiments, observations, and results, serving as evidence of work and supporting repeatability.
- **Protective clothing**: Specialised garments such as laboratory coats, gloves, and goggles that shield the body from chemical splashes, burns, or contamination.
- **Safety equipment**: Tools and installations in the laboratory, such as fire extinguishers, fume hoods, and eye wash stations, designed to protect individuals from harm.

Concept Check Questions [Series 1: Laboratory Safety and Rules]

Objective questions

1. Which term refers to consistent adherence to laboratory rules and procedures? (Linked to SLO 1.1)
   a) Conduct
   b) Discipline
   c) Hygiene
   d) Responsibility
2. What is the immediate care given to an injured person before medical help arrives called? (Linked to SLO 1.4)
   a) Emergency procedure
   b) First aid
   c) Accident prevention
   d) Safety protocol

3. Which item of safety equipment is used to remove harmful vapours from the laboratory? (Linked to SLO 1.3)
   a) Fire extinguisher
   b) Eye wash station
   c) Fume hood
   d) First aid kit
4. Protective clothing such as coats, gloves, and goggles are worn to prevent what? (Linked to SLO 1.6)
   a) Contamination and chemical splashes
   b) Poor record keeping
   c) Noise pollution
   d) Data loss
5. Improper disposal of chemical waste can lead to which two major hazards? (Linked to SLO 1.5)
   a) Environmental pollution and health hazards
   b) Poor hygiene and record loss
   c) Fire outbreaks and noise pollution
   d) Lack of discipline and misconduct

Short-answer questions

1. Explain why accurate laboratory records are essential for scientific reliability. (Linked to SLO 1.1)
2. Outline two examples of responsible conduct in the laboratory. (Linked to SLO 1.2)
3. Describe one emergency procedure that should be followed in case of a chemical spill. (Linked to SLO 1.4)
4. List three hygiene practices that reduce contamination risks in the laboratory. (Linked to SLO 1.6)

Long-answer questions

1. Analyse the importance of discipline and personal responsibility in maintaining a safe and effective laboratory environment. (Linked to SLO 1.1 and SLO 1.2)
2. Evaluate the role of safety equipment and chemical waste disposal in preventing accidents and protecting the environment. (Linked to SLO 1.3 and SLO 1.5)
3. Design a personal safety checklist that includes protective clothing, hygiene practices, and accident prevention strategies for use during laboratory sessions. (Linked to SLO 1.6)

Answers to Concept Check Questions [Series 1: Laboratory Safety and Rules]

Objective questions

1. b) Discipline
2. b) First aid
3. c) Fume hood
4. a) Contamination and chemical splashes
5. a) Environmental pollution and health hazards

Short-answer questions

1. Laboratory records provide evidence of experiments, ensure repeatability, and support scientific reliability.
2. Examples include handling chemicals carefully and respecting peers and instructors.
3. Raise the alarm, evacuate if necessary, and use appropriate neutralising agents or absorbents.
4. Wash hands, avoid eating or drinking, and keep work surfaces clean.

Long-answer questions

1. **Basic response:** Discipline ensures order and safety, while personal responsibility prevents careless behaviour and accidents. Together, they create a safe and effective environment for learning and experimentation.
   Value-added response: Beyond safety, discipline and responsibility foster teamwork, respect, and scientific integrity. They also prepare learners for professional laboratory settings where accountability and precision are critical.
2. **Basic response:** Safety equipment protects individuals from harm, while proper chemical waste disposal prevents hazards and pollution. Both are essential for accident prevention.
   Value-added response: In addition to immediate safety, these practices contribute to sustainable science. Proper waste management protects ecosystems, while equipment use reflects compliance with international laboratory standards.
3. **Basic response:** A checklist should include wearing coats, gloves, and goggles, practising hygiene such as hand washing, and preventing accidents by keeping workspaces uncluttered.
   Value-added response: An advanced checklist may also include monitoring equipment functionality, reporting unsafe conditions, and integrating institutional safety policies. This ensures comprehensive protection for both individuals and the environment.

Answers to Pilot Questions [Series 1: Laboratory Safety and Rules]

Pilot questions 1.1 (General Laboratory Rules)

1. Discipline
2. It ensures order and safety in laboratory work.
3. Personal responsibility means taking ownership of one's actions and ensuring equipment and safety measures are used correctly.
4. Laboratory records provide evidence of experiments and support repeatability.
5. Record data immediately, use clear formats, avoid alterations, and ensure accuracy.

Pilot questions 1.2 (Safety Procedures and Equipment)

1. Fire extinguisher and eye wash station (other examples include fume hood and first aid kit).
2. To remove harmful vapours from the laboratory.
3. First aid is immediate care given to an injured person before medical help arrives.
4. To prevent hazards and pollution.
5. Separate waste into categories, use labelled containers, neutralise acids and bases, and follow regulations.

Pilot questions 1.3 (Personal Protective Measures)

1. To protect the body from chemical splashes, burns, or contamination.
2. Washing hands and keeping work surfaces clean (other examples include tying back hair and avoiding food or drink).
3. Because rushing increases the risk of spills, breakages, and accidents.
4. Accident prevention refers to proactive measures taken to avoid harm in the laboratory.
5. Handle glassware carefully, avoid cluttered workspaces, store sharp instruments properly, and report unsafe conditions.

References and Attributions [Series 1: Laboratory Safety and Rules]

General references

- Open Educational Resources (OER Commons). (n.d.). *Chemistry laboratory safety guidelines*. Retrieved from https://www.oercommons.org
- Royal Society of Chemistry. (n.d.). *Laboratory safety and best practices*. Retrieved from https://www.rsc.org

Illustrations

- *Figure 1.1 A disciplined laboratory environment*
  Suggested AI prompt: "Illustration of a chemistry laboratory with students working safely and orderly, wearing protective gear."
  Search string: "chemistry laboratory discipline OER image"
- *Plate 1.1 Demonstrating responsible conduct in the laboratory*
  Suggested AI prompt: "Photo-style image of a student measuring chemicals responsibly in a chemistry lab."
  Search string: "responsible conduct chemistry laboratory OER photo"
- *Box 1.1 Key guidelines for laboratory record keeping*
  Suggested AI prompt: "Create a simple box-style infographic listing guidelines for laboratory record keeping."
  Search string: "laboratory record keeping guidelines OER infographic"
- *Figure 1.2 Common safety equipment in a chemistry laboratory*
  Suggested AI prompt: "Diagram of a chemistry laboratory highlighting fire extinguisher,

eye wash station, fume hood, and first aid kit."
Search string: "chemistry laboratory safety equipment diagram OER"

- *Plate 1.2 Applying first aid in a laboratory emergency*
  Suggested AI prompt: "Photo-style image of students applying first aid in a chemistry laboratory after a minor accident."
  Search string: "laboratory first aid OER photo"
- *Box 1.2 Guidelines for safe chemical waste disposal*
  Suggested AI prompt: "Create a simple infographic box listing guidelines for safe chemical waste disposal in laboratories."
  Search string: "safe chemical waste disposal guidelines OER infographic"
- *Plate 1.3 Proper use of protective clothing in the laboratory*
  Suggested AI prompt: "Photo-style image of chemistry students wearing lab coats, gloves, and goggles while conducting experiments."
  Search string: "chemistry laboratory protective clothing OER photo"
- *Figure 1.3 Hygiene practices in the laboratory*
  Suggested AI prompt: "Diagram of students washing hands, keeping benches clean, and tying back hair in a chemistry laboratory."
  Search string: "laboratory hygiene practices OER diagram"
- *Box 1.3 Key strategies for preventing laboratory accidents*
  Suggested AI prompt: "Create a simple infographic box listing strategies for preventing laboratory accidents."
  Search string: "preventing laboratory accidents OER infographic"

Course Code: CHM 108
Course Title: General Chemistry II
Course Unit: 1 Units

Series 1: Laboratory Safety and Rules
Series 2: Scientific Data Collection and Experimentation
Series 3: Glassware and Equipment Identification
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Series 2: Scientific Data Collection and Experimentation

Series outline

2.1 Principles of Scientific Data Collection

- 2.1.1 Types of scientific data (qualitative and quantitative)
- 2.1.2 Accuracy, precision, and reliability in data collection

- 2.1.3 Common sources of error in data collection

2.2 Experimental Design and Procedures

- 2.2.1 Steps in planning an experiment
- 2.2.2 Variables: independent, dependent, and controlled
- 2.2.3 Replication and validity of experiments

2.3 Recording and Presenting Experimental Data

- 2.3.1 Laboratory notebooks and digital records
- 2.3.2 Data organisation using tables and charts
- 2.3.3 Ethical considerations in data reporting

Introduction

In the last Series, we explored laboratory safety and rules, which gave you the foundation for working responsibly in a chemistry laboratory. With that groundwork in place, we now turn to the next essential skill: collecting scientific data and conducting experiments. Reliable data and well-structured experiments are the backbone of chemistry, as they allow scientists to draw valid conclusions and build knowledge that can be trusted and reproduced.

The aim of this Series is to help you develop the ability to collect accurate data, design sound experiments, and record and present findings in a clear and ethical manner. These skills are central to becoming a competent and confident laboratory practitioner.

We shall commence this Series by examining the principles of scientific data collection, focusing on types of data, accuracy, precision, and common sources of error. Next, we will move on to experimental design and procedures, where we will consider planning steps, the role of variables, and the importance of replication. Finally, we will wrap up by looking at how to record and present experimental data, using laboratory notebooks, tables, and charts, while also reflecting on ethical considerations in reporting. This progression will prepare you to carry out experiments with both technical skill and scientific integrity.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **2.1** define the different types of scientific data, distinguishing between qualitative and quantitative forms.
- **2.2** explain the concepts of accuracy, precision, and reliability in data collection.
- **2.3** identify common sources of error in scientific data collection and suggest ways to minimise them.
- **2.4** describe the key steps involved in planning an experiment.
- **2.5** classify variables as independent, dependent, or controlled within an experimental design.
- **2.6** analyse the importance of replication in ensuring the validity of experimental results.

- **2.7** demonstrate how to record experimental data systematically using laboratory notebooks or digital records.
- **2.8** organise data effectively using tables and charts for clear presentation.
- **2.9** evaluate ethical considerations in reporting and presenting scientific data.

2.1 Principles of Scientific Data Collection

2.1.1 Types of scientific data

Scientific data can be broadly classified into **qualitative data** and **quantitative data**. **Qualitative data** refers to descriptive information that captures characteristics or qualities, such as colour changes, odours, or physical appearances during an experiment. **Quantitative data** refers to numerical information obtained through measurement, such as temperature readings, mass, or volume. Both types of data are important, as qualitative observations often provide context while quantitative measurements allow for precise analysis.
Fill in the blank: Observations such as colour changes or odours are examples of __________ data.

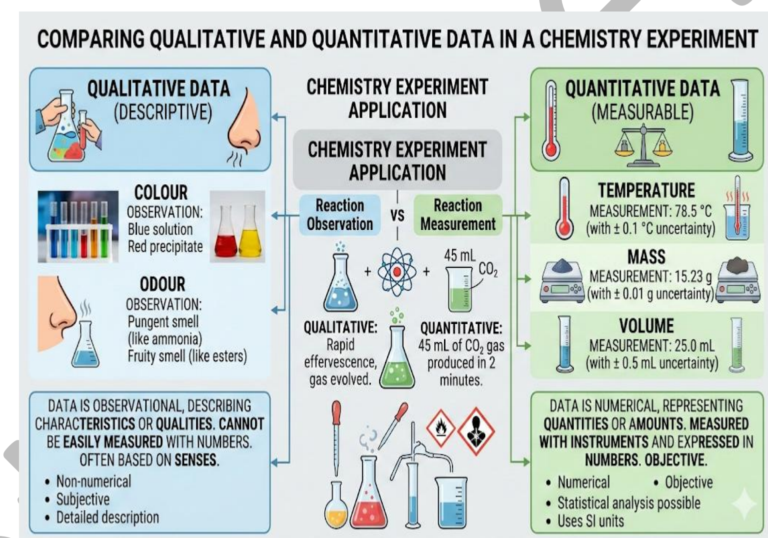


Figure 2.1 Types of scientific data.

2.1.2 Accuracy, precision, and reliability in data collection

Accuracy refers to how close a measurement is to the true or accepted value. **Precision** refers to how consistent repeated measurements are, even if they are not close to the true value. **Reliability** refers to the overall trustworthiness of data, which depends on both accuracy and precision. For example, if a thermometer consistently reads 25.0 °C when the actual temperature is 25.1 °C, the measurement is both accurate and precise.
Fill in the blank: The closeness of a measurement to the true value is called __________.

Concept	Definition	Key Characteristic
Accuracy	The degree to which a measurement matches the true or accepted value.	High accuracy means low systematic error (hitting the bullseye).
Precision	The degree of agreement between repeated measurements under the same conditions.	High precision means low random error (tight grouping of results).
Reliability	The overall consistency and stability of a data set over time and across different trials.	High reliability means results are reproducible and trustworthy.

Box 2.1: Distinguishing accuracy, precision, and reliability

2.1.3 Common sources of error in data collection

Errors in data collection can arise from several sources. **Systematic errors** are consistent biases caused by faulty equipment or flawed procedures, while **random errors** occur unpredictably due to factors such as human reaction time or environmental fluctuations. Minimising errors requires careful calibration of instruments, adherence to procedures, and awareness of potential sources of variation.

Fill in the blank: Errors caused by faulty equipment or flawed procedures are known as __________ errors.

Plate 2.1 Calibrating equipment to reduce systematic errors.

Pilot questions 2.1

1. Define qualitative data and give one example.
2. Define quantitative data and give one example.
3. What is the difference between accuracy and precision?
4. How is reliability in data collection achieved?
5. Identify two common sources of error in scientific data collection.

2.2 Experimental Design and Procedures

2.2.1 Steps in planning an experiment

Planning an experiment begins with identifying a clear **research question**, which is the specific problem or inquiry the experiment seeks to address. From there, learners must develop a **hypothesis**, defined as a testable statement predicting the outcome of the experiment. The next steps include selecting appropriate materials, designing procedures, and determining how data will be collected. A well-planned experiment ensures that results are meaningful and can be replicated by others.

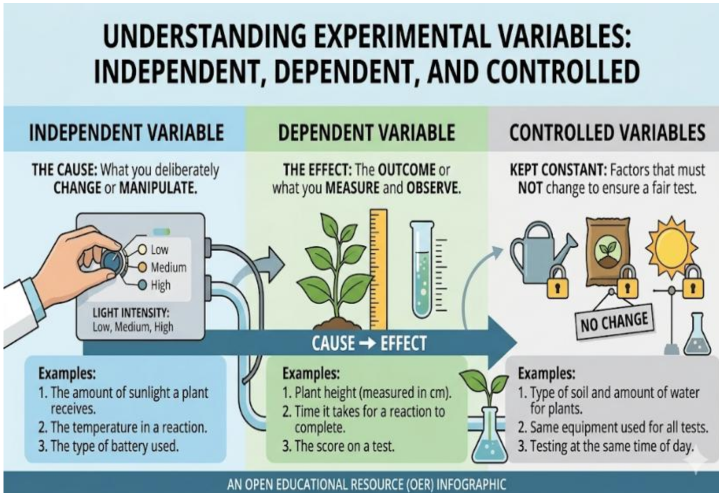
Fill in the blank: A testable statement predicting the outcome of an experiment is called a __________.

Figure 2.2 Steps in planning an experiment.

2.2.2 Variables: independent, dependent, and controlled

Variables are factors that can change in an experiment. An **independent variable** is the factor deliberately changed by the experimenter, while a **dependent variable** is the factor measured to observe the effect of the change. **Controlled variables** are factors kept constant to ensure that only the independent variable influences the outcome. For example, in testing the effect of temperature on reaction rate, temperature is the independent variable, reaction rate is the dependent variable, and factors such as concentration and pressure are controlled.

Fill in the blank: The factor measured to observe the effect of change in an experiment is the __________ variable.



Box 2.2: Types of variables in experiments

2.2.3 Replication and validity of experiments

Replication refers to repeating an experiment under the same conditions to confirm that results are consistent. **Validity** refers to the extent to which an experiment accurately measures what it is intended to measure. Replication strengthens validity by reducing the influence of random errors and increasing confidence in the findings. For instance, repeating a titration several times ensures that the measured concentration is reliable and not due to chance.

Fill in the blank: Repeating an experiment under the same conditions to confirm consistency is called __________.

Plate 2.2 Replicating experiments to strengthen validity.

Pilot questions 2.2

2.3 Recording and Presenting Experimental Data

2.3.1 Laboratory notebooks and digital records

A **laboratory notebook** is a bound record where learners document experiments, observations, and results in a systematic manner. It serves as a permanent record of scientific work and supports repeatability. **Digital records** are electronic formats such as spreadsheets or databases used to store and organise data. Both methods require clarity, accuracy, and timeliness. Entries should be made immediately after observations to avoid errors or omissions.

Fill in the blank: A bound record where experiments and observations are documented systematically is called a laboratory __________.

Plate 2.3 Recording data in a laboratory notebook.

2.3.2 Data organisation using tables and charts

Data organisation refers to arranging information in a clear and structured format for easy interpretation. Tables allow for systematic presentation of numerical values, while charts such as bar graphs or line graphs provide visual representation of trends and relationships. Choosing the right format depends on the type of data and the purpose of analysis. For example, a line graph is suitable for showing changes over time, while a bar chart is useful for comparing categories.

Fill in the blank: A __________ graph is most suitable for showing changes in data over time.

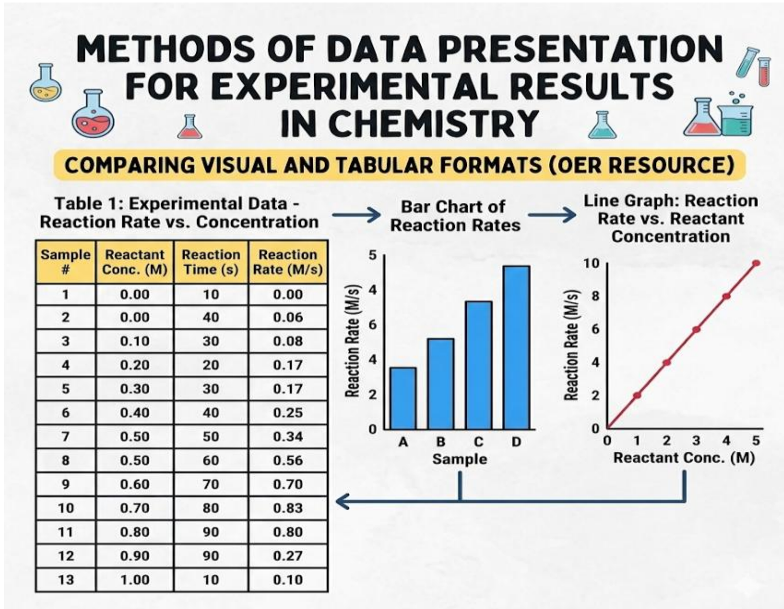
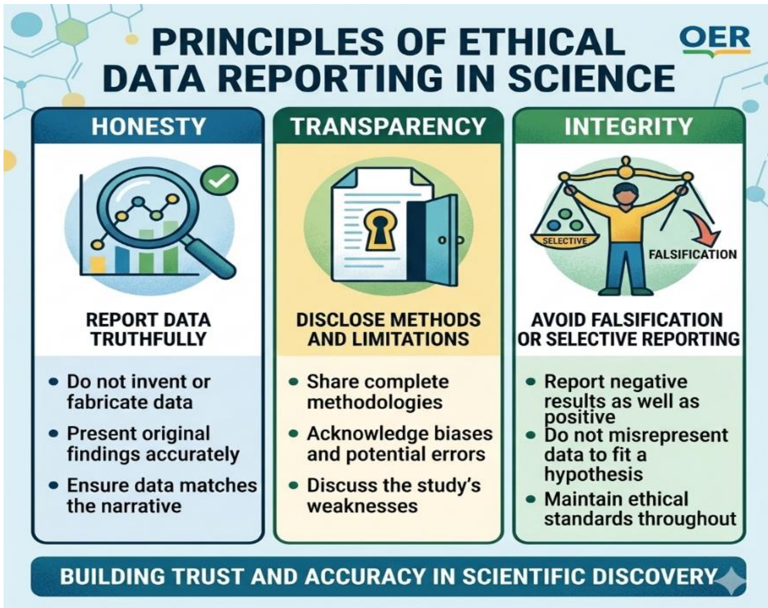


Figure 2.3 Organising data using tables and charts.

2.3.3 Ethical considerations in data reporting

Ethical considerations in data reporting refer to the principles of honesty, transparency, and integrity when presenting scientific findings. Learners must avoid falsifying, fabricating, or selectively reporting data, as such practices undermine scientific credibility. Ethical reporting also involves acknowledging errors and limitations, ensuring that conclusions are supported by evidence. By adhering to these principles, learners contribute to trustworthy science and uphold professional standards.

Fill in the blank: Altering or fabricating data in scientific reporting undermines __________ credibility.



Box 2.3: Principles of ethical data reporting

Pilot questions 2.3

1. What is the purpose of a laboratory notebook?
2. Give one advantage of using digital records for data storage.
3. Which type of graph is best for showing changes over time?
4. Why is it important to follow ethical principles in data reporting?
5. List two principles of ethical data reporting.

Series Summary

This Series has highlighted the importance of collecting and handling scientific data with care, showing how reliable experimentation depends on accuracy, precision, and integrity. We began by examining the principles of scientific data collection, where you learned to distinguish between qualitative and quantitative data, and to recognise the role of accuracy, precision, and reliability while also identifying common sources of error. We then moved on to experimental design and procedures, focusing on the planning of experiments, the classification of variables, and the significance of replication in ensuring validity. Finally, we explored how to record and present experimental data, emphasising the use of laboratory notebooks, digital records, tables, charts, and ethical reporting practices.

By completing this Series, you should now be able to define different types of data, explain accuracy and precision, identify sources of error, describe steps in experiment planning, classify variables, analyse the importance of replication, demonstrate systematic data recording, organise data effectively, and evaluate ethical considerations in reporting. These abilities directly align with the Series Learning Outcomes and provide you with the essential skills to conduct experiments confidently and present findings responsibly.

Glossary of Terms

- **Accuracy**: The closeness of a measurement to the true or accepted value.
- **Controlled variable**: A factor kept constant in an experiment to ensure that only the independent variable affects the outcome.
- **Dependent variable**: The factor measured in an experiment to observe the effect of changes made to the independent variable.
- **Digital records**: Electronic formats such as spreadsheets or databases used to store and organise experimental data.
- **Ethical considerations**: Principles of honesty, transparency, and integrity that guide the reporting and presentation of scientific data.
- **Hypothesis**: A testable statement predicting the outcome of an experiment.
- **Independent variable**: The factor deliberately changed by the experimenter to study its effect.
- **Laboratory notebook**: A bound record where experiments, observations, and results are documented systematically.
- **Precision**: The consistency of repeated measurements, even if they are not close to the true value.
- **Qualitative data**: Descriptive information that captures characteristics or qualities, such as colour, odour, or texture.
- **Quantitative data**: Numerical information obtained through measurement, such as mass, volume, or temperature.
- **Random error**: An unpredictable variation in measurements caused by factors such as human reaction time or environmental changes.
- **Reliability**: The overall trustworthiness of data, based on both accuracy and precision.
- **Replication**: Repeating an experiment under the same conditions to confirm consistency of results.
- **Research question**: The specific problem or inquiry that an experiment seeks to address.
- **Systematic error**: A consistent bias in measurements caused by faulty equipment or flawed procedures.
- **Validity**: The extent to which an experiment accurately measures what it is intended to measure.

Concept Check Questions [Series 2: Scientific Data Collection and Experimentation]

Objective questions

1. Which type of data refers to descriptive information such as colour or odour? (Linked to SLO 2.1)
   a) Quantitative data
   b) Qualitative data
   c) Controlled variable
   d) Digital record
2. The closeness of a measurement to the true value is called: (Linked to SLO 2.2)
   a) Precision

b) Accuracy
c) Reliability
d) Validity

3. Which variable is deliberately changed by the experimenter? (Linked to SLO 2.5)
   a) Dependent variable
   b) Controlled variable
   c) Independent variable
   d) Random variable
4. Repeating an experiment under the same conditions to confirm consistency is known as: (Linked to SLO 2.6)
   a) Reliability
   b) Replication
   c) Validity
   d) Accuracy
5. Which principle of ethical data reporting requires disclosing methods and limitations? (Linked to SLO 2.9)
   a) Honesty
   b) Transparency
   c) Integrity
   d) Reliability

Short-answer questions

1. Define quantitative data and give one example. (Linked to SLO 2.1)
2. Explain the difference between accuracy and precision. (Linked to SLO 2.2)
3. Identify one source of systematic error in data collection. (Linked to SLO 2.3)
4. State the purpose of a hypothesis in an experiment. (Linked to SLO 2.4)
5. List two advantages of using laboratory notebooks for recording data. (Linked to SLO 2.7)

Long-answer questions

1. Analyse the importance of classifying variables correctly in experimental design. (Linked to SLO 2.5)
2. Evaluate the role of replication in strengthening the validity of experimental results. (Linked to SLO 2.6)
3. Design a simple data presentation plan that includes tables, charts, and ethical reporting principles. (Linked to SLO 2.8 and SLO 2.9)

Answers to Concept Check Questions [Series 2: Scientific Data Collection and Experimentation]

Objective questions

1. b) Qualitative data
2. b) Accuracy
3. c) Independent variable
4. b) Replication
5. b) Transparency

Short-answer questions

1. Quantitative data refers to numerical information obtained through measurement. Example: recording the mass of a substance in grams.
2. Accuracy is closeness to the true value, while precision is consistency of repeated measurements.
3. A faulty thermometer consistently reading too high is a source of systematic error.
4. A hypothesis provides a testable prediction of the experiment's outcome.
5. Laboratory notebooks provide a permanent record and support repeatability of experiments.

Long-answer questions

1. **Basic response:** Classifying variables ensures clarity in experimental design by distinguishing what is changed, what is measured, and what is controlled.
   Value-added response: Correct classification prevents misinterpretation of results, supports reproducibility, and aligns with international standards of scientific practice.
2. **Basic response:** Replication confirms that results are consistent and not due to chance, thereby strengthening validity.
   Value-added response: Replication also allows comparison across different conditions, reduces random errors, and builds confidence in findings for wider scientific acceptance.
3. **Basic response:** A simple plan should include recording data in tables, presenting trends in charts, and reporting findings honestly.
   Value-added response: An advanced plan integrates digital records, uses appropriate chart types for different data sets, and explicitly acknowledges limitations, ensuring ethical and professional reporting.

Answers to Pilot Questions [Series 2: Scientific Data Collection and Experimentation]

Pilot questions 2.1 (Principles of Scientific Data Collection)

1. Qualitative data; example: colour change during a reaction.
2. Quantitative data; example: measuring mass in grams.

3. Accuracy is closeness to the true value, while precision is consistency of repeated measurements.
4. Reliability is achieved through both accuracy and precision.
5. Systematic errors and random errors.

Pilot questions 2.2 (Experimental Design and Procedures)

1. A hypothesis provides a testable prediction of the experiment's outcome.
2. Independent variable: deliberately changed (e.g., temperature). Dependent variable: measured outcome (e.g., reaction rate). Controlled variables: kept constant (e.g., concentration).
3. Replication ensures results are consistent and not due to chance.
4. Validity refers to measuring what the experiment intends to measure, while reliability refers to the trustworthiness of the data.
5. Research question, hypothesis, materials, procedure, and data collection.

Pilot questions 2.3 (Recording and Presenting Experimental Data)

1. A laboratory notebook provides a permanent and systematic record of experiments.
2. Digital records allow easy organisation, storage, and sharing of data.
3. A line graph is best for showing changes over time.
4. Ethical principles ensure credibility and trustworthiness of scientific findings.
5. Honesty and transparency.

References and Attributions [Series 2: Scientific Data Collection and Experimentation]

General references

- Open Educational Resources (OER Commons). (n.d.). *Scientific methods and data collection*. Retrieved from https://www.oercommons.org
- Royal Society of Chemistry. (n.d.). *Experimental design and laboratory practice*. Retrieved from https://www.rsc.org
- UNESCO. (n.d.). *Ethics in science and technology*. Retrieved from https://unesdoc.unesco.org

Illustrations

- *Figure 2.1 Types of scientific data*
  Suggested AI prompt: "Diagram comparing qualitative data (colour, odour) and quantitative data (temperature, mass, volume) in a chemistry experiment."
  Search string: "qualitative vs quantitative data chemistry OER diagram"
- *Box 2.1 Distinguishing accuracy, precision, and reliability*
  Suggested AI prompt: "Infographic box explaining accuracy, precision, and reliability in scientific data collection."
  Search string: "accuracy precision reliability science OER infographic"

- *Plate 2.1 Calibrating equipment to reduce systematic errors*
  Suggested AI prompt: “Photo-style image of a student calibrating a balance or thermometer in a chemistry laboratory.”
  Search string: “calibrating laboratory equipment OER photo”
- *Figure 2.2 Steps in planning an experiment*
  Suggested AI prompt: “Flowchart diagram of experiment planning steps: research question, hypothesis, materials, procedure, data collection.”
  Search string: “experiment planning steps OER diagram”
- *Box 2.2 Types of variables in experiments*
  Suggested AI prompt: “Infographic box explaining independent, dependent, and controlled variables with examples.”
  Search string: “independent dependent controlled variables OER infographic”
- *Plate 2.2 Replicating experiments to strengthen validity*
  Suggested AI prompt: “Photo-style image of students repeating a titration experiment in a chemistry laboratory.”
  Search string: “replication validity experiment chemistry OER photo”
- *Plate 2.3 Recording data in a laboratory notebook*
  Suggested AI prompt: “Photo-style image of a student documenting observations in a laboratory notebook during an experiment.”
  Search string: “laboratory notebook chemistry OER photo”
- *Figure 2.3 Organising data using tables and charts*
  Suggested AI prompt: “Diagram showing a table of experimental results alongside a bar chart and line graph.”
  Search string: “tables and charts data presentation chemistry OER diagram”
- *Box 2.3 Principles of ethical data reporting*
  Suggested AI prompt: “Infographic box listing principles of ethical data reporting in science.”
  Search string: “ethical data reporting science OER infographic”

Course Code: CHM 108
Course Title: General Chemistry II
Course Unit: 1 Units

Series 1: Laboratory Safety and Rules
Series 2: Scientific Data Collection and Experimentation
Series 3: Glassware and Equipment Identification
Series 4: Organic Compound Testing and Analysis
Series 5: Functional Group and Quantitative Analysis

Series 3: Glassware and Equipment Identification

Series Outline

3.1 Common laboratory glassware

- 3.1.1 Beakers and flasks
- 3.1.2 Pipettes and burettes
- 3.1.3 Test tubes and measuring cylinders

3.2 Essential laboratory equipment

- 3.2.1 Balances and weighing devices
- 3.2.2 Heating equipment (Bunsen burner, hot plate)
- 3.2.3 Safety equipment (fume hood, fire extinguisher, eye wash station)

3.3 Proper use and maintenance

- 3.3.1 Handling and cleaning of glassware
- 3.3.2 Calibration and care of equipment
- 3.3.3 Storage and safety precautions

Introduction

In every chemistry laboratory, the ability to recognise and correctly use glassware and equipment is fundamental to safe and effective practice. Misidentifying a piece of apparatus or using it incorrectly can lead to inaccurate results or even accidents. This Series will therefore guide you through the essential tools of the laboratory, helping you to build confidence in identifying, handling, and maintaining them.

The aim of this Series is to familiarise you with common laboratory glassware and equipment, and to equip you with the skills needed to use, care for, and store them properly. By the end, you will be able to identify key items, explain their functions, and apply safe handling practices.

We shall commence this Series by exploring common laboratory glassware, including beakers, flasks, pipettes, burettes, test tubes, and measuring cylinders. Next, we will move on to essential laboratory equipment such as balances, heating devices, and safety tools. Finally, we will wrap up by considering the proper use and maintenance of both glassware and equipment, focusing on cleaning, calibration, storage, and safety precautions. This progression will ensure you are well prepared to work confidently and responsibly in the laboratory.

Series Learning Outcomes
Upon completing this Series, you should be able to:

- **3.1** identify common laboratory glassware such as beakers, flasks, pipettes, burettes, test tubes, and measuring cylinders.
- **3.2** explain the specific functions of different types of laboratory glassware.
- **3.3** recognise essential laboratory equipment including balances, heating devices, and safety tools.
- **3.4** describe the proper use of balances, heating equipment, and safety apparatus in laboratory practice.
- **3.5** demonstrate correct handling and cleaning techniques for laboratory glassware.
- **3.6** apply appropriate calibration and care procedures for laboratory equipment.
- **3.7** evaluate safe storage and precautionary measures for both glassware and equipment.

3.1 Common Laboratory Glassware

3.1.1 Beakers and flasks

Beakers are cylindrical containers with a flat bottom, used for mixing, heating, and roughly measuring liquids. They usually have graduations but are not highly accurate for precise measurements. **Flasks** are glass containers with narrow necks, such as Erlenmeyer flasks or volumetric flasks. Erlenmeyer flasks are useful for mixing solutions without spillage, while volumetric flasks are designed for preparing solutions of exact volumes.
Fill in the blank: A flask designed for preparing solutions of exact volumes is called a __________ flask.

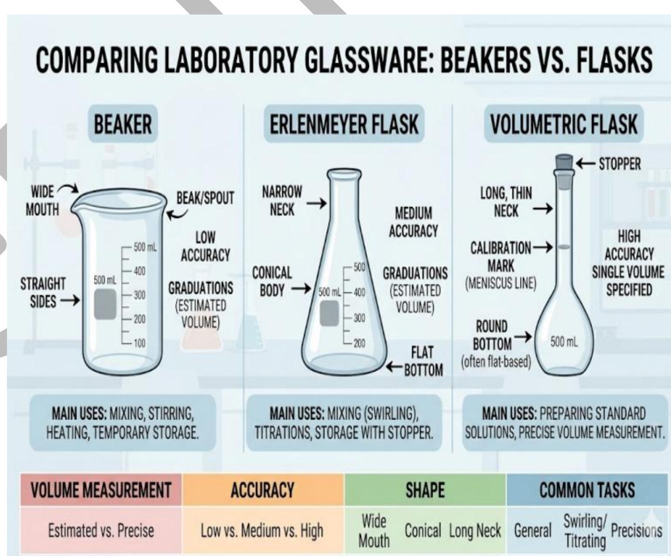


Figure 3.1 Common beakers and flasks.

3.1.2 Pipettes and burettes

Pipettes are slender glass tubes used to transfer or measure small volumes of liquid accurately. Volumetric pipettes deliver a single, fixed volume, while graduated pipettes allow measurement of varying volumes. **Burettes** are long, graduated glass tubes with a tap at the bottom, used to deliver precise volumes of liquid during titrations. They are essential for experiments requiring controlled addition of reagents.

Fill in the blank: A long graduated glass tube with a tap at the bottom, used in titrations, is called a __________.

Plate 3.1 Using a burette in titration.

3.1.3 Test tubes and measuring cylinders

Test tubes are small cylindrical glass containers used for holding, mixing, or heating small amounts of substances. They are commonly used for qualitative observations such as colour changes or precipitate formation. **Measuring cylinders** are tall, graduated glassware designed for measuring liquid volumes more accurately than beakers, though less precise than volumetric flasks.

Fill in the blank: A tall graduated glassware used for measuring liquid volumes more accurately than beakers is called a __________ cylinder.

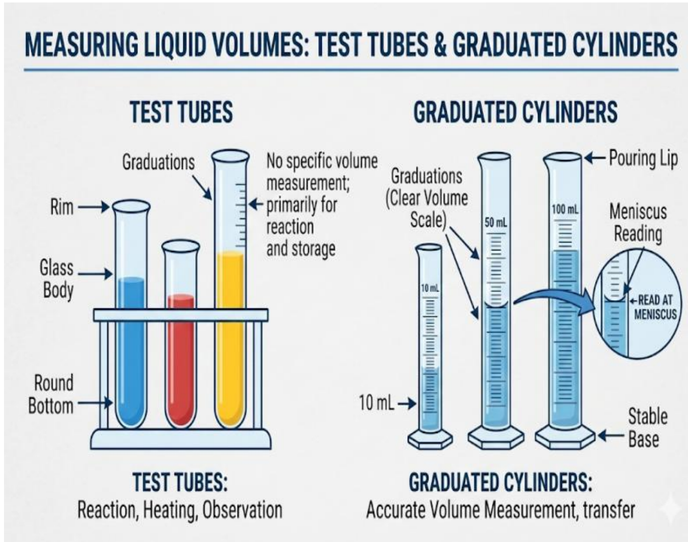


Figure 3.2 Test tubes and measuring cylinders.

Pilot questions 3.1

1. What is the main difference between a beaker and a volumetric flask?
2. Name two types of pipettes and state their uses.
3. What is the function of a burette in titration?
4. Give one use of a test tube in laboratory practice.
5. Why are measuring cylinders more accurate than beakers for measuring liquid volumes?

3.2 Essential Laboratory Equipment

3.2.1 Balances and weighing devices

Balances are instruments used to measure the mass of substances. Analytical balances provide highly accurate measurements, often to four decimal places, while top-loading balances are less precise but suitable for routine laboratory work. Proper use requires calibration and ensuring the balance is placed on a stable, vibration-free surface.
Fill in the blank: An instrument that measures mass to four decimal places is called an __________ balance.

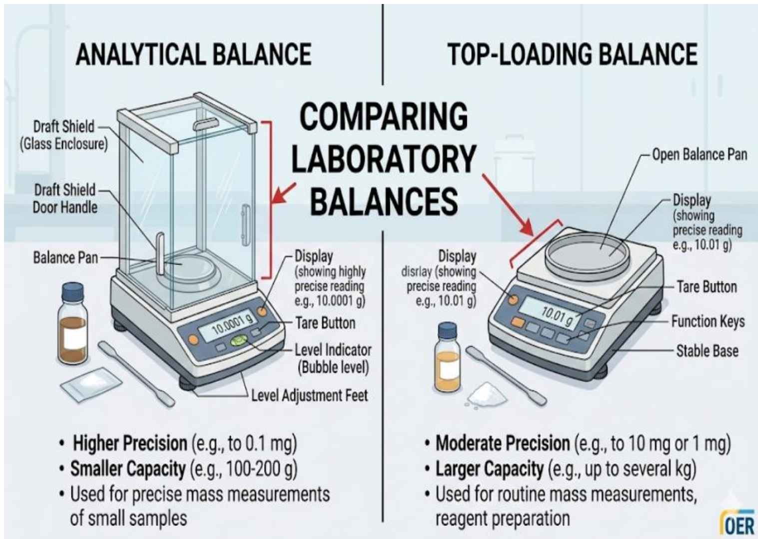


Figure 3.3 Analytical and top-loading balances.

3.2.2 Heating equipment (Bunsen burner, hot plate)

Heating equipment provides controlled heat for experiments. A **Bunsen burner** is a gas-fuelled device that produces a flame, commonly used for heating, sterilisation, and combustion. A **hot plate** is an electrically powered device that provides uniform heating without an open flame, making it safer for certain applications. Choosing between them depends on the experiment's requirements and safety considerations.

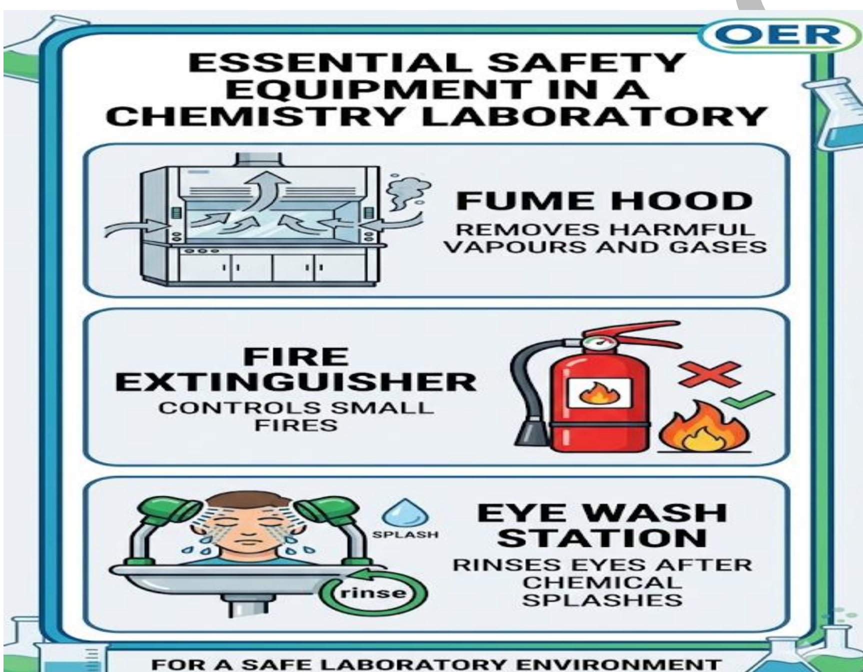
Fill in the blank: A gas-fuelled device that produces a flame for heating substances is called a __________ burner.

Plate 3.2 Heating substances with a Bunsen burner.

3.2.3 Safety equipment (fume hood, fire extinguisher, eye wash station)

Safety equipment protects laboratory users from hazards. A **fume hood** is a ventilated enclosure that removes harmful vapours and gases, ensuring safe handling of volatile substances. A **fire extinguisher** is a device used to control small fires, while an **eye wash station** provides immediate rinsing in case of chemical splashes. Familiarity with the location and proper use of safety equipment is essential for laboratory practice.

Fill in the blank: A ventilated enclosure that removes harmful vapours and gases is called a __________ hood.



Box 3.1: Essential safety equipment in the laboratory

Pilot questions 3.2

1. What is the difference between an analytical balance and a top-loading balance?
2. State one advantage of using a hot plate instead of a Bunsen burner.
3. What is the primary function of a fume hood?
4. Name two pieces of safety equipment and explain their uses.
5. Why is calibration important when using balances?

3.3 Proper Use and Maintenance

3.3.1 Handling and cleaning of glassware

Handling refers to the correct way of using laboratory glassware to avoid breakage and contamination. Glassware should always be carried upright and never held by the neck alone.

Cleaning involves removing residues after experiments to ensure accuracy in future work. This is usually done with detergent and water, followed by rinsing with distilled water. For stubborn residues, specialised cleaning solutions may be required.
Fill in the blank: Laboratory glassware should always be rinsed with __________ water after cleaning to avoid contamination.

Plate 3.3 Cleaning laboratory glassware.

3.3.2 Calibration and care of equipment

Calibration is the process of adjusting equipment to ensure accurate measurements. For example, balances must be calibrated regularly to maintain precision. **Care of equipment** involves routine checks, proper storage, and avoiding misuse. Instruments should be used according to manufacturer guidelines, and protective covers should be applied when equipment is not in use.
Fill in the blank: The process of adjusting equipment to ensure accurate measurements is called __________.

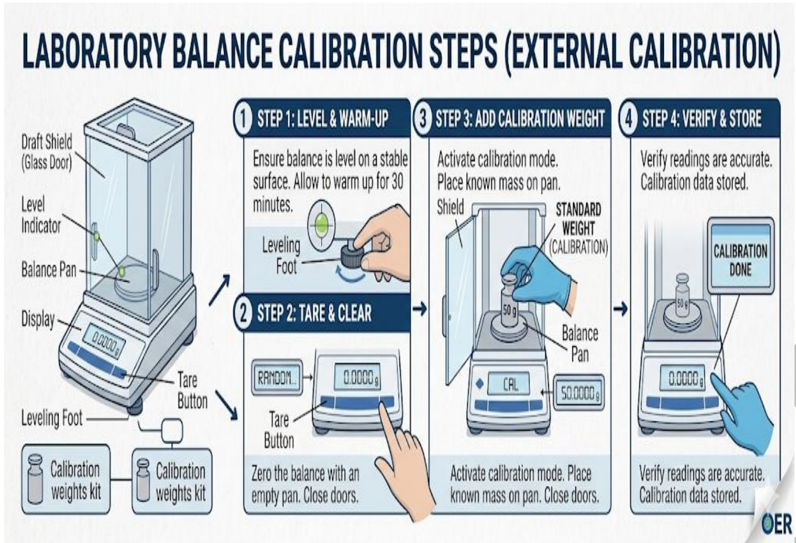


Figure 3.4 Calibration of a laboratory balance.

3.3.3 Storage and safety precautions

Storage refers to keeping glassware and equipment in designated areas to prevent damage and contamination. Glassware should be stored upright in racks, while sensitive equipment should be kept in protective cases. **Safety precautions** include wearing protective gear, avoiding overcrowding of storage spaces, and ensuring that hazardous materials are clearly labelled. Proper storage and safety practices extend the lifespan of laboratory tools and protect users from harm.

Fill in the blank: Hazardous materials should always be clearly __________ to ensure safe laboratory practice.

Box 3.2: Storage and safety guidelines

Pilot questions 3.3

1. Why is it important to rinse glassware with distilled water after cleaning?
2. Define calibration and give one example of equipment that requires it.
3. State two practices that ensure proper care of laboratory equipment.
4. How should glassware be stored to prevent damage?
5. List two safety precautions related to laboratory storage.

Series Summary

This Series has emphasised the importance of recognising and correctly using laboratory glassware and equipment, which is fundamental to safe and effective scientific practice. We began by examining common laboratory glassware such as beakers, flasks, pipettes, burettes, test tubes, and measuring cylinders, highlighting their specific functions and applications. We then moved on to essential laboratory equipment, including balances, heating devices, and safety tools, focusing on their roles in accurate measurement, controlled heating, and protection against hazards. Finally, we explored proper use and maintenance, covering handling, cleaning, calibration, storage, and safety precautions to ensure both reliability and longevity of laboratory tools.

By completing this Series, you should now be able to identify and explain the functions of common glassware, recognise and describe essential equipment, demonstrate correct handling and cleaning techniques, apply calibration and care procedures, and evaluate safe storage and precautionary measures. These abilities directly align with the Series Learning Outcomes and provide you with the practical competence needed to work confidently and responsibly in the laboratory.

Glossary of Terms

- **Analytical balance**: A highly precise instrument used to measure mass, often to four decimal places.
- **Beaker**: A cylindrical glass container with a flat bottom, used for mixing, heating, and roughly measuring liquids.
- **Burette**: A long, graduated glass tube with a tap at the bottom, used to deliver precise volumes of liquid during titrations.
- **Calibration**: The process of adjusting equipment to ensure accurate measurements.
- **Cleaning**: The removal of residues from laboratory glassware, usually with detergent and water, followed by rinsing with distilled water.
- **Distilled water**: Water that has been purified by distillation, used for rinsing glassware to avoid contamination.
- **Erlenmeyer flask**: A flask with a conical body and narrow neck, useful for mixing solutions without spillage.
- **Eye wash station**: A safety facility that provides immediate rinsing in case of chemical splashes to the eyes.
- **Fire extinguisher**: A device used to control small fires in the laboratory.
- **Fume hood**: A ventilated enclosure that removes harmful vapours and gases, ensuring safe handling of volatile substances.

- **Hot plate**: An electrically powered device used to provide uniform heating without an open flame.
- **Measuring cylinder**: A tall, graduated glassware designed for measuring liquid volumes more accurately than beakers.
- **Pipette**: A slender glass tube used to transfer or measure small volumes of liquid accurately.
- **Safety equipment**: Tools and facilities such as fume hoods, fire extinguishers, and eye wash stations that protect laboratory users from hazards.
- **Storage**: The practice of keeping glassware and equipment in designated areas to prevent damage and contamination.
- **Test tube**: A small cylindrical glass container used for holding, mixing, or heating small amounts of substances.
- **Top-loading balance**: A less precise weighing device suitable for routine laboratory work.**Volumetric flask**: A flask designed to prepare solutions of exact volumes, marked with a single calibration line.

Concept Check Questions [Series 3: Glassware and Equipment Identification]

Objective questions

1. Which glassware is designed to prepare solutions of exact volumes? (Linked to SLO 3.1)
   a) Beaker
   b) Erlenmeyer flask
   c) Volumetric flask
   d) Measuring cylinder
2. Which instrument measures mass to four decimal places? (Linked to SLO 3.3)
   a) Top-loading balance
   b) Analytical balance
   c) Measuring cylinder
   d) Pipette
3. Which heating device provides uniform heating without an open flame? (Linked to SLO 3.4)
   a) Bunsen burner
   b) Hot plate
   c) Fume hood
   d) Fire extinguisher
4. Which safety equipment removes harmful vapours and gases? (Linked to SLO 3.7)
   a) Fire extinguisher
   b) Eye wash station
   c) Fume hood
   d) Safety goggles

Short-answer questions

1. Define a burette and state its primary use. (Linked to SLO 3.2)

2. Explain the difference between an analytical balance and a top-loading balance. (Linked to SLO 3.4)
3. Give one advantage of using a hot plate instead of a Bunsen burner. (Linked to SLO 3.4)
4. State two practices that ensure proper care of laboratory equipment. (Linked to SLO 3.6)
5. Why should hazardous materials be clearly labelled in the laboratory? (Linked to SLO 3.7)

Long-answer questions

1. Analyse the importance of correctly handling and cleaning glassware in laboratory practice. (Linked to SLO 3.5)
2. Evaluate the role of calibration in ensuring accuracy of laboratory equipment. (Linked to SLO 3.6)
3. Design a storage and safety plan for a small teaching laboratory, including guidelines for glassware, equipment, and hazardous materials. (Linked to SLO 3.7)

Answers to Concept Check Questions [Series 3: Glassware and Equipment Identification]

Objective questions

1. c) Volumetric flask
2. b) Analytical balance
3. b) Hot plate
4. c) Fume hood

Short-answer questions

1. A burette is a long graduated glass tube with a tap at the bottom, used to deliver precise volumes of liquid during titrations.
2. An analytical balance provides highly precise measurements to four decimal places, while a top-loading balance is less precise and used for routine work.
3. A hot plate provides uniform heating without an open flame, making it safer for certain applications.
4. Practices include regular calibration, proper storage, and following manufacturer guidelines.
5. Clear labelling prevents accidents and ensures safe handling of hazardous materials.

Long-answer questions

1. **Basic response:** Correct handling and cleaning prevent breakage, contamination, and inaccurate results.
   Value-added response: Proper cleaning also ensures reproducibility of experiments, reduces chemical hazards, and extends the lifespan of glassware.

2. **Basic response:** Calibration ensures equipment provides accurate measurements.
   Value-added response: Regular calibration builds confidence in results, aligns with international standards, and prevents systematic errors in scientific work.
3. **Basic response:** A storage and safety plan should include storing glassware upright, keeping equipment in protective cases, and labelling hazardous materials.
   Value-added response: An advanced plan would also incorporate designated storage zones, regular safety audits, training for users, and integration of emergency equipment such as fire extinguishers and eye wash stations.

Answers to Pilot Questions [Series 3: Glassware and Equipment Identification]

Pilot questions 3.1 (Common laboratory glassware)

1. A beaker is used for mixing and rough measurement, while a volumetric flask is designed for preparing solutions of exact volumes.
2. Volumetric pipette (delivers a fixed volume) and graduated pipette (measures varying volumes).
3. A burette delivers precise volumes of liquid during titrations.
4. A test tube is used for holding, mixing, or heating small amounts of substances.
5. Measuring cylinders are graduated and therefore provide more accurate volume measurements than beakers.

Pilot questions 3.2 (Essential laboratory equipment)

1. An analytical balance provides highly precise measurements to four decimal places, while a top-loading balance is less precise and used for routine work.
2. A hot plate provides uniform heating without an open flame, making it safer for certain experiments.
3. A fume hood removes harmful vapours and gases, ensuring safe handling of volatile substances.
4. Fire extinguisher (controls small fires) and eye wash station (rinses eyes after chemical splashes).
5. Calibration ensures accuracy and reliability of measurements.

Pilot questions 3.3 (Proper use and maintenance)

1. Distilled water prevents contamination and ensures accuracy in future experiments.
2. Calibration is the process of adjusting equipment to ensure accurate measurements; balances require regular calibration.
3. Practices include routine checks, proper storage, and following manufacturer guidelines.
4. Glassware should be stored upright in racks to prevent breakage.
5. Safety precautions include wearing protective gear and labelling hazardous materials clearly.

References and Attributions [Series 3: Glassware and Equipment Identification]

General references

- Open Educational Resources (OER Commons). (n.d.). *Laboratory glassware and equipment basics*. Retrieved from https://www.oercommons.org
- Royal Society of Chemistry. (n.d.). *Practical chemistry: laboratory techniques and safety*. Retrieved from https://www.rsc.org
- UNESCO. (2019). *Science laboratory safety and ethics*. Paris: UNESCO Publishing.

Illustrations

- *Figure 3.1 Common beakers and flasks*
  AI prompt: "Diagram comparing beakers, Erlenmeyer flasks, and volumetric flasks with labels."
  Search string: "beakers flasks chemistry OER diagram"
- *Plate 3.1 Using a burette in titration*
  AI prompt: "Photo-style image of a student performing titration with a burette in a chemistry laboratory."
  Search string: "burette titration chemistry OER photo"
- *Figure 3.2 Test tubes and measuring cylinders*
  AI prompt: "Diagram showing labelled test tubes and measuring cylinders with graduations."
  Search string: "test tubes measuring cylinders chemistry OER diagram"
- *Figure 3.3 Analytical and top-loading balances*
  AI prompt: "Diagram comparing analytical balance and top-loading balance with labels."
  Search string: "analytical balance vs top-loading balance chemistry OER diagram"
- *Plate 3.2 Heating substances with a Bunsen burner*
  AI prompt: "Photo-style image of a student heating a beaker with a Bunsen burner in a laboratory."
  Search string: "Bunsen burner heating beaker chemistry OER photo"
- *Box 3.1 Essential safety equipment in the laboratory*
  AI prompt: "Infographic box listing essential safety equipment in a chemistry laboratory."
  Search string: "fume hood fire extinguisher eye wash station OER infographic"
- *Plate 3.3 Cleaning laboratory glassware*
  AI prompt: "Photo-style image of a student rinsing laboratory glassware with distilled water at a laboratory sink."
  Search string: "cleaning laboratory glassware distilled water OER photo"
- *Figure 3.4 Calibration of a laboratory balance*
  AI prompt: "Diagram showing steps in calibrating a laboratory balance with labelled parts."
  Search string: "calibration of laboratory balance OER diagram"
- *Box 3.2 Storage and safety guidelines*
  AI prompt: "Infographic box listing storage and safety guidelines for laboratory

glassware and equipment."
Search string: "laboratory storage safety guidelines OER infographic"

Course Code: CHM 108
Course Title: General Chemistry II
Course Unit: 1 Units

Series 1: Laboratory Safety and Rules
Series 2: Scientific Data Collection and Experimentation
Series 3: Glassware and Equipment Identification
Series 4: Organic Compound Testing and Analysis
Series 5: Functional Group and Quantitative Analysis

Series 4: Organic Compound Testing and Analysis
Series Outline

4.1 Preliminary tests for organic compounds

- 4.1.1 Physical observations (colour, odour, solubility)
- 4.1.2 Combustion test for organic matter
- 4.1.3 Distinguishing organic from inorganic samples

4.2 Functional group identification

- 4.2.1 Tests for hydrocarbons (unsaturation test, bromine water)
- 4.2.2 Tests for alcohols and phenols
- 4.2.3 Tests for aldehydes and ketones
- 4.2.4 Tests for carboxylic acids

4.3 Analytical techniques and interpretation

- 4.3.1 Chromatography basics (paper and thin-layer)
- 4.3.2 Simple qualitative analysis of mixtures
- 4.3.3 Recording and interpreting results

Introduction
Organic compounds form the basis of countless substances we encounter daily, from fuels and plastics to medicines and food additives. In the laboratory, the ability to test and analyse these compounds is essential for identifying their structures and understanding their behaviour. This Series will guide you through practical methods of recognising organic compounds and

interpreting their properties, building on the skills you have already developed in handling laboratory glassware and equipment.
The aim of this Series is to introduce you to the fundamental techniques used in testing and analysing organic compounds, and to equip you with the ability to identify functional groups and interpret experimental results with confidence.
We shall commence this Series by examining preliminary tests for organic compounds, including physical observations, combustion tests, and ways of distinguishing organic from inorganic samples. Next, we will move on to functional group identification, where you will learn specific tests for hydrocarbons, alcohols, phenols, aldehydes, ketones, and carboxylic acids. Finally, we will wrap up by exploring analytical techniques such as chromatography and qualitative analysis of mixtures, before concluding with guidance on recording and interpreting results. This progression will ensure you are well prepared to carry out organic compound testing and analysis effectively.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **4.1** describe preliminary tests for organic compounds, including physical observations and combustion behaviour.
- **4.2** explain how to distinguish organic samples from inorganic ones using simple laboratory tests.
- **4.3** demonstrate functional group identification tests for hydrocarbons, alcohols, phenols, aldehydes, ketones, and carboxylic acids.
- **4.4** apply chromatography techniques such as paper and thin-layer chromatography to separate organic mixtures.
- **4.5** analyse qualitative data obtained from organic compound testing and interpret the results accurately.
- **4.6** record experimental findings systematically and evaluate their significance in relation to organic compound analysis.

4.1 Preliminary Tests for Organic Compounds

4.1.1 Physical observations (colour, odour, solubility)

Physical observations are the first step in testing organic compounds. These include noting the **colour** of the sample, which may give clues about conjugated systems or impurities, the **odour**, which can suggest the presence of volatile organic substances, and **solubility**, which helps distinguish polar from non-polar compounds. For example, hydrocarbons are generally insoluble in water but soluble in organic solvents.
Fill in the blank: Hydrocarbons are generally insoluble in __________ but soluble in organic solvents.

Plate 4.1 Observing colour and solubility of organic compounds.

4.1.2 Combustion test for organic matter

The **combustion test** is a simple way to confirm the presence of organic matter. Organic compounds typically burn with a flame, producing carbon dioxide and water. The nature of the flame can also provide information: a **sooty flame** often indicates unsaturated hydrocarbons or aromatic compounds, while a clean flame suggests saturated hydrocarbons.
Fill in the blank: A sooty flame during combustion often indicates the presence of __________ hydrocarbons or aromatic compounds.

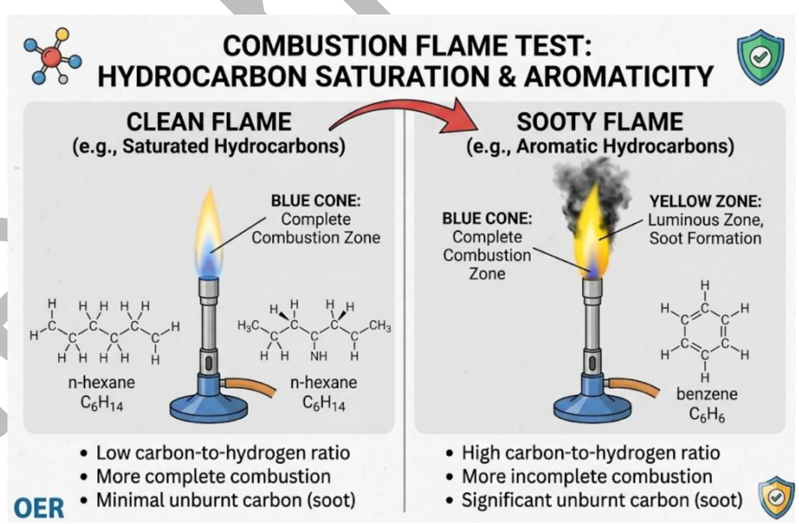
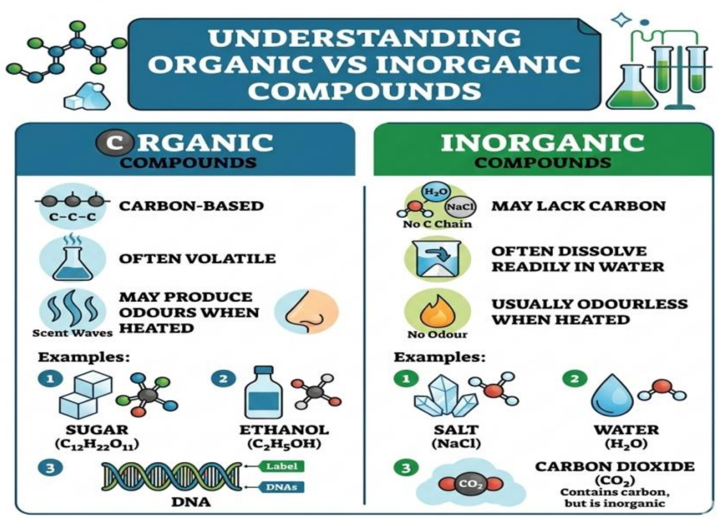


Figure 4.1 Combustion test for organic compounds.

4.1.3 Distinguishing organic from inorganic samples

Organic compounds are primarily carbon-based, while **inorganic compounds** may lack carbon or contain it in simple forms such as carbonates. Simple tests can help distinguish them. For

example, heating organic compounds often produces characteristic odours, while inorganic salts may simply decompose without such odours. Solubility tests also assist, as many inorganic salts dissolve readily in water, unlike most organic compounds.
Fill in the blank: Organic compounds are primarily __________-based, while inorganic compounds may lack this element or contain it in simple forms.



Box 4.1: Simple distinctions between organic and inorganic compounds

Pilot questions 4.1

1. What physical observations can be made to identify organic compounds?
2. What does a sooty flame in the combustion test indicate?
3. State one difference between organic and inorganic compounds.
4. Why are solubility tests useful in preliminary analysis?
5. What products are typically formed when organic compounds undergo combustion?

4.2 Functional Group Identification

4.2.1 Tests for hydrocarbons (unsaturation test, bromine water)

Hydrocarbons are compounds made up of carbon and hydrogen. To test for **unsaturation**, bromine water is used. When bromine water is added to an unsaturated hydrocarbon such as an alkene, the orange colour disappears, indicating the presence of double bonds. Saturated hydrocarbons, such as alkanes, do not decolourise bromine water under normal conditions.
Fill in the blank: The disappearance of the orange colour of __________ water indicates the presence of unsaturation in hydrocarbons.

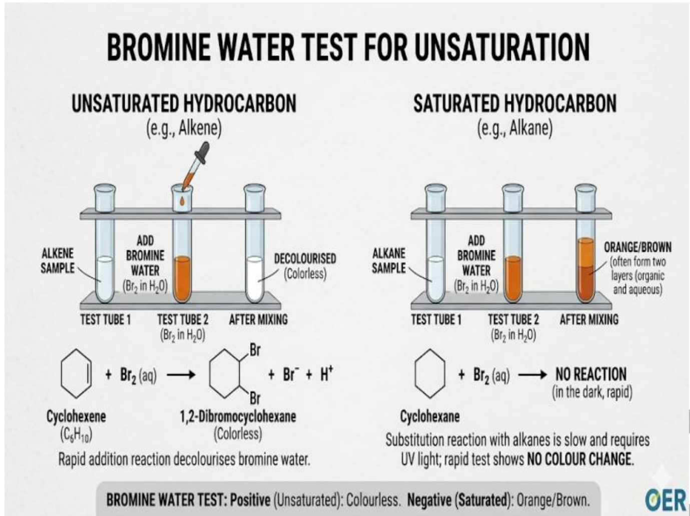


Figure 4.2 Bromine water test for hydrocarbons.

4.2.2 Tests for alcohols and phenols

Alcohols are organic compounds containing the hydroxyl group (-OH). A common test is the sodium metal test, where alcohol reacts with sodium to produce hydrogen gas. **Phenols**, which are aromatic compounds with a hydroxyl group attached to a benzene ring, can be tested using ferric chloride solution. A purple or violet colour indicates the presence of phenols.

Fill in the blank: A purple colour with ferric chloride solution indicates the presence of __________.

Plate 4.2 Ferric chloride test for phenols.

4.2.3 Tests for aldehydes and ketones

Aldehydes and **ketones** are carbonyl compounds. Aldehydes can be tested using **Tollens' reagent**, which produces a silver mirror on the test tube walls. Ketones generally do not react with Tollens' reagent. Another test is **Fehling's solution**, which gives a brick-red precipitate with aldehydes but not with ketones.
Fill in the blank: The formation of a silver mirror with Tollens' reagent indicates the presence of an __________.

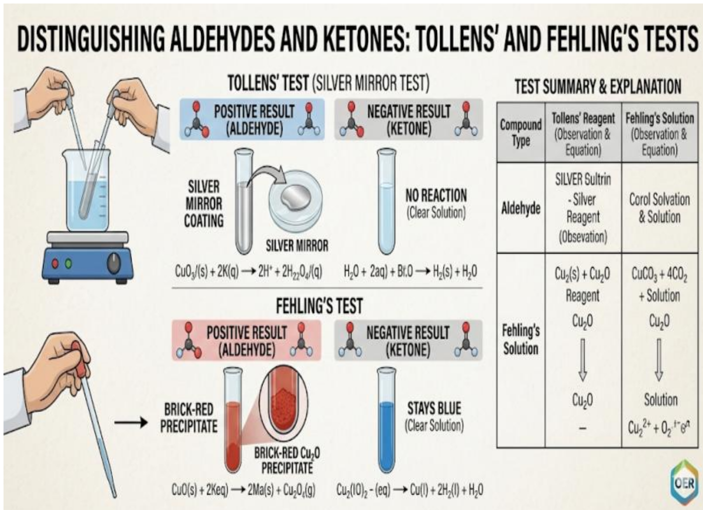


Figure 4.3 Tests for aldehydes and ketones.

4.2.4 Tests for carboxylic acids

Carboxylic acids contain the carboxyl group (-COOH). They can be identified by their reaction with sodium carbonate or sodium bicarbonate, which produces effervescence due to carbon dioxide gas. Another test is the litmus test, where carboxylic acids turn blue litmus paper red, confirming their acidic nature.
Fill in the blank: Effervescence observed when carboxylic acids react with sodium carbonate is due to the release of __________ gas.

Plate 4.3 Reaction of carboxylic acid with sodium carbonate.

Pilot questions 4.2

1. What reagent is used to test for unsaturation in hydrocarbons?
2. What colour change indicates the presence of phenols in the ferric chloride test?
3. Which reagent produces a silver mirror with aldehydes?
4. What precipitate is formed when aldehydes react with Fehling's solution?
5. What gas is released when carboxylic acids react with sodium carbonate?

4.3 Analytical Techniques and Interpretation

4.3.1 Chromatography basics (paper and thin-layer)

Chromatography is a technique used to separate mixtures into their individual components. In **paper chromatography**, a drop of the mixture is placed on filter paper, which is then dipped into a solvent. As the solvent rises, different compounds travel at different rates, producing a separation pattern. **Thin-layer chromatography (TLC)** uses a thin layer of silica gel or alumina on a plate instead of paper, offering better resolution and faster results.
Fill in the blank: In thin-layer chromatography, the stationary phase is usually a thin layer of __________ gel or alumina.

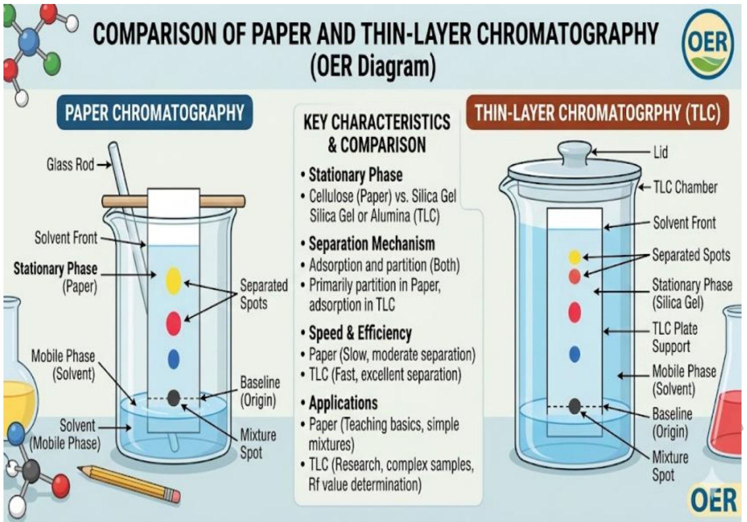


Figure 4.4 Paper and thin-layer chromatography.

4.3.2 Simple qualitative analysis of mixtures

Qualitative analysis involves identifying the types of compounds present in a mixture rather than measuring their exact amounts. Chromatography patterns, colour changes in chemical tests, and odour observations can all contribute to qualitative analysis. For example, a mixture of alcohols and acids may show distinct spots on a TLC plate, each corresponding to a different compound.

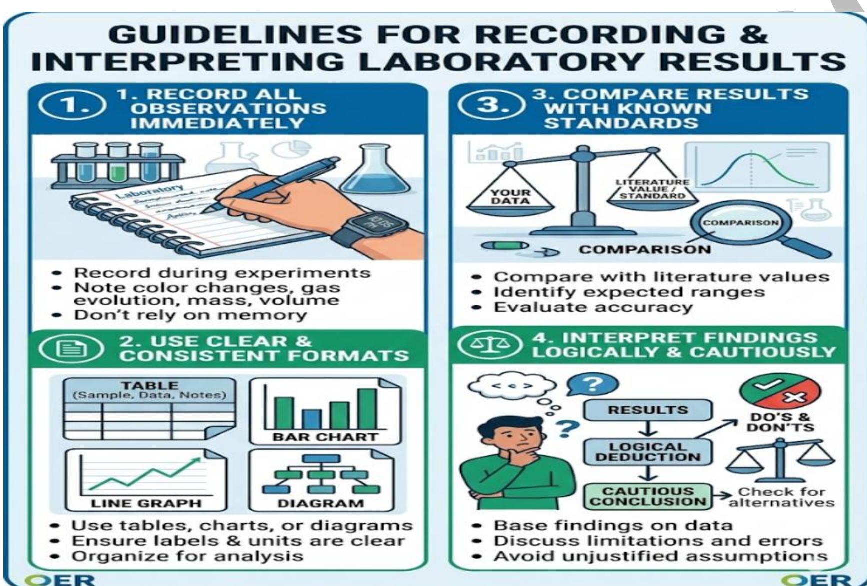
Fill in the blank: Qualitative analysis focuses on identifying the __________ of compounds present rather than their exact amounts.

Plate 4.4 Thin-layer chromatography plate showing separation of compounds.

4.3.3 Recording and interpreting results

Recording results means documenting observations such as colour changes, precipitate formation, or chromatographic separations. **Interpreting results** involves drawing conclusions from these observations, such as identifying functional groups or confirming the presence of specific compounds. Accurate record-keeping ensures reproducibility and reliability of experiments.

Fill in the blank: Accurate record-keeping ensures __________ and reliability of experiments.



Box 4.2: Guidelines for recording and interpreting results

Pilot questions 4.3

1. What is the main difference between paper chromatography and thin-layer chromatography?
2. What does qualitative analysis aim to achieve?
3. Why is silica gel commonly used in TLC?
4. State two guidelines for recording laboratory results.
5. How does accurate record-keeping support reproducibility in experiments?

Series Summary

This Series has focused on practical methods for testing and analysing organic compounds, which are central to laboratory chemistry. We began with preliminary tests such as physical observations, combustion behaviour, and simple distinctions between organic and inorganic samples. We then moved on to functional group identification, exploring specific tests for hydrocarbons, alcohols, phenols, aldehydes, ketones, and carboxylic acids. Finally, we examined analytical techniques including chromatography, qualitative analysis of mixtures, and the systematic recording and interpretation of results.

By completing this Series, you should now be able to describe preliminary tests, explain distinctions between organic and inorganic compounds, demonstrate functional group identification, apply chromatography techniques, analyse qualitative data, and evaluate recorded results. These abilities directly align with the Series Learning Outcomes and provide you with the competence to confidently test, identify, and interpret organic compounds in a laboratory setting.

Glossary of Terms

- **Alcohols**: Organic compounds containing the hydroxyl group (-OH), often tested by their reaction with sodium metal to produce hydrogen gas.
- **Aldehydes**: Carbonyl compounds with the carbonyl group (-CHO) at the end of a carbon chain, identified by the silver mirror test using Tollens' reagent.
- **Carboxylic acids**: Organic compounds containing the carboxyl group (-COOH), which react with sodium carbonate to release carbon dioxide gas.
- **Chromatography**: A separation technique used to distinguish components of a mixture based on their movement through a stationary phase with the aid of a solvent.
- **Combustion test**: A preliminary test for organic matter where compounds burn to produce carbon dioxide and water, with flame characteristics indicating saturation or unsaturation.
- **Fehling's solution**: A chemical reagent used to test for aldehydes, producing a brick-red precipitate when positive.
- **Functional group**: A specific group of atoms within a molecule that determines its characteristic chemical reactions, such as hydroxyl, carbonyl, or carboxyl groups.
- **Hydrocarbons**: Compounds composed of carbon and hydrogen, tested for unsaturation using bromine water.
- **Phenols**: Aromatic compounds with a hydroxyl group attached to a benzene ring, identified by a purple colour with ferric chloride solution.
- **Qualitative analysis**: The process of identifying the types of compounds present in a mixture without measuring their exact amounts.
- **Recording results**: The systematic documentation of laboratory observations such as colour changes, precipitate formation, or chromatographic separations.
- **Sooty flame**: A flame observed during combustion that indicates the presence of unsaturated hydrocarbons or aromatic compounds.
- **Thin-layer chromatography (TLC)**: A type of chromatography using a thin layer of silica gel or alumina as the stationary phase, offering better resolution than paper chromatography.
- **Tollens' reagent**: A chemical solution used to test for aldehydes, producing a silver mirror when positive.

Concept Check Questions [Series 4: Organic Compound Testing and Analysis]

Objective questions

1. Which reagent is used to test for unsaturation in hydrocarbons? (Linked to SLO 4.3)
   a) Sodium carbonate
   b) Bromine water
   c) Ferric chloride
   d) Fehling's solution
2. Which reagent produces a silver mirror when testing aldehydes? (Linked to SLO 4.3)
   a) Fehling's solution
   b) Tollens' reagent
   c) Bromine water
   d) Sodium hydroxide
3. Which technique separates mixtures using a stationary phase and a solvent? (Linked to SLO 4.4)
   a) Distillation
   b) Chromatography
   c) Combustion
   d) Precipitation
4. Which observation confirms the presence of carboxylic acids when reacting with sodium carbonate? (Linked to SLO 4.3)
   a) Silver mirror formation
   b) Brick-red precipitate
   c) Effervescence
   d) Purple colour

Short-answer questions

1. Define hydrocarbons and explain how bromine water is used to test them. (Linked to SLO 4.3)
2. State one difference between paper chromatography and thin-layer chromatography. (Linked to SLO 4.4)
3. What colour change indicates the presence of phenols when tested with ferric chloride? (Linked to SLO 4.3)
4. Why is accurate record-keeping important in organic compound analysis? (Linked to SLO 4.6)
5. What gas is released when carboxylic acids react with sodium carbonate? (Linked to SLO 4.3)

Long-answer questions

1. Analyse the importance of preliminary tests such as physical observations and combustion in organic compound analysis. (Linked to SLO 4.1, SLO 4.2)
2. Evaluate the role of chromatography in separating and identifying organic compounds. (Linked to SLO 4.4, SLO 4.5)
3. Design a systematic approach for recording and interpreting results in organic compound testing. (Linked to SLO 4.6)

Answers to Concept Check Questions [Series 4: Organic Compound Testing and Analysis]

Objective questions

1. b) Bromine water
2. b) Tollens' reagent
3. b) Chromatography
4. c) Effervescence

Short-answer questions

1. Hydrocarbons are compounds made of carbon and hydrogen. Bromine water decolourises in the presence of unsaturated hydrocarbons, indicating double bonds.
2. Paper chromatography uses filter paper as the stationary phase, while TLC uses silica gel or alumina, giving better resolution.
3. A purple colour indicates the presence of phenols.
4. Accurate record-keeping ensures reproducibility and reliability of experiments.
5. Carbon dioxide gas is released.

Long-answer questions

1. **Basic response:** Preliminary tests such as colour, odour, solubility, and combustion provide quick clues about the nature of organic compounds.
   Value-added response: These tests also help narrow down possible functional groups, distinguish organic from inorganic samples, and guide further detailed analysis.
2. **Basic response:** Chromatography separates mixtures into components, making identification easier.
   Value-added response: It also allows comparison with standards, provides qualitative insights into complex mixtures, and is widely used in research and industry for purity checks.
3. **Basic response:** Recording results should include observations of colour changes, precipitates, and chromatographic separations.
   Value-added response: A systematic approach would involve using structured tables, diagrams, and comparisons with literature values, ensuring clarity, reproducibility, and meaningful interpretation of findings.

Answers to Pilot Questions [Series 4: Organic Compound Testing and Analysis]

Pilot questions 4.1 (Preliminary tests for organic compounds)

1. Colour, odour, and solubility.

2. Presence of unsaturated hydrocarbons or aromatic compounds.
3. Organic compounds are carbon-based, while inorganic compounds may lack carbon or contain it in simple forms.
4. They help distinguish polar from non-polar compounds and differentiate organic from inorganic samples.
5. Carbon dioxide and water.

Pilot questions 4.2 (Functional group identification)

1. Bromine water.
2. Purple colour.
3. Tollens' reagent.
4. Brick-red precipitate.
5. Carbon dioxide gas.

Pilot questions 4.3 (Analytical techniques and interpretation)

1. Paper chromatography uses filter paper, while thin-layer chromatography uses silica gel or alumina for better resolution.
2. It identifies the types of compounds present in a mixture.
3. Silica gel.
4. Record observations immediately and use clear formats such as tables or charts.
5. It ensures reproducibility and reliability of experiments.

References and Attributions [Series 4: Organic Compound Testing and Analysis]

General references

- Open Educational Resources (OER Commons). (n.d.). *Organic chemistry laboratory techniques*. Retrieved from https://www.oercommons.org
- Royal Society of Chemistry. (n.d.). *Practical chemistry: organic compound testing*. Retrieved from https://www.rsc.org
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- UNESCO. (2019). *Science laboratory safety and ethics*. Paris: UNESCO Publishing.

Illustrations

- *Plate 4.1 Observing colour and solubility of organic compounds*
  AI prompt: "Photo-style image of a student examining test tubes with organic samples, noting colour and solubility."
  Search string: "organic compound colour solubility test OER photo"
- *Figure 4.1 Combustion test for organic compounds*
  AI prompt: "Diagram showing clean flame for saturated hydrocarbons and sooty flame

for aromatic hydrocarbons."
Search string: "combustion test organic compounds clean vs sooty flame OER diagram"

- *Box 4.1 Simple distinctions between organic and inorganic compounds*
  AI prompt: "Infographic box listing differences between organic and inorganic compounds with examples."
  Search string: "organic vs inorganic compounds differences OER infographic"
- *Figure 4.2 Bromine water test for hydrocarbons*
  AI prompt: "Diagram showing bromine water test with colour change for unsaturated hydrocarbons."
  Search string: "bromine water test hydrocarbons OER diagram"
- *Plate 4.2 Ferric chloride test for phenols*
  AI prompt: "Photo-style image of test tubes showing purple colour after ferric chloride test for phenols."
  Search string: "ferric chloride test phenols OER photo"
- *Figure 4.3 Tests for aldehydes and ketones*
  AI prompt: "Diagram showing silver mirror test with Tollens' reagent and brick-red precipitate with Fehling's solution."
  Search string: "Tollens test Fehling test aldehydes ketones OER diagram"
- *Plate 4.3 Reaction of carboxylic acid with sodium carbonate*
  AI prompt: "Photo-style image of effervescence in a test tube during carboxylic acid reaction with sodium carbonate."
  Search string: "carboxylic acid sodium carbonate effervescence OER photo"
- *Figure 4.4 Paper and thin-layer chromatography*
  AI prompt: "Diagram comparing paper chromatography and thin-layer chromatography with labelled solvent front and separated spots."
  Search string: "paper chromatography vs thin layer chromatography OER diagram"
- *Plate 4.4 Thin-layer chromatography plate showing separation of compounds*
  AI prompt: "Photo-style image of a TLC plate with multiple separated spots indicating different compounds."
  Search string: "TLC plate separated compounds OER photo"
- *Box 4.2 Guidelines for recording and interpreting results*
  AI prompt: "Infographic box listing guidelines for recording and interpreting laboratory results."
  Search string: "laboratory recording interpreting results guidelines OER infographic"

Course Code: CHM 108
Course Title: General Chemistry II
Course Unit: 1 Units

Series 1: Laboratory Safety and Rules
Series 2: Scientific Data Collection and Experimentation
Series 3: Glassware and Equipment Identification
Series 4: Organic Compound Testing and Analysis
Series 5: Functional Group and Quantitative Analysis

Series 5: Functional Group and Quantitative Analysis

Series Outline

5.1 Functional group tests

- 5.1.1 Identification of amines
- 5.1.2 Tests for esters
- 5.1.3 Distinguishing aldehydes from ketones (confirmatory tests)

5.2 Quantitative analysis of organic compounds

- 5.2.1 Determination of acidity and basicity (acid-base titrations)
- 5.2.2 Estimation of functional groups (e.g., hydroxyl, carbonyl)
- 5.2.3 Gravimetric and volumetric approaches

5.3 Data interpretation and reporting

- 5.3.1 Recording quantitative results in tabular form
- 5.3.2 Calculating yields and concentrations
- 5.3.3 Presenting findings with accuracy and clarity

Introduction

In the last Series, we explored how to test and analyse organic compounds, focusing on preliminary observations, functional group identification, and basic analytical techniques. Building on that foundation, this Series takes you further into the practical chemistry of organic compounds by introducing functional group tests in greater detail and guiding you through quantitative analysis. These skills are essential for confirming the identity of compounds and for measuring their properties with precision, which is a key aspect of laboratory practice.

The aim of this Series is to equip you with the ability to carry out functional group tests confidently and to perform quantitative analyses that yield reliable data. By mastering these techniques, you will strengthen your competence in both qualitative and quantitative aspects of organic chemistry.

We shall commence this Series by examining functional group tests, including methods for identifying amines, esters, and confirmatory tests for aldehydes and ketones. Next, we will move on to quantitative analysis of organic compounds, where you will learn how to determine acidity and basicity, estimate functional groups, and apply gravimetric and volumetric approaches. Finally, we will wrap up by focusing on data interpretation and reporting, covering how to record results in tabular form, calculate yields and concentrations, and present findings with accuracy and clarity. This progression will ensure you are well prepared to carry out functional group and quantitative analysis effectively.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **5.1** demonstrate functional group tests for amines, esters, and confirmatory tests for aldehydes and ketones.
- **5.2** apply acid–base titrations to determine the acidity and basicity of organic compounds.
- **5.3** estimate selected functional groups such as hydroxyl and carbonyl using quantitative methods.
- **5.4** explain gravimetric and volumetric approaches used in quantitative analysis of organic compounds.
- **5.5** record quantitative results systematically in tabular form for clarity and accuracy.
- **5.6** calculate yields and concentrations from experimental data with precision.
- **5.7** present findings clearly and evaluate their significance in relation to functional group and quantitative analysis.

5.1 Functional Group Tests

5.1.1 Identification of amines

Amines are organic compounds derived from ammonia, where one or more hydrogen atoms are replaced by alkyl or aryl groups. A common test for amines is the reaction with nitrous acid. Primary amines produce nitrogen gas, while secondary amines form nitroso compounds. Tertiary amines generally do not react under these conditions. Another useful test is the reaction with hydrochloric acid, where amines form soluble salts.
Fill in the blank: Primary amines react with nitrous acid to release __________ gas.

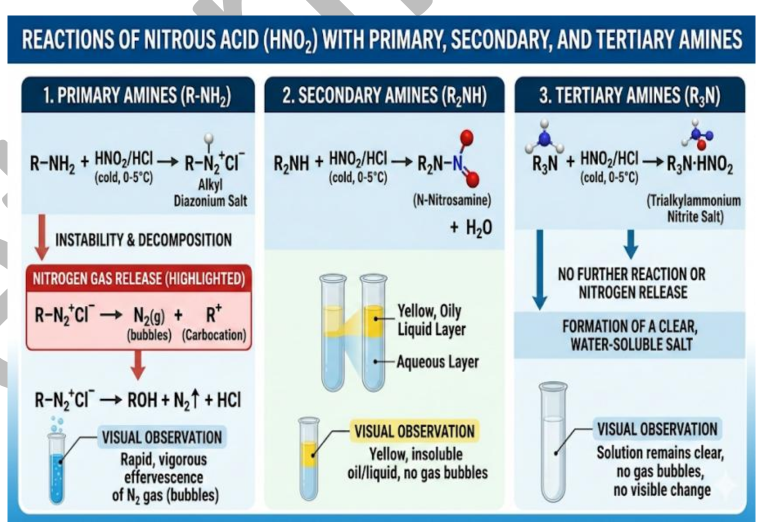


Figure 5.1 Nitrous acid test for amines.

5.1.2 Tests for esters

Esters are organic compounds formed from the reaction between an acid and an alcohol. They are often identified by their characteristic fruity odours. A confirmatory test involves hydrolysis:

esters react with dilute acid or alkali to produce the parent alcohol and acid. The alcohol can then be detected by its odour or by specific tests such as the iodoform test (for ethanol).
Fill in the blank: Hydrolysis of esters produces the parent __________ and acid.

Plate 5.1 Hydrolysis of esters in the laboratory.

5.1.3 Distinguishing aldehydes from ketones (confirmatory tests)

Aldehydes and **ketones** are carbonyl compounds, but they can be distinguished using confirmatory tests. Aldehydes react with **Tollens' reagent** to produce a silver mirror, while ketones do not. Aldehydes also react with **Fehling's solution**, forming a brick-red precipitate of copper(I) oxide. Ketones generally remain unreactive in these tests, although some α-hydroxy ketones may give positive results.
Fill in the blank: The formation of a silver mirror with Tollens' reagent confirms the presence of an __________.

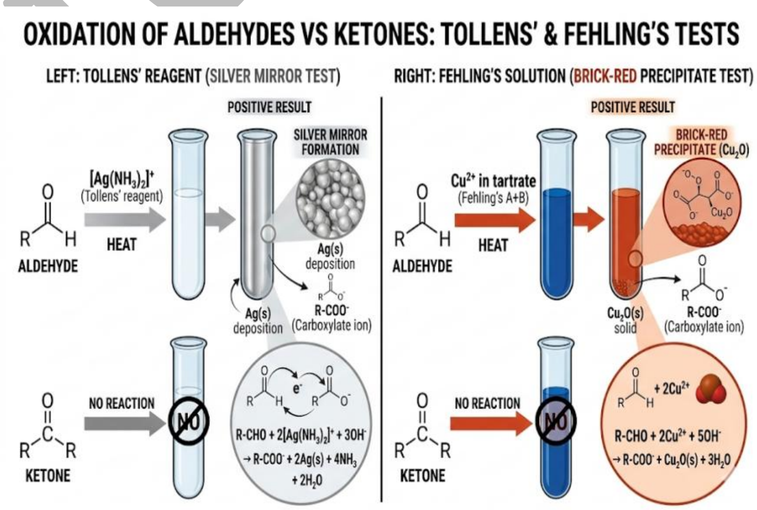


Figure 5.2 Confirmatory tests distinguishing aldehydes from ketones.

Pilot questions 5.1

1. What gas is released when primary amines react with nitrous acid?
2. What products are formed during ester hydrolysis?
3. Which reagent produces a silver mirror with aldehydes?
4. What precipitate is formed when aldehydes react with Fehling's solution?
5. Why do esters often have distinctive fruity odours?

5.2 Quantitative Analysis of Organic Compounds

5.2.1 Determination of acidity and basicity (acid–base titrations)

Acid–base titration is a quantitative technique used to determine the concentration of an acid or base in a solution. In organic chemistry, this method is often applied to carboxylic acids and amines. A known concentration of a standard solution (such as sodium hydroxide or hydrochloric acid) is added gradually to the organic sample until neutralisation occurs, indicated by a suitable pH indicator or pH meter.

Fill in the blank: Acid–base titration is used to determine the __________ of an acid or base in a solution.

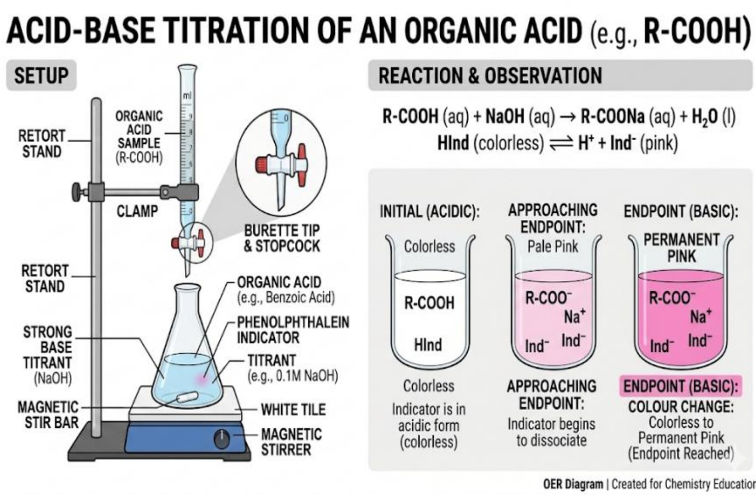


Figure 5.3 Acid–base titration for organic compounds.

5.2.2 Estimation of functional groups (hydroxyl, carbonyl)

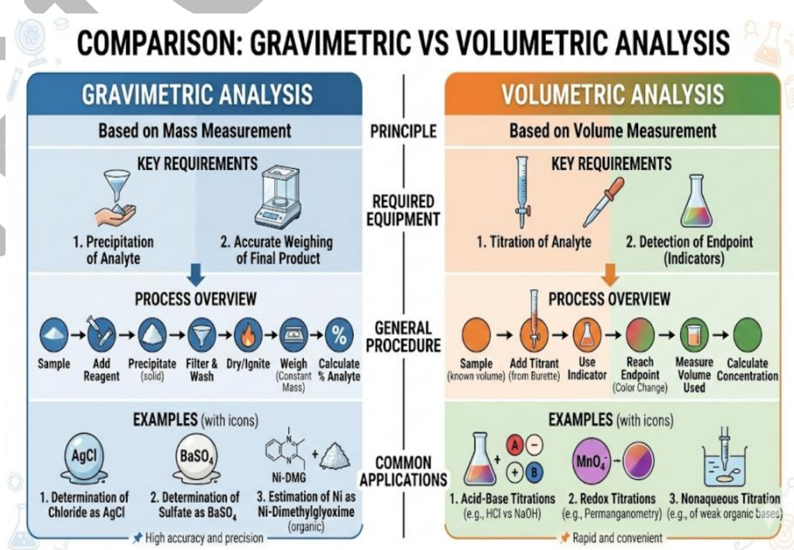
Functional group estimation involves measuring the quantity of specific groups such as hydroxyl (-OH) or carbonyl (C=O). For hydroxyl groups, acetylation followed by titration can be used to determine the number of groups present. Carbonyl groups may be estimated using reactions with reagents like 2,4-dinitrophenylhydrazine, followed by gravimetric or

spectroscopic analysis. These methods provide quantitative data that complement qualitative identification.
Fill in the blank: Hydroxyl groups can be estimated by __________ followed by titration.

Plate 5.2 Estimation of hydroxyl groups in organic compounds.

5.2.3 Gravimetric and volumetric approaches

Gravimetric analysis involves measuring the mass of a substance to determine its quantity. For example, precipitating a compound and weighing the solid product provides a direct measure of the analyte. **Volumetric analysis**, on the other hand, relies on measuring the volume of a solution required to react completely with the analyte, as in titrations. Both approaches are widely used in organic chemistry to quantify compounds accurately.
Fill in the blank: Gravimetric analysis determines the quantity of a substance by measuring its __________.



Box 5.1: Comparison of gravimetric and volumetric analysis

Pilot questions 5.2

1. What is the purpose of acid–base titration in organic compound analysis?
2. Which functional groups can be estimated quantitatively in organic compounds?
3. What method is used to estimate hydroxyl groups?
4. What reagent is commonly used to estimate carbonyl groups?
5. State one difference between gravimetric and volumetric analysis

5.3 Data Interpretation and Reporting

5.3.1 Recording quantitative results in tabular form

Recording results refers to documenting experimental observations and measurements in a clear and structured way. In quantitative analysis, results are often presented in tables to ensure clarity and easy comparison. Tables should include headings such as sample name, volume or mass measured, and calculated concentration. This systematic approach helps prevent errors and supports reproducibility.

Fill in the blank: Recording results in __________ form ensures clarity and easy comparison of data.

TABLE 1: SUMMARY OF TITRATION RESULTS

SAMPLE NAME	TITRANT USED	AVERAGE TITRANT VOLUME (mL)	SAMPLE VOLUME (mL)	CALCULATED CONCENTRATION (M)
Acidic Fruit Juice (A)	0.100 M NaOH	18.75	10.00	0.188 M (total acidity)
Vinegar Sample (B)	0.100 M NaOH	12.50	2.00	0.625 M (acetic acid)
Water Hardness (C)	0.010 M EDTA	24.30	50.00	0.00486 M (Ca^{2+} + Mg^{2+})

NOTES:
* NaOH Molarity = 0.100 M, EDTA Molarity = 0.010 M. Concentration calculation based on: $M_1V_1/n_1 = M_2V_2/n_2$.

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Table 5.1 Example of tabular recording of titration results

5.3.2 Calculating yields and concentrations

Yield is the amount of product obtained from a chemical reaction, usually expressed as a percentage of the theoretical maximum. **Concentration** refers to the amount of solute present in a given volume of solution, often measured in molarity (moles per litre). Calculations of yield and concentration are essential for evaluating the efficiency of experiments and for comparing results with expected values.

Fill in the blank: Yield is usually expressed as a __________ of the theoretical maximum.

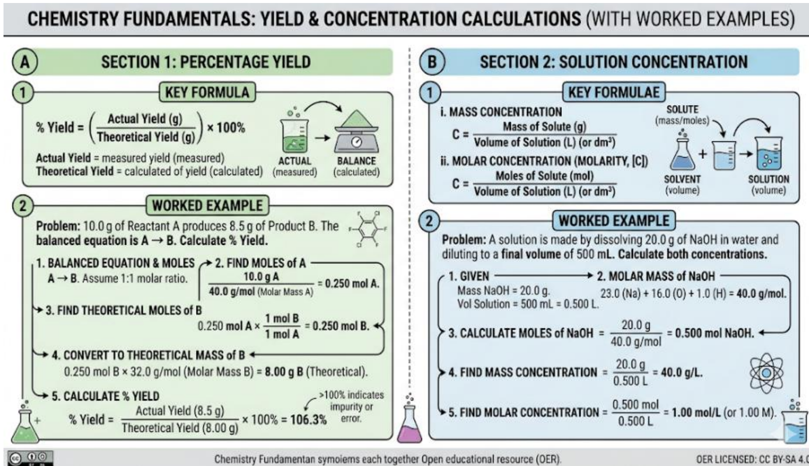
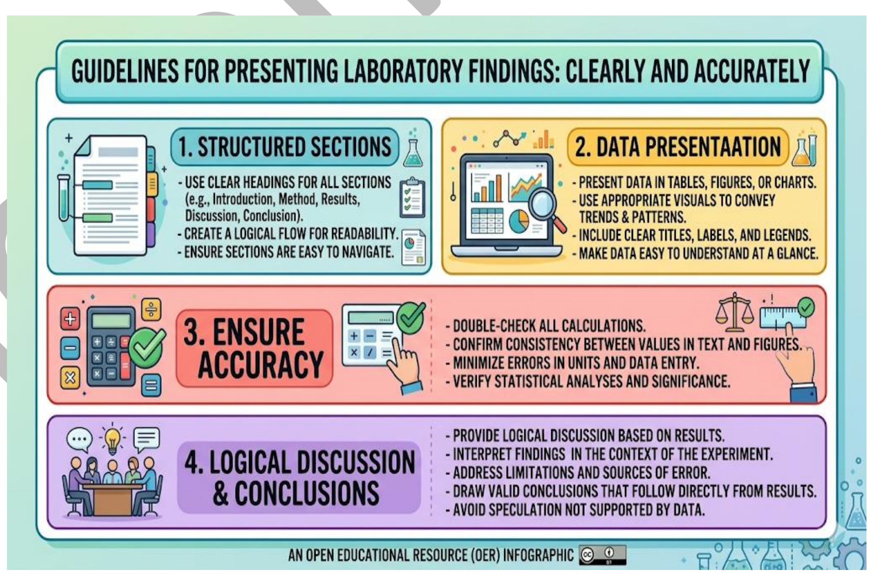


Figure 5.4 Calculating yield and concentration in organic analysis.

5.3.3 Presenting findings with accuracy and clarity

Presenting findings involves communicating results in a way that is accurate, clear, and meaningful. This may include writing laboratory reports, preparing charts, or giving oral presentations. Accuracy ensures that data reflects the true outcome of experiments, while clarity makes the information understandable to others. Reports should include objectives, methods, results, discussion, and conclusions, following standard scientific formats.

Fill in the blank: Presenting findings with __________ ensures that data reflects the true outcome of experiments.



Box 5.2: Guidelines for presenting findings

Pilot questions 5.3

1. Why are tables useful for recording quantitative results?
2. How is yield usually expressed in chemistry?
3. What unit is commonly used to measure concentration?
4. What sections should be included in a standard laboratory report?
5. Why is clarity important when presenting findings?

Series Summary

This Series has focused on functional group and quantitative analysis, which are essential skills for confirming the identity of organic compounds and measuring their properties with precision. We began by examining functional group tests, including methods for identifying amines, esters, and confirmatory tests for aldehydes and ketones. We then moved on to quantitative analysis, where you learned how to determine acidity and basicity through titrations, estimate functional groups such as hydroxyl and carbonyl, and apply gravimetric and volumetric approaches. Finally, we explored data interpretation and reporting, covering how to record results systematically, calculate yields and concentrations, and present findings clearly.

By completing this Series, you should now be able to demonstrate functional group tests, apply titration methods, estimate functional groups quantitatively, explain gravimetric and volumetric approaches, record and calculate results accurately, and present findings with clarity. These abilities directly align with the Series Learning Outcomes and ensure that you are well prepared to carry out functional group and quantitative analysis confidently in the laboratory.

Glossary of Terms

- **Acid–base titration**: A quantitative technique used to determine the concentration of an acid or base in a solution by neutralising it with a standard solution.
- **Aldehydes**: Carbonyl compounds with the carbonyl group (-CHO) at the end of a carbon chain, identified by tests such as Tollens' reagent which produces a silver mirror.
- **Amines**: Organic compounds derived from ammonia, where one or more hydrogen atoms are replaced by alkyl or aryl groups.
- **Carbonyl group**: A functional group consisting of a carbon atom double-bonded to an oxygen atom (C=O), found in aldehydes and ketones.
- **Concentration**: The amount of solute present in a given volume of solution, often expressed in molarity (moles per litre).
- **Esters**: Organic compounds formed from the reaction between an acid and an alcohol, often recognised by their fruity odours.
- **Fehling's solution**: A chemical reagent used to test for aldehydes, producing a brick-red precipitate when positive.
- **Functional group estimation**: Quantitative methods used to measure the number of specific groups such as hydroxyl (-OH) or carbonyl (C=O) in organic compounds.
- **Gravimetric analysis**: A quantitative method that determines the amount of a substance by measuring its mass, often after precipitation.
- **Hydroxyl group**: A functional group consisting of an oxygen atom bonded to a hydrogen atom (-OH), commonly found in alcohols.

- **Ketones**: Carbonyl compounds with the carbonyl group (C=O) located within the carbon chain, generally unreactive to Tollens' and Fehling's tests.
- **Recording results**: The systematic documentation of experimental data, often in tabular form, to ensure clarity and reproducibility.
- **Tollens' reagent**: A chemical solution used to test for aldehydes, producing a silver mirror when positive.
- **Volumetric analysis**: A quantitative method that determines the amount of a substance by measuring the volume of solution required to react completely with it, as in titrations.
- **Yield**: The amount of product obtained from a chemical reaction, usually expressed as a percentage of the theoretical maximum.

Concept Check Questions [Series 5: Functional Group and Quantitative Analysis]

Objective questions

1. Which reagent produces a silver mirror when testing aldehydes? (Linked to SLO 5.1)
   a) Fehling's solution
   b) Tollens' reagent
   c) Bromine water
   d) Hydrochloric acid
2. What is the main purpose of acid–base titration in organic analysis? (Linked to SLO 5.2)
   a) To identify functional groups
   b) To determine concentration
   c) To measure odour
   d) To produce precipitates
3. Which functional group is commonly estimated using acetylation followed by titration? (Linked to SLO 5.3)
   a) Carbonyl group
   b) Hydroxyl group
   c) Amino group
   d) Ester group
4. Gravimetric analysis determines the quantity of a substance by measuring its: (Linked to SLO 5.4)
   a) Volume
   b) Mass
   c) Colour change
   d) Odour

Short-answer questions

1. Define amines and describe one test used to identify them. (Linked to SLO 5.1)
2. State one difference between gravimetric and volumetric analysis. (Linked to SLO 5.4)
3. What unit is commonly used to express concentration in chemistry? (Linked to SLO 5.6)
4. Why are tables useful for recording quantitative results? (Linked to SLO 5.5)

5. What is yield and how is it usually expressed? (Linked to SLO 5.6)

Long-answer questions

1. Analyse the importance of functional group tests in confirming the identity of organic compounds. (Linked to SLO 5.1)
2. Evaluate the role of quantitative analysis in determining properties of organic compounds. (Linked to SLO 5.2, SLO 5.3, SLO 5.4)
3. Design a systematic approach for recording and presenting findings in organic compound analysis. (Linked to SLO 5.5, SLO 5.7)

Answers to Concept Check Questions [Series 5: Functional Group and Quantitative Analysis]

Objective questions

1. b) Tollens' reagent
2. b) To determine concentration
3. b) Hydroxyl group
4. b) Mass

Short-answer questions

1. Amines are organic compounds derived from ammonia. One test is reaction with nitrous acid, where primary amines release nitrogen gas.
2. Gravimetric analysis measures mass, while volumetric analysis measures volume of solution required for complete reaction.
3. Molarity (moles per litre).
4. Tables provide clarity, organisation, and easy comparison of data.
5. Yield is the amount of product obtained, expressed as a percentage of the theoretical maximum.

Long-answer questions

1. **Basic response:** Functional group tests provide direct evidence of specific groups such as amines, esters, aldehydes, and ketones.
   Value-added response: They also help distinguish between closely related compounds, guide further quantitative analysis, and confirm structural features essential for practical chemistry.
2. **Basic response:** Quantitative analysis measures acidity, basicity, and functional groups, ensuring accurate data.
   Value-added response: It also supports industrial applications, quality control, and research by providing reproducible and precise measurements that complement qualitative tests.
3. **Basic response:** Recording results systematically in tables and presenting findings clearly ensures accuracy and reproducibility.
   Value-added response: A robust approach includes structured laboratory reports with

objectives, methods, results, discussion, and conclusions, supported by charts or figures for clarity and effective communication.

Answers to Pilot Questions [Series 5: Functional Group and Quantitative Analysis]

Pilot questions 5.1 (Functional group tests)

1. Nitrogen gas.
2. The parent alcohol and acid.
3. Tollens' reagent.
4. Brick-red precipitate of copper(I) oxide.
5. Because their molecular structures often produce distinctive fruity odours.

Pilot questions 5.2 (Quantitative analysis of organic compounds)

1. To determine the concentration of an acid or base.
2. Hydroxyl and carbonyl groups.
3. Acetylation followed by titration.
4. 2,4-dinitrophenylhydrazine.
5. Gravimetric analysis measures mass, while volumetric analysis measures volume.

Pilot questions 5.3 (Data interpretation and reporting)

1. They provide clarity, organisation, and easy comparison of data.
2. As a percentage of the theoretical maximum.
3. Molarity (moles per litre).
4. Objectives, methods, results, discussion, and conclusions.
5. Because it ensures results are understandable and meaningful to others.

References and Attributions [Series 5: Functional Group and Quantitative Analysis]

General references

- LibreTexts Chemistry. (2020). *Organic qualitative analysis*. Retrieved from https://chem.libretexts.org
- Open Educational Resources (OER Commons). (n.d.). *Organic chemistry laboratory techniques*. Retrieved from https://www.oercommons.org
- Royal Society of Chemistry. (n.d.). *Practical chemistry: functional group and quantitative analysis*. Retrieved from https://www.rsc.org
- UNESCO. (2019). *Science laboratory safety and ethics*. Paris: UNESCO Publishing.

Illustrations

- *Figure 5.1 Nitrous acid test for amines*
  AI prompt: "Diagram showing nitrous acid reactions with primary, secondary, and tertiary amines, highlighting nitrogen gas release."
  Search string: "nitrous acid test amines OER diagram"
- *Plate 5.1 Hydrolysis of esters in the laboratory*
  AI prompt: "Photo-style image of ester hydrolysis experiment with test tubes and heating setup."
  Search string: "ester hydrolysis laboratory experiment OER photo"
- *Figure 5.2 Confirmatory tests distinguishing aldehydes from ketones*
  AI prompt: "Diagram showing silver mirror formation with Tollens' reagent and brick-red precipitate with Fehling's solution for aldehydes."
  Search string: "Tollens Fehling test aldehydes ketones OER diagram"
- *Figure 5.3 Acid–base titration for organic compounds*
  AI prompt: "Diagram of acid–base titration setup with burette, flask, and colour change indicator."
  Search string: "acid base titration setup organic compounds OER diagram"
- *Plate 5.2 Estimation of hydroxyl groups in organic compounds*
  AI prompt: "Photo-style image of acetylation experiment for hydroxyl group estimation in organic compounds."
  Search string: "hydroxyl group estimation acetylation titration OER photo"
- *Box 5.1 Comparison of gravimetric and volumetric analysis*
  AI prompt: "Infographic box comparing gravimetric and volumetric analysis with examples."
  Search string: "gravimetric vs volumetric analysis OER infographic"
- *Table 5.1 Example of tabular recording of titration results*
  AI prompt: "Simple table showing titration results with sample names, volumes, and concentrations."
  Search string: "titration results table OER chemistry"
- *Figure 5.4 Calculating yield and concentration in organic analysis*
  AI prompt: "Diagram showing formulae for calculating yield and concentration with worked example."
  Search string: "yield concentration calculation chemistry OER diagram"

Box 5.2 Guidelines for presenting findings
AI prompt: "Infographic box listing guidelines for presenting laboratory findings clearly and accurately."
Search string: "guidelines presenting laboratory findings OER infographic"