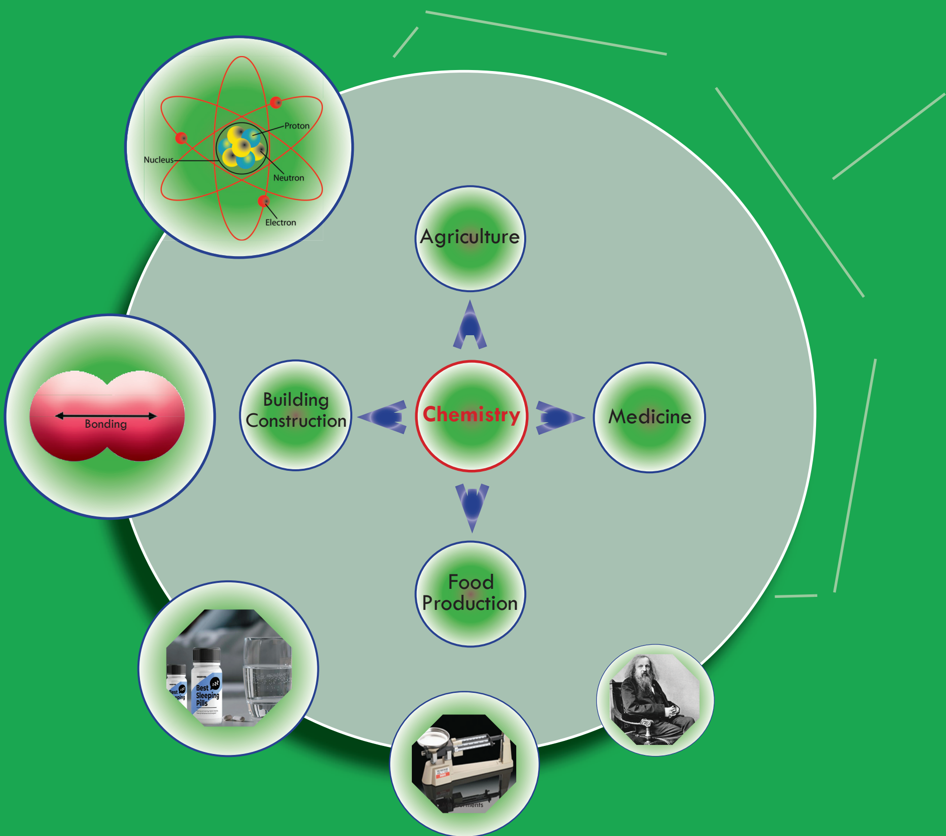
CHEMISTRY

TEACHER'S GUIDE

GRADE 9



FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
MINISTRY OF EDUCATION

CHEMISTRY

TEACHER'S GUIDE
GRADE 9

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Introduction

The study of chemistry at the beginning of secondary school, prepares your students for the future nation building, both practically and philosophically. Studying chemistry provides students not only with specific concepts and theories in chemistry, but also with tools, confidence and attitudes for constructing their future prosperous society. Besides learning to think efficiently and effectively, your students come to understand how chemistry deals with the daily and routine lives of theirs and the citizens at large. On a higher level, the role of chemistry is also significant nationally as well as internationally.

To materialize the above stated major goals, encourage the students to apply high-level reasoning, and values to their daily life and also to their understanding of the social, economic, and cultural realities of the surrounding context. In turn, this will help the students to actively and effectively participate in the wider range scope of the development activities of their nation.

At this cycle, the students are expected to gain solid knowledge of the fundamental theories, rules and procedures of chemistry. It is also expected that they should develop reliable skills for using this knowledge to solve problems independently. To this end, the specific objectives of chemistry learning at this cycle are to enable them to:

- gain a solid knowledge of chemistry.
- appreciate the power, elegance and structure of chemistry.
- use chemistry in their daily life.
- understand the essential contributions of chemistry to the fields of engineering, science, and economics at large.

Recent research gives strong arguments for changing the way in which chemistry has been taught. The traditional teaching-learning paradigm has been replaced by active and participatory student-centered model. A student-centered classroom atmosphere and approach stimulates student's inquiry. Your role in such student-oriented approach would be a mentor who guides the student constructs their own knowledge and skills. A primary goal when you teach a concept is for them to discover the concept by themselves, particularly as you recognize threads and patterns in the data and theories that they encounter under the teacher's guidance.

You are also encouraged to motivate students to develop personal qualities that will help them in real life. For example, student-oriented teachers encourage students' self confidence and their confidence in their knowledge, skills and general abilities. Motivate your students to express their ideas and observations with courage and confidence. As the students develop personal confidence and feel comfortable they could motivate addressing their material to groups and to present themselves and their ideas well. Support students and give them chance to stand before the class and present their work.

Similarly, help them by creating favorable conditions for students to come together in groups and exchange ideas about what they have learned and about material they have read. In this process, the students are given many opportunities to openly discuss the knowledge they have acquired and to talk about issues raised in the course of the discussion.

Teamwork is one of the acceptable ways of approach in a student-centered classroom setting. For example, some experiments are performed by more than one student. Each student has a crucial role – one student might be responsible for carefully handling and mixing chemicals and another student may make quick and accurate measurements during the process.

This teacher's guide helps you only as a guide. It is very helpful for budgeting your teaching time as you plan how to approach a topic. The guide suggests teaching-time periods for each subject you will teach. The guide also contains answers to the review questions at the end of each topic.

Each section of your teacher's guide includes student-assessment guidelines. Use them to evaluate your students' work. Based on your conclusions, you will give special attention to students who are working either above or below the standard level of achievement. Check each student's performance against the learning competencies presented by the guide. Be sure to consider both the standard competencies and the minimum competencies. Minimum requirement level is not the standard level of achievement. To achieve the standard level, your students must fulfill all of their grade level's competencies successfully.

When you identify students who are working either below the standard level or the minimum level, give them extra help. For example, you can give them supplementary presentations and reviews of the materials in the class. Extra time to study, and develop extra activities to those who are performing below the minimum level is commendable. You can also encourage high-level students with advanced activities

and extra exercises.

Some helpful references are listed at the end of this teacher's guide. For example, if you get an access for internet it could be a rich resource for you. Search for new web sites is well worth your time as you investigate your subject matter. Use one of the many search engines that exist – for example, Yahoo and Google are widely accepted.

Do not forget that, although this guide provides many ideas and guidelines, you are encouraged to be innovative and creative in the ways you put them into practice in your classroom. Use your own full capacity, knowledge and insights in the same way as you encourage your students to use theirs.

General Information to the Teacher

The students' text is designed and prepared based on the participatory approach of the teaching– learning process. At present, it is believed that students should gain most of their knowledge from the teaching – learning process on their own and some from the teacher. The teacher is expected to give guidance and the necessary assistance, play a role as facilitator, harmonize concepts, provide students with materials required, create a conducive atmosphere for the teaching – learning process and evaluate of students' performance. The teacher needs to assist students to discover facts, realize concepts, develop skills in performing experiments, solving problems etc. So, he/she should not dominate the teaching – learning process by giving lecture or explaining concepts throughout the period.

Thus, whenever you have contact with your students, you need to plan how to promote active – learning. The following information will help you understand what you are expected to do before and during the entire teaching – learning process.

1. Organizing Groups

You need to organize different groups in each section you are going to teach during your first contact with the students. To do so, you better have the list of all students in each section. You may organize the groups based on their seats, or on their ability as slow learners, medium and fast learners or by mixing them. After organizing groups, give them group numbers as group 1, group 2 etc. and register the names of students in each group. Every group needs to have a group leader and a secretary to jot down the main points during discussions. The groups as well as their members need not be permanent throughout the year. You can reorganize groups whenever necessary. You can do so per semester or mid-semester or even per month or two months etc.

2. Discussion

In all units, sections and subtopics, there are activities suggested for students to help them discuss and discover concepts. When you allow them to discuss points in each activity:

- follow up how every student participates in the discussion.
- be part of the discussion in some groups for a few minutes and see how the discussion among students is going on.
- give assistance and guidance when students are in need.
- give them hints when they face difficulties or have questions on the points suggested in the activities.
- ask questions related to the points in the activity to facilitate the interaction among students during discussion.

3. Presentation

Students are expected to present:

i) the concepts they gained during discussion in each activity in all units.

ii) their observation and analysis after performing experiments in groups to the class.

iii) the content prepared a specific topic. So you need to give emphasis to the following points in order to maximize student participation.

a. Groups should present their opinion turn by turn. For example, if you allow group 1 and group 2 to make a presentation on ***Activity 1.1***, the following groups 3 and 4 or others will present ***Activity 1.2*** etc.

b. Whenever a group gets the chance to make presentation for the second or third time, let other members of the group accomplish the task. Do not allow the same student from the same group to do so.

c. Give the opportunity to the rest of the class to ask questions or give their comments on the presentation of a particular group.

4. Experiment

Several experiments are suggested in the first three units. Most of these experiments should be performed by students. So, you are expected to accomplish the following tasks before or when students carry out the experiment.

a. To carry out the experiment by yourself before allowing students to do it.

a. To prepare chemicals and apparatus required for the experiment.

b. To give instruction on how students should handle chemicals and apparatus during every experiment.

c. To provide materials they need for the experiment.

d. Assist them whenever they have questions or difficulties in understanding the procedures suggested for the experiment.

e. Give instructions that students should perform the experiment only based on the procedures suggested for it.

f. Never allow them to conduct an experiment on their own other than the one they are supposed to do during the period.

g. Make them write a laboratory report in groups, present their observation to the rest of the class or submit it to you for correction as suggested in the students' text.

h. Make sure that every student in each group participates in the experiment.

5. Harmonizing Concepts

You are not expected to lecture throughout the period on most of the contents in the students' text. Your major role is harmonizing concepts suggested by students during presentations after discussing activities or performing an experiment with those they are expected to know. So, you need only to build a mini – lecture.

The concepts intended for students to discover in all activities, and answers to questions on the observation and analysis part of all experiments, are included as short notes in the subject matter presentation part of every section in this teachers' guide. So you are advised to use them. While harmonizing concepts in a mini–lecture, you better include other contents of the topic that have not been covered when students discuss activities.

6. Continuous Assessment

Previously, the performance of a student has been assessed in terms of his/her achievements in quizzes, tests, homework, mid – semester and semester final examinations. Although these evaluation techniques are useful tools for the assessment, they may not give a clear picture of the performance of a student. Therefore, a student's work should be assessed throughout every topic, section and unit as well as during each period. So, you need to have a record of every student's work as a student performance list. You can make a record about each student in the performance list, based on the following points.

- Involvement in discussions.
- Participation in presentations after discussion.
- Participation in answering questions during the process of harmonizing concepts or stabilization.
- Role of the student in performing experiments.
- Role of the student in presenting concepts gained from the experiment.
- Presentation of the project work.
- Presentation of research and writing.
- Presentation of topics given to the group as homework.
- Answering questions accordingly given as
  - class work
  - homework
  - quizzes
  - tests
  - mid – semester and semester final examinations

Here, it is very important to note that the assessment system is continuous assessment. That is, every performance of the student during the teaching-learning process should be given value and contribute its own share, as do quizzes, tests, mid-semester and semester final examinations, to the semester total. You are empowered to decide the percent of the contribution. However, your decision should not violate either the policy of the Ministry of Education or that of the Education Bureau of the regional state or that of your school.

7. Additional Questions

Some questions are given in this teachers' guide in each section before the answers to the exercises in the section. Use the questions indicated by an asterisk (*) for students working below the minimum requirement level, while students working above the minimum requirement level can attempt all of them. Give these questions as class work for fast learners after they complete their work during each period so that they will not sit idle and the period will not be boring for them.

8. Giving Note

You are not expected to write notes on the board related to the contents in each section. You need to give short notes on those contents left for students to discover after discussing the suggested activities and performing experiments. Be sure to offer any note that is available in the teachers guide, but not in the students' text. However you can write short notes related to the main points as you harmonize concepts. Tell students how they can take notes, either from the text or during the teaching learning process. Tell them the main points they should emphasize, in taking notes from the text. Also tell them to jot down the main points as fast as they can as you harmonize concepts or give a mini-lecture.

9. Answers to Exercise

In all units, the answers to the suggested exercise are given at the end of each section, and answers to the review exercises in each unit at the end of the unit. So you can refer to them whenever you are in need.

10. Suggested Methodologies

Teaching all contents of grade 9 chemistry requires implementing active learning methodologies. Active learning involves providing opportunities for students to participate in meaningful talk and to listen, write and reflect on the content, ideas, issues and concerns of an academic subject. It is more of a student activity. The teacher is a facilitator. The teacher guides and directs the students.

Rationale for active learning

- an increase in academic achievements
- an increase in critical thinking skills
- increased student retention
- a more positive attitude toward the subject matter
- improvement in communication skills

There are many methods that can be used to implement active learning. However, all of them are not suitable for teaching chemistry. So, some of the methodologies that can be used to promote active learning in teaching chemistry at this level are suggested as follows.

A. Gapped Lectures

You divide your lecture into small sections (lecture for a period of 15 minutes) and give the students a quick activity of 5 to 10 minutes. After the activity, you proceed with another 15 minutes lecture followed by another activity. The activities usually emphasize the concepts included in the lecture. For example, you can apply this methodology to teach the information on the atomic theory.

B. Cooperative (Collaborative) Learning

This is a form of group work and it is helpful in group project work and group assignments. This can be applicable for students in doing their group assignments or in doing suggested project work. For example constructing a model of atoms.

C. Group discussion

Is a simple interaction pattern in which 4 – 6 students work together on a given task and produce a written work or presentation. This method can be used in all sections and units at this level.

D. Demonstration

This is a method where the teacher shows the students how something is done. For example, preparation of iron sulphide from sulphur and iron.

E. Experiments

It usually involves a very specific and controlled method of procedures, where results are usually recorded. This method is applicable in performing laboratory experiments throughout unit 3 – 5 at this level.

F. Concept Map

It is a visual representation of ideas on any given topic. Students write the topic at the center of the page and then divide it into subtopics from which smaller branches will go off in different directions. For example, classification of matter into subatomic particles in unit one.

G. Question and Answer (Inquiry)

When this method is used, the teacher lectures and asks questions periodically relating to the information being given.

H. Spider Diagram

Students write a topic at the middle and write ideas related to the topic around the topic and draw a line connecting each idea to the central idea. For example, factors affecting rate of reactions.

I. Visual-based Active Learning

This method helps students learn using real object models, pictures, drawings and charts. For example, this method can help in teaching chemical bonding, periodic table.

J. Brain Storming

This is an activity in which students write everything they know or think about a given topic. The ideas might be right or wrong. This can be done individually, in pairs, small groups or as a whole class with the teacher or a student recording the ideas on the board. This method is used to find out what students already know on a topic before you start teaching. For example this method can be used while teaching importance of periodic classification.

K. Drawing a Picture, Map or Graph

This is a very useful way for visual learners to internalize, knowledge, concepts and information. For example, this method can be applied in unit 2, 5 etc.

You can use the following websites to get more information on active-learning methodologies.

i. http://www.ntlf.com/html/lib/bib/91-9dig.htm
ii. http:ctl.byu.edu/active-learning-techniques/
iii. http:pdfcast.org/pdf/strategies-to-incorporate-active-learning-into-onlineteaching
iv. http://ijklo.org/volume5/IJELLOv5p215-232Pundak669.pdf

11. Motivation of Students and its Importance

Motivation of students means getting students to exert a high degree of effort in their learning activities. The teacher is expected to motivate the students to create a conducive atmosphere for the teaching learning process. To motivate students, the teacher needs to encourage them to get ready for the lesson, appreciate students for their attempts in answering questions or any other activity they perform during the teaching-learning process and give them recognition. Motivating students helps the teacher.

- ☞ to pass information to students according to the plan
- ☞ to make students active participants
- ☞ make students realize concepts easily
- ☞ make his/her teaching interesting
- ☞ achieve the desired goals etc.

Motivation also helps students to

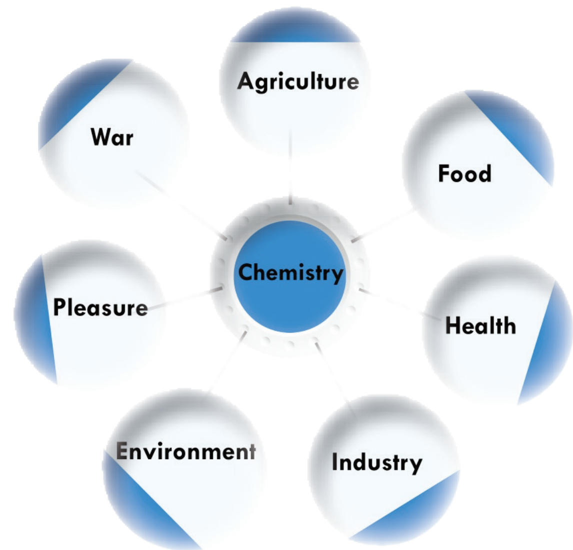
- ☞ follow the lesson attentively
- ☞ increase their participation
- ☞ enhance their understanding
- ☞ develop interest in the subject

- achieve good results in their performance

Implementing active learning methodologies has a role of its own in motivating teachers as well. It is not as tiresome as that of lecturing although; the teacher has a lot of tasks to accomplish when applying the methods. Using active learning methodologies during the teaching learning process motivate the teacher to:

- enjoy friendly and interesting relationships with students.
- develop new teaching skills by practicing the new teaching techniques, observing their results, and contrasting them with those of the old method of lecture-based teaching.
- become more interested in the teaching profession. For example, it is interesting and satisfying to develop new skills. The teaching-learning approach guides the teacher, helping him or her to develop professionally.
- investigate each student's talents and creativity. In this way, the teacher learns more about the age group of the students he or she teaches. This process is interesting in itself and helps the teacher develop professionally.
- guide students individually as they learn on their own. In this way, the teacher learns more about the dynamics of learning and also of teaching.
- actively engage in furthering the students' development. Because the students develop important social skills and attitudes, as well as increasing their knowledge and learning skills, the teacher has the satisfaction of contributing to their community and therefore to the country as a whole.
- expand his or her own creativity by developing appropriate presentations and assembling the apparatus and the local materials required for demonstrations and experiments.
- develops a greater interest in the teaching profession. As he or she assumes direct responsibility for each student's development.

CONTENTS



UNIT 1

CHEMISTRY AND ITS IMPORTANCE

1. STRUCTURE OF THE ATOM

Total Period Allotted 4

Unit Overview

Unit one has four sections.

Section 1.1 defines chemistry. It also briefly describes the scope of chemistry.

Section 1.2 describes the relationship between chemistry and natural sciences such as biology, physics, mathematics, medicine, and geology. It deals with the overlap between chemistry and other natural sciences making chemistry at the centre. Students have little understanding about the branches of science (chemistry, biology, and physics) and their relationships from grade 7, unit 1 lessons. They, therefore, need in depth discussion on this topic at this level as they will not have any content related to this in the higher grades.

Section 1.3 presents the role chemistry played in the production of useful materials. The central role of chemical knowledge in improving agricultural productivity, production and processing of food, contribution to improved health, environment protection, industry, and weapon production is presented in detail. It also deals with the role played by chemistry in society with special emphasis in providing comfort, pleasure, and luxuries. Environmental pollution and protection will be covered in grade 12, unit 5 "Introduction to Environmental Chemistry" in detail.

Section 1.4 presents some common chemical industries found in Ethiopia. The manufacturing of valuable products will be covered in Unit 3 "Industrial Chemistry", in grade 12. At this stage only the list of chemical industries found in Ethiopia and their products is presented.

It is your duty to encourage students to read the student's textbook before and after class. Every section begins with activities and ends with exercise questions which could help the student to grasp the outcomes of the topic in that specific section or sub-section and in the unit in general. It would be helpful if they read the contents and attempt to do all activities before coming to class.

The methods/techniques used in this unit includes, group discussion, visual-based active leaning, demonstration, collaborative learning, gapped lecture, question and answer, and more.

Unit Outcomes

At the end of this unit students will be able to

- define chemistry;
- describe its' scope;
- discuss the relationships between chemistry with physiscs, biology, medcine gology and other subjects;
- describe the application of chemistry in the field of agriculture, medicine, food production and building construction;
- name some common chemical industries in Ethiopia and their product.

Main Contents

1.1 Definition and scope of chemistry
1.2 Relationship between chemistry and other natural sciences
1.3 Role played by chemistry in production and society
1.4 Some common chemical industries in Ethiopia
Answers to the Review Exercises

Teacher, read the student's textbook before presenting each lesson to the students in order to get a good understanding of the contents of each lesson. Read also the teacher's guide to get guidance regarding the teaching aids needed, the methodology, handling students' activities, students' assessment, and continuous evaluation. It is your responsibility to plan how to handle the start-up activity, facilitate the group discussion, present the lesson, handle students' questions and time budgeting.

Assess the students' work throughout each period. Check how every student does during discussions, explanations, class work and homework. Evaluate whether or not most of the students have achieved the competencies suggested for the section. Appreciate students working above the minimum requirement level and give them extra work. Assist those working below the minimum requirement level by arranging additional lesson time or giving them additional exercises on points they didn't understand.

1.1 Definition and Scope of Chemistry

Period Allotted 1

Competency

At the end of this section students will be able to

- define chemistry
- Eexplain the scope of chemistry

Teaching Aid

Biscuit, salt, sugar, piece of cloth, paracetamol, orange, cosmetics ("እንሶስላ"), soap, sanitizer, etc. You can add more examples of substances that could support you in this lesson to show them examples of a substance and the scope of chemistry.

Subject Matter Presentation

The methods to be used in this section could be group discussion, gapped lecture, visual based active learning, question and answer.

One possible way of beginning this lesson is by making the students discuss the start-up activity. It is advisable to make a group of two or three for the discussion as students often sit in a group of two or three in class. This saves discussion time that was meant to spend by movement when they form large groups. It also saves space. You can make two to three students present their discussion points to the rest of the class. Giving time for the whole class to discuss might be advisable.

You may summarize the discussion points as follows:

The start-up activities were designed to make students grasp the meaning and importance of chemistry.

For question #1 one way of tackling this question is tellling them that air, water, cloth, and food are made up of very small and invisible materials. It is also advisable to inform them that they will discuss in detail about these materials in Unit Three.

For question #2 you may need to inform them that these very small and invisible materials are undergoing changes as time goes owing to external forces.

For question #3 you may also inform them that the understanding of the materials form which every substance is made is crucial in order to protect the substances from being damaged, or to reproduce them, or change them in a way we want.

For question #4 consideration of some of the materials that most people do use in their day-to-day activities such as salt, cloth, sugar, soap, vinegar and others might be important. Informing them that these materials are manufactured by industries would help them understand the question more. The production of all of them involves the application of chemical knowledge. You may brief them the extent of the scope of chemistry in the society.

1.1.1 Definition of Chemistry

You may begin the lesson by asking students what 'chemistry' is. Make sure students have their textbooks with them in the class. Defining the term chemistry and making students discuss in groups the questions under ***Activity 1.1*** might help them understand the lesson.

After the students completed the discussions, you can invite two or three groups to present their discussion points to the rest of the students. You can also allow the rest of the students to add anything missing on the presentation made by the groups. Thereafter you can summarize the activities and the lesson as follows:

Informing them about the composition of table salt (NaCl) or sodium and chlorine followed by briefing them with the meaning of the concept 'composition' might help them understand better. It is the nature of something's ingredients or constituents; the way in which a whole or mixture is made up.

For activity question #2 most probably students shall provide the correct answer. You are encouraged to describe how the sugar molecules dissolve in a cup of tea. You can tell them that this is a type of physical change and one property of sugar. You may explain the meaning of the property of a substance. The property of a substance is its attribute, quality, or characteristic.

For activity question #3 it is by their properties that they can distinguish salt and sugar. Sugar has a sweet taste whereas salt is salty. Physically, sugar is relatively small crystalline solid whereas salt is a bit larger crystal.

Activity question #4 deals with chemical changes. It is obvious to the students that when wood burns in fire, it forms flame, smoke, and a residual ash. You may describe what happens when wood burns in terms of change in the composition of the wood. Wood is a mainly composed of carbon and hydrogen. Air contains oxygen and when they come together through the application of heat energy, the wood will be converted into carbon dioxide and water. The residual ash is calcium carbonate, potash, phosphate and some trace metals.

You may tell them that wood is changed in structure and is transformed into carbon dioxide, water and the constituents of ash. At this stage, it is better if you define the terms 'structure' and 'transformation of a substance'. You may also tell them that the heat used in burning the wood is a form of heat energy. Then defining the term 'Energy' might help you clarify the concept Energy.

The overall change in the course of burning the wood is a substance change. Tell them that this change is associated with releasing heat to the surrounding just as burning the wood releases heat.

You can show them some of the substances you brought as a teaching aid so that they could get the impression that everything around them is a substance. Encourage them to ask questions if in case they have mis conceptions or misunderstandings. Explain the misconceptions or the misunderstandings they have.

After defining and briefly discussing the activity questions in relation to the concepts that make up the definition of chemistry, you can ask students the questions under ***Exercise 1.1*** in order to check whether the students achieved the desired learning competency.

Answers to Exercise 1.1

1. **Chemistry** is the science that deals with the properties, composition, and structure of substances (elements and compounds), the transformations they go through, and the energy that is released or absorbed during these processes.
2. The **property** of a substance is its attribute, quality, or characteristic.

Composition is the nature of something's ingredients or constituents; the way in which a whole or mixture is made up.

The arrangement of and relations between the parts or elements of something complex is known as its **structure**.

The **transformation** of a substance is a marked change in form, nature, or appearance. A substance absorbs energy when exerted externally in the form of heat.

You can revise any concept if there is still misunderstanding or misconception by the students.

Scope of chemistry

You may make students to discuss the questions listed under ***Activity 1.2.*** Facilitate the group discussions by encouraging shy or timid students, providing hints whenever needed. Move around so that you can evaluate the performances of students in the group discussions. You can make three to four groups to present their discussion points to the rest of the class. This time be careful not to give the chance to the groups presented earlier. You may receive questions and additional points, from other groups. You can write down the relevant discussion points of students on the board to make work easy in your summary. You can summarize on the facts written on the student's textbook. Encourage students to take notes on the necessary points you have summarized and from the student's textbook.

Following students' presentation, you can summarize the lesson by associating the contents of the lesson with the activity questions as follows.

Activity question #1 you may tell them that they can use soap for cleaning dirt from cloth, detergents to clean dishes, and soap or hand sanitizers to clean hand. These are some of the chemical products they need in their everyday lives. You may tell them that the scope of chemistry includes food, health and sanitation facilities, saving the environment, increase in comfort, pleasure and luxuries, industry, and war.

At this point you can show them oranges as products of food that are produced through the use of fertilizers, biscuits, salt and sugar are the products of industry; paracetamol, soap and sanitizer as health and sanitation facilities; cosmetics and piece of cloth as an example of increase in comfort, pleasure and luxury.

Activity questions #2-4 are designed to describe the involvement of the scope of chemistry in the microscopic world which enabled human kind to produce the various goods.

Question #2 deals with measurement. The butcher cuts meat and weighs it in a balance. You can tell them measurement is one of the scientific methods we use in chemistry and related sciences.

Question #3 is about the chemical processes that are taking place in different manufacturing industries. All the substances mentioned in the question are made up of chemicals or they are chemical products that involve different disciplines of chemistry. At this stage you can define the different disciplines of chemistry.

Question #4 is about the metabolic processes that are taking place in the human body. They also belong to chemical reactions. They are the subject of 'biochemistry'. Now you can define the term 'biochemistry'.

You can inform them the fact that chemistry does not only improve life but it also brings problems to the human race and to the environment. It has been only recently, however, that we have also become painfully aware of a host of problems arising from this growth of technology. It is the solution of such problems that poses much of the challenge for chemistry in the future.

You can also inform them also the following as a quick remedy for the problem: minimize the production and utilization of those environmentally non friendly substances and replace them by environmentally benign substances to keep safe humanity and our planet in particular and the Universe in general.

You can inform them that they belong to the global citizenship and have the responsibility to keep it from damage. You can give more emphasis on the roles students need to play to keep the human race and the environment they are living safe. You can emphasize the fact that they should be heroes in this regard.

After completing your summary, you can ask students question #1 listed under ***Exercise 1.2***, orally. Listen to the students' responses and revise any misconception or misunderstanding. You can give questions 2-4 as a homework. You can use this as a formative assessment.

Encourage students to read about the next lesson i.e., 1.2 Relationship between chemistry and other natural sciences before coming to the next lesson. This is the self-reading assignment and helps them save time in the group discussion and have better understanding about the next lesson.

Additional Reading

The degree to which chemistry has changed civilization is evident everywhere. A good part of the clothing we wear, the automobiles we drive, and the other products we encounter daily are composed of materials that simply did not exist at the turn of the century. In recent years, the realization that a living organism is a complex chemical 'factory' has generated a strong interest in the study of biochemistry, and has brought great advances in our knowledge of the nature of life. Medicines which were synthesized in the laboratory and produced in pharmaceutical industries have made us healthier and, through the cure of disease, have prolonged our lives.

Chemistry, however, is not only involved in providing useful substances in the areas of development and technology, but it can also result in very dangerous substances that can negatively affect human being's life and the environment (eg. fluorochlorohydrocarbons, oxides of nitrogen, carbon, and sulphur). It has been only recently, however, that we have also become painfully aware of a host of problems arising from this growth of technology. It is the solution to such problems that pose much of the challenge for chemistry now and in the future. It is, therefore, first of all highly recommended to minimize the production of such types of chemicals. Secondly we need to reduce the utilization of those environmentally unfriendly substances. Thirdly replacing them with environmentally friendly substances will keep safe humanity and our Planet in particular, and the Universe in general. You will learn about the effects of chemical wastes on polluting the environment and the legitimate remedies in grade 11 in detail. It, however is necessary to not that we belong to global citizenship, and have the responsibility to keep it from damage. We must be heroes in this regard.

Answers to Exercise 1.2

1. Examples of chemicals or chemical products that are used in the following areas:

   Agriculture: farmers use fertilizers, pesticides, herbicides, etc. to increase food productivity.

   Food Production: Preservative chemicals are used to protect food from deterioration.

   Medicine: Health professionals use different medicines for different diseases and disinfectants to prevent infections.

   Building Construction: By providing building resources such as glass, steel and cement, chemistry helps in the construction of safer houses and multi-storey structures.

2. Some of the problems caused by dangerous chemicals affecting the environment.

   Potential health effects

   - organ damage.
   - weakening of the immune system.
   - development of allergies or asthma.
   - reproductive problems and birth defects.
   - effects on the mental, intellectual or physical development of children.

- cancer.
- mercury is carcinogenic.
- Nuclear energy is useful but the disposal of nuclear waste poses a serious problem to humanity.
- Phonograph records have added to our pleasure for listening to music but they are made of polyvinyl chloride. This is produced from vinyl chloride which can cause liver cancer in industrial workers.
- Antibiotics have eliminated infectious diseases but the overuse is very harmful. Chemistry has given drugs like LSD (lysergic acid diethylamide), cocaine, brown sugar. These prove to be a curse to the society.

3. Teacher reads the students answers and compare it with the problems they gathered from the internet. Make your judgment on the answers.
4. The solution to the problem caused by any toxic or hazardous chemical is either avoiding using it, or replacing it by another environment friendly chemical.

1.2 Relationship Between Chemistry and Other Natural Sciences

Period Allotted 1

Competency

- At the end of this section students will be able to discuss the relationship of chemistry with physics, biology, and geology.

Teaching Aid

Spider diagram showing the relationship of chemistry and other subjects. Put chemistry at the centre and connect all other natural science subjects around. You can have a large size of ***Figure 1.2*** (student textbook).

Subject Matter Presentation

In this section, you can use visual-guided active learning, group discussion, gapped mini- lecture, and question and answer methods of teaching.

You can begin the lesson by revising the previous lesson by asking questions from the homework (***Exercise 1.1***). You may give chance for students to respond to the homework questions, orally. You may use the first five minutes of the period for the revision and then you can introduce the topic of the day's lesson and brief them with the MLC.

You may arrange another better group considering gender and disability disparity. Do not forget recording these groups for you may use them for few weeks or days. It is your decision to reorganize groups because you have the knowledge of students' capabilities and problems. Now you can give them ***Activity 1.3*** for the group discussion. Do not forget encouraging, helping and giving them hints or clues whenever they get stuck. Carefully evaluate the performance of each student in the group discussion. You can gather the discussion points from the presentation of three or four groups and may draw a spider diagram on the board. You can ask other groups to add more if still they have more points. You may also allow them also to ask a question in case they have any on the presented points.

You can consider the relevant group discussion points and add more incase students missed some from the student's textbook in your gapped mini- lecture. You can use your spider diagram in the mini- lecture.

Activity question #1: Students will probably list down the subjects that are categorized under natural science as chemistry, physics and biology. You can add geology, medicine and biochemistry to the list. Following this you can define all of the aforementioned subjects.

Activity questions #2-4 is designed to show the relationship between chemistry and biology.

You can show them the fact that carbon dioxide from atmosphere, water and minerals from the earth, the heat and light from the sun, and the chlorophyl in the plants leaf will undergo a chemical reaction in order to produce glucose and energy. It is therefore impossible to understand how plants produce their own food without the prior knowledge of the chemical reaction that takes place during photosynthesis. This is another example of the overlap between chemistry and biology.

You may define the terms 'chemical physics', and 'geochemistry' and briefly explain the overlap between chemistry and physics and chemistry and geology.

You can ask students the questions under ***Exercise 1.3*** to stabilize the day's lesson. Give special emphasis to question number three. Make sure that you gave opportunities for slow, medium and fast learners so that you can check their MLC achievement. Revise any misunderstanding as needed. You can give the next day lesson i.e., 1.3 Role played by chemistry in production and society as self-reading assignment.

Answers to Exercise 1.3

1. The aspects of nature are studied in;
   - Physics: properties of matter and energy.
   - Biology: the study of living things or about life.
   - Geology: the study of rocks and the earth.
   - Geochemistry: the study of the processes that control the abundance, composition, and distribution of chemical compounds and isotopes in geologic environments.
   - Biochemistry: the study of the chemical processes occurring in living matter.
   - Physical chemistry: concerned with the application of the techniques and theories of physics to the study of chemical systems.
2. The regions of overlap between;
   - Chemistry and biology: the chemical processes.
   - Chemistry and physics: chemical systems.
   - Chemistry and geology: the processes that control composition and distribution of chemical compounds and isotopes.

1.3 Role Played by Chemistry in Production and Society (Period Allotted 1)

Competency

At the end of this section, students will be able

- to describe the application of chemistry in the field of agriculture, medicine, food production and building construction.

Pre planning

Teacher read the student's text to get a clear understanding about role played by chemistry in production and society. Read also the teacher's guide to get guidance regarding the teaching aids needed, the methodology, handling students' activities, students' assessment, and continuous evaluation. It is your responsibility to plan how to revise the previous lesson, facilitate the group discussion, the presentation of the lesson, handle students' questions and time budgeting.

Teaching aid: food items (***Figure 1.3***), medicine (paracetamol & sanitizer), building construction (picture of GERD dam ***Figure 1.5***, piece of copper, piece of iron, your gold ring, sugar, paper, glass, plastic, cellphone camera), spider diagram (***Figure 1.6*** from student's text).

Subject Matter Presentation

Method used for the section could be: visual-aided active learning, group discussion, gapped mini- lecture, question and answer, collaborative learning.

You may begin the lesson through revision of the previous class lesson by reconsidering question number two of ***Exercise 1.3***. You may give chance for students to respond orally to the question. You can use the first five minutes of the period for the revision. Try to participate as many students as possible keeping gender balance and inclusiveness. Right after the revision of the previous lesson, you can brief the topic of the lesson and the MLC.

You can make students to discuss the questions under ***Activities 1.4 – 1.8***, in group. You may ask students to draw a spider diagram putting chemistry at the center and its role around it. You can make three or four groups to present their spider diagram to the class. You can use the students' responses to construct a large spider diagram showing the many different fields in which chemistry plays an important role, by putting 'chemistry' at the center and putting students' responses around it. Thereafter, you can summarize the contents of the topic by associating to the activity questions.

Activity 1.4 question #1: is designed to show the role of chemistry in agriculture. Students might reply correctly to this question by giving the common fertilizers that are used by the Ethiopian farmers. You can draw a spider diagram by putting 'chemistry' at the center and leaving empty circles around it so that students write their discussion points on them. ***Activity 1.5*** questions go along with this.

Questions #1-3 of ***Activity 1.5***: students are expected to list the common pests, the common herbs, and the commercial and traditional pesticides and herbicides used in their locality. You can include all these in the circle where 'agriculture' is written. All of these are the role chemistry played in increasing productivity of fruits, vegetables and crops. You can use ***Figure 1.3*** as visual-aid, as well.

Activity 1.4 questions #2-4 are designed to show them the role chemistry played in bringing improved health and in industry.

Question #2: house hold cleaning materials- soap, Dettol, detergents; baking powder or baking soda for baking 'diffo dabbo'; vinegar for disinfecting salad; table salt for preserving raw meat; different ointments for treating hair. Those substances used for cleaning, as disinfectant, and preservative are examples of substances used to improve health. You can tell them all of these are manufactured in industries and that the knowledge of chemistry is applied in all of them. You can also add also other industrial products such as textile, leather, glass, paper, cement, dye, etc. manufacturing.

Question #3: Students may provide you with the list of some modern and traditional medicines that are used to treat the various diseases. You can add more on their list from the student's textbook. This is an addition to the role chemistry played in health improvement. Give special emphasis to the traditional herbal medicines the students are listing. You need to add some traditionally used herbal medicines.

Question #4: You may tell them that kerosene, gasoline and diesel are the three commonly sold fuels in the gas stations. These are the products of the petroleum industry that are used in the transportation and energy sectors. Telling them the fact that these fuels are the products of fractional distillation of petroleum will support their learning.

Answers for Activity 1.6

Disinfectants: To kill the microbe present in toilets, floors, and drains. The sanitizers we use for Covid-19 belong to this group. As we all know, Covid-19 has no curative medication thus far. Due to this fact, the best way to protect humanity from this pandemic is frequently cleaning our hands by disinfectant or hand sanitizer. This could be considered as a medical emergency prevention means for the transmission of the dangerous pandemic, Covid-19. The Ethiopian Ministry of Health follows the principle "Prevention is better than cure" in protecting the citizens from the various diseases.

Analgesics: An analgesic or painkiller is any member of the group of drugs used to achieve analgesia, relief from pain. Examples of analgesics: acetaminophen, ibuprofen, naproxen, and paracetamol.

Anesthetics: Has made medical operations more and more effective via relieving pain. Examples of anesthetic drugs include: sevoflurane, desflurane, isoflurane, propofol (Diprivan®), ketamine, and etomidate.

Antibiotics: To control infection and cure diseases. Examples of antibiotics drugs include: phenoxymethylpenicillin, flucloxacillin, amoxicillin, cefadroxil, cefalexin, and gentamicin.

Antiseptics: To stop contamination of the wounds by bacteria. Examples of antiseptics

drugs include: chlorhexidine, povidone-iodine, chloroxylenol, isopropyl alcohol, hexachlorophene, benzalkonium chloride, and hydrogen peroxide. It is therefore advisable cleaning wounds when we get injuries as medical emergency.

Tranquillizers: To reduce tension and bring about calm and peace to patients suffering from mental diseases. Examples of tranquillizers include: phenelzine, noradrenaline, chlordiazepoxide, and iproniazid. Tranquilizers can relax a person's mind. In a higher dose, it leads to a sense of "free" and "high". Therefore, tranquilizers have been widely used by drug abusers. The frequent and without doctor's prescription use of prohibited drugs is very dangerous because it leads to addiction. The effects of drug addiction in society include increased crime rates, hospitalizations, child abuse, and child neglect. In this regard we should, therefore, protect ourselves and the society we are living in.

Insecticides: To reduce the dangers of diseases caused by rats, mosquitoes, and flies. Examples, lindane, aldrin, dieldrin, Dichlorodiphenyldichloroethane (DDD) and Dichlorodiphenyldichloroethylene (DDE). The use of these chemicals needs high level of care because they are dangerous for human health. It is therefore advisable to read carefully and follow the instructions written on the chemical packages. We know that safety comes first.

Show students the teaching aids you brought at each point of your lecture. Relate them to each of the roles that chemistry played. You may need to ask the following question in order to check whether students achieved the MLC of the day's lesson.
Oral question: List the major roles that chemistry plays in the society. (Answer: points A-G, student's textbook)

Show them the spider diagram (***Figure 1.6***) to sum up your mini- lecture. You can give ***Exercise 1.4*** as group assignment. This will be the second formative assessment and you need to rectify students' paper and give appropriate value. Encourage students to read the next lesson i.e., 1.4 Some common chemical industries in Ethiopia before coming to class, as homework.

Answers to Exercise 1.4

1. Consider the students' answers and make your own judgment.
2. Human life would be tough and full of problems and challenges. Different diseases, especially pandemic diseases like Covid-19, sars, HIV AIDS, Ebola, etc. would have killed more than we can imagine. Scarcity of food could have caused famine and

children would have been affected by deficiency diseases. The problem of air and water pollution would have been rampant. In general, life would have been much more challenging than it is today.

3. Chemical knowledge needs to increase so that toxic and hazardous chemicals that pollute the environment and endanger human life should be replaced by safer and environmentally benign chemicals. Chemical processes need to be efficient and effective. This needs the discovery of novel catalysts.

1.4 Some Common Chemical Industries in Ethiopia

(Period Allotted 1)

At the end of this section, students will be able to name some common chemical industries in Ethiopia and their products.

Teaching Aid

These are some of the examples of the industrial products: food item (corn or wheat), medicine (paracetamol and sanitizer), building construction ***Figure 1.5*** piece of copper, piece of iron, your gold ring, sugar, paper, glass, plastic, cell phone camera), pictures of industries (***Figures1.7)*** and table 1.1.

Subject Matter Presentation

You can use the following teaching methods for this section: question and answer, group discussion, gapped mini- lecture, collaborative learning, and visual-aided active learning.

You can begin the lesson by considering the previous group assignment exercises as a revision. You may add other important points/questions as well. Encourage students to tell you orally their answers to the group assignment questions. Right after completing the revision, you can brief them the topic of the lesson and the MLC.

Give them ***Activity 1.9*** to discuss in group. Make sure that they form proper groups. Encourage the shy or timid students to actively engage in the group discussion. Give some hints for the slow learners to motivate them. Visit all groups and observe the progress of the discussion. Make three or four groups to present their discussion points to the class. Write the relevant answers on the board during the group work reporting time. Then stabilize them with gapped mini -lecture considering their relevant points and adding more from the student's text.

The questions under ***Activity 1.7*** are designed to help students understand that most of the substances around us are the products of chemical industries.

Question #1: students might list down some of the household chemicals or chemical products like salt, sugar, vinegar, baking soda, baking powder, bleaching agents, detergents, paints, kerosene, glass, plastic materials, oil, synthetic butter, cloth, plastic bags, light lamps, television, medicines, etc. Briefly show that some of them are chemicals and others are chemical products. Explain the difference between chemicals and chemical products.

Question #2: students might tell you some of the industries that produce the chemicals or chemical products. Tell them to look at ***Table 1.1*** large and medium scale chemical enterprises in Ethiopia. You may also add the common chemical product industries in Ethiopia, such as

- Cement (Mugher, Diredawa, Mesobo, Derba, Midroc, Dangote)
- Sugar (Metehara, Wonji, Finchaa, Omokuraz)
- Paper and pulp (Wonji)
- Pharmaceuticals (Addis, Ethiopia, Adigrat)
- Tyre (Horizon Addis Tyre)

Define the terms 'industry' and 'chemical industry'.

- An industry is defined as an economic activity concerned with the processing of raw materials and manufacture of goods in factories.
- The chemical industries comprise the companies that produce inorganic- and organic-industrial chemicals, ceramic products, petrochemicals, agrochemicals, polymers and rubber (elastomers), oleochemicals (oils, fats, and waxes), explosives, fragrances and flavors.

Question #3: students might list down some of the chemical industries or enterprises that are found in their locality. Make sure that they are listed under ***Table 1.1***. Briefly inform them that the Federal Government is highly engaged in expanding industries in the industrial parks. Show them the pictures of some of these industries (***Figures 1.7***). Show them also the chemical products you brought as a teaching aid.

Assessment

At the end of the mini lecture, you can ask questions #1 & #3 under ***Exercise 1.6*** to stabilize the lesson. You can also add more questions of your own to make sure that they achieved the MLCs of the lesson. You can give question #2 under ***Exercise 1.6*** as a group assignment.

Answers to Exercise 1.6

1. See the table "Common chemicals used in home" given below.
2. See the table "Common chemicals used in home" given below.

Common chemicals used in home.

Common name	Chemical name	Molecular formula	Use
Alcohol	Ethanol	C_2H_6O	Component of alcoholic beverages and in thermometers
Antiperspirant	Aluminum chlorohydrate	$Al_2Cl(OH)_5$	Used in perspirants and deodorants
Antifreeze	Ethylene glycol	$C_2H_6O_2$	Used as an automotive antifreeze
Aspirin	Acetylsalicylic acid	$C_9H_8O_4$	Pain killer
Baking powder	Sodium bicarbonate	$NaHCO_3$	Baking bread
Battery acid	Sulphuric acid	H_2SO_4	Lead-acid battery for cars
Bleach	Sodium hypochlorite	NaClO	Domestic bleach (Berekina)
Caustic soda	Sodium hydroxide	NaOH	Unblocking sinks
Chalk	Calcium carbonate	$CaCO_3$	Writing on black board
Diamond	Alloy of carbon	C	Ornament and glass cutting
Glycerin	Glycerol	$C_3H_5(OH)_3$	Ingredient of toothpastes, mouthwashes, skincare products, shaving creams, hair care products, soaps
Graphite	Carbon	C	The "lead" in pencil
Gypsum	Calcium sulphate hydrate	$CaSO_4.2H_2O$	Used in construction of interior walls and roofs of houses
Liquid paper	Titanium oxide	TiO_2	Correction fluid
Magnesia	Magnesium oxide	MgO	Antacid used in heartburn and score stomach
Marble	Calcium carbonate	$CaCO_3$	Construction of house and floor
Margarine	Partially saturated fatty acid	Various	Used as an ingredient in cooking, and with bread
Plaster	Calcium hydroxide	$Ca(OH)_2$	Used in construction including interior walls in houses
Potash	Potassium carbonate	K_2CO_3	Fertilizer
Salt (Table salt)	Sodium chloride	NaCl	Food additive, and preservative
Sand	Silicon dioxide	SiO_2	Construction
Silica	Silicon dioxide	SiO_4	Desiccant used for absorbing moisture in different product packaging including cloth
Sugar (Table sugar)	Sucrose	$C_{12}H_{22}O_{11}$	Food additive as sweetener
Teflon	Polymer of tetrafluoroethylene	$(C_2F_4)_n$	Non-stick coating for cookware
Vinegar	Acetic acid/ ethanoic acid	$C_2H_4O_2$	Food seasoning (additive) and various house hold cleaning

3. Refer to ***Table 1.1*** in the student text.

Project work: An industrial trip to the local industries

Objective: students will be able to visit a local chemical industry and present their observations to the class, in group.

Arrange an industrial tour so that students will see practically the raw materials, the chemical processes involved and the finished products in the industries that are located in their vicinity. After the trip, request the students to write a report and present it to the class, in group. Use the format given below for the students' report.

Format to be filled after the industrial tour

Name of industry	Name of town/ city	Raw materials and name of chemical process used	Finished product

Collect the report and evaluate it. Listen students' presentation and give feedback. Give test at the end of the unit. You can consider some of the review exercise questions in your test. Encourage students to do all the review exercise questions.

Answers to Review Questions

Part I: True/False Type Questions.

1. False – because it deals with the properties, composition, structure, and transformation of substances.

2. True
3. True
4. False – because it also involves macroscopic information.
5. False – because it is the study of carbon compounds.

Part II. Fill in the Blank Spaces.

6. Attribute, quality or characteristics
7. Composition
8. Structure
9. Energy
10. Physical chemistry
11. Analytical chemistry

Part III. Short Answer Type Questions

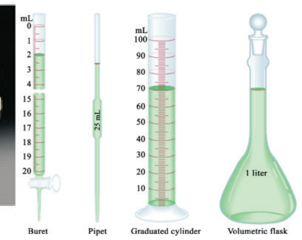
12. An industry is defined as an economic activity concerned with the processing of raw materials and the manufacture of goods in factories.

    The chemical industries comprise the companies that produce inorganic and organic-industrial chemicals, ceramic products, petrochemicals, agrochemicals, polymers and rubber (elastomers), oleo-chemicals (oils, fats, and waxes), explosives, fragrances, and flavors.

    The chemical products mean products manufactured, processed, sold, or distributed by the company/companies.
13. Supply of food, contribution to improved health and sanitation facilities, saving the environment, increase in comfort, pleasure and luxuries, industry and war.
14. By producing synthetic fibres, building materials, supply of metals for ornamental purposes, articles of domestic use, entertainment, transport and communication, and nuclear atomic energy.
15. Please have a look at ***Table 1.1*** for an answer. Since the number of chemical industries is too many, it is difficult to write them all here.
16. Analytical chemistry has the maximum scope because quality control and analysis are required in every type of industry.
17. Traditionally, chemistry has been broken into five main sub-disciplines: organic, analytical, physical, inorganic, and biochemistry.
18. The chemical sciences will likely be increasingly required to solve challenges in health, energy and climate change, water and food production. Chemistry might have a greater role in biochemistry and the pharmaceutical industry, as well as in the maintenance, and development of infrastructure.
19. Careers in chemistry
    - Analytical chemist.
    - Accountant/ Auditor pertinent to chemicals.
    - Chemical engineer.
    - Chemical development engineer.
    - Lecturer.
    - Environmental chemist.
    - Forensic researcher.
    - Forensic scientist.

UNIT 2

Triple-beam balance



MEASUREMENTS AND SCIENTIFIC METHODS

UNIT OVERVIEW

Total Period allotted: 15 periods

This unit reviews basic mathematical techniques and measuring principles that are important in problem solving and laboratory work. In addition, the factor-label method of problem solving is introduced and used throughout the unit.

SI measurement units are used throughout the text with few exceptions. SI is used to globally facilitate communication among people all over the world.

Briefing on the contents of the unit and the minimum learning competencies as it will be presented in the next sections. Before going to the topics you are expected to make a brainstorming session at the beginning by giving the students a chance to tell any indigenous way of estimating or measurement they know like measurement of length, mass, volume and so on.

Unit outcomes

Students will be able to

- use proper SI units;
- identify the causes of uncertainty in measurement;
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- apply scientific methods in solving problems;
- demonstrate an understanding of experimental skills in chemistry;
- demonstrate a knowledge of basic laboratory apparatuses and safety rules;
- describe scientific enquiry skills along this unit: observing, inferring, predicting, comparing & contrasting, communicating, analyzing, classifying, applying, theorizing, measuring, asking question, developing hypothesis, designing experiment, interpreting data, drawing conclusion, making generalizations and problem solving.

2.1 Measurements and Units in Chemistry

Total Period Alloted: 10 Periods

Learning competencies

At the end of this section, students should be able to

- list the seven SI units and their prefixes
- describe the seven SI units and their prefixes
- write the names and symbols of derived SI units
- use the factor label method for solving problems and making conversion of SI units.
- describe uncertainty of measurement
- identify the digits that are certain and the ones that are uncertain given a number representing measurement
- identify causes of uncertainty in measurement
- define precision and accuracy
- estimate the precision possible for any instrument they use in the laboratory
- explain systematic and random errors
- analyse given data in terms of precision and accuracy
- define significant figures
- determine the number of significant figures in a calculated result
- use the scientific notation in writing very large or very small numbers

Start-up Activity

The purpose of this start-up activity is to motivate students for active participation during discussions on the definition of chemistry. Therefore, form groups of students and engage them in discussing questions raised and them in presenting the consensus reached by the groups to the rest of the class.

Forward Planning

Teaching SI unit needs first familiarizing yourself with the system. It is possible to use supplementary materials to assist the teaching-learning process.

This section mainly deals with how data can be collected by chemists, and the data collected is used in computations. You can prepare countable items, measuring instruments such as balances, volumetric glassware, thermometers, rulers, clocks, etc,.

You should familiarize yourself with a wide variety of units of measured quantities. For example, volume could be measured and expressed in units such as cubic decimeter, cubic centimeter, gallon, liter, cubic foot, etc. You can also devise a technique to investigate the students knowledge of SI units.

Start the lesson using start-up activity by forming groups and let the students in group discuss and list down traditional way of measurement of mass and volume in the market or other places. Encourage students to meet what is expected from them after completing the lesson (the minimum learning competency). Let them mention indigenous methods used for measurement of mass, volume and time. Then you can invite some student to present their lists of traditional measurement methods to the class. After their presentations, make a class room discussion.

Teaching Aids

Read activities suggested under this topic thoroughly and prepare the materials required for yourself and let the students be ready ahead of time. You may prepare different objects with different mass, thermometers, meter sticks, graduated cylinders and also watches and balances of the same sensitivity.

Subject Matter Presentation

SI Units (The International System of Unit)

You can apply teaching methodologies such as discussion, experiment and independent work. In introducing this section, you may start discussion by emphasizing the importance of quantitative data in chemistry. Let your students notice that measured quantity without a unit attached to it is meaningless. For example, the distance between Addis Ababa and Hwassa is 275 is a meaningless statement unless units like km, mile, meter, etc are attached to it. Measurement, therefore, must be expressed both in numbers and units. Help students, to have a combined idea of English unit of measurements and SI units, of course giving emphasis to the SI units. This approach is preferable because students in their future careers are likely to encounter these non-SI nits. So do not hesitate to introduce the common English units. See the following examples of SI and English units:

Units of Mass	Units of Volume	Units of length
1 kg = 2.205 lb	1L = 1000 cm^3 = 1.057 qt	1 m = 39.37 in
1 lb = 453.6 g	1 m^3 = 1000 L	1 in = 2.54 cm
28.35 g = 1 OZ	1 gal = 3. 785 L	30.48 cm = 1 ft
1 metric ton = 1000 kg = 1.102 tons		1.609 km = 1 mi

Introduce that all numbers obtained as a result of counting carry the name of the item. For example, 25 students in a class room, 602 atoms of hydrogen, 12 eggs in a basket etc. Numbers that are obtained as a result of measurements taken should

be associated with a unit. For example, 12 kg of sugar, a 21cm stick, 56 seconds to leave etc.

For better illustration, organize your students into groups and ask each group to perform one of the following measurements. Encourage the students to perform each measurement very carefully. Let each student in a group measure and report accordingly:-

1. the mass of a pen, using any available balance, in grams;
2. the room temperature (in °C) of their working room;
3. the length of a desk in their classroom, using a ruler or meter stick;
4. 15 mL of water, using a graduated cylinder;
5. the time required to count numbers from 1 up to 100 (in seconds).

Give ***Activity 2.1*** for the same group and encourage the students to participate actively and report to the class. This activity is intended to familiarize students with SI units and measuring devices. After group discussion and presentations, briefly explain the way you view the activities, which may or may not be the same as the students' presentation.

For example, a meter stick is used for measuring length, a beam balance for measuring mass, a measuring cylinder for measuring the volume of HCl, a stopwatch to measure the time taken for a reaction, and a thermometer to record the temperature. The units used to express these physical quantities might be centimeter, gram, milliliter, minutes and degree centigrade, respectively.

Derived units

Let your students notice the difference between basic SI units and derived SI units. There are many examples in the student text to illustrate the mathematical relations described in this section. Let the students study independently the examples given. Support them whenever there is ambiguity in their understanding.

Emphasize dimensional analysis. You may prefer to use the phrases unit analysis or conversion factor for dimensional analysis. Investigate the knowledge of students, emphasizing:

- the importance of cancellation of unit
- the relationship between the conversion factor and its inverse
- the technique of keeping track of the status of a series of conversions
- the requirement, at times, to convert units in both the numerator and the

denominator of an expression.

Uncertainty in Measurement

You may use ***Activity 2.2*** in giving the lesson on uncertainty in measurements. Feel sure, you will come across different reports on the results of their measurements. This will help you to discuss with the students the impossibility of obtaining completely perfect measurements. I.e., it is impossible to obtain the exact value of any measurement. Indicate a margin of error when you come to the discussion on significant figures.

Precision and Accuracy

Your discussion on precision and accuracy can be done using ***Activity 2.3.*** Help students to pay attention and discuss on the fact that precision and accuracy are two important terms that describe reliability of measurements. You may ask the students first define the terms precision and accuracy. Help them to have a clear idea of the distinction of these two terms – precision and accuracy. Have the students perform this activity and discuss it in their groups. Then invite some students to present their answers to the class. After their presentations, make a class room discussion. After the discussion, please harmonize concepts suggested by the students with the truth as follows:

The measurements obtained from balances 1 and 3 are reproducible (precise) and are close to the accepted value (accurate), those obtained from balance 2 are neither. Even if the measurements obtained from balance 2 had been precise (if, for example, they had been 1.125, 1.124, and 1.125), they still would not have been accurate. We can assess the precision of a set of measurements by calculating the average deviation of the measurements as follows:

1. Calculate the average value of all the measurements:

$$\text{Average} = \frac{\text{Sum of measurments}}{\text{Number of measurments}} \quad (1)$$

2. Calculate the deviation of each measurement, which is the absolute value of the difference between each measurement and the average value:

$$\text{deviation} = |\text{measurement} - \text{average}| \quad (2)$$

where | | means absolute value (i.e., convert any negative number to a positive number).

3. Add all the deviations and divide by the number of measurements to obtain the average deviation:

$$\text{Average} = \frac{\text{Sum of deviations}}{\text{Number of measurments}} \quad (3)$$

Then we can express the precision as a percentage by dividing the average deviation by the average value of the measurements and multiplying the result by 100. In the case of balance 2, the average value is

$$average = \frac{1.125g + 1.158g + 1.067g}{3} = 1.117g$$

The deviations are

$|1.125g - 1.117g| = 0.008g$

$|1.158g - 1.117g| = 0.041g$, and

$|1.067g - 1.117g| = 0.050g$.

So the average deviation is

$$\frac{0.008g + 0.041g + 0.050g}{3} = 0.033g$$

The precision of this set of measurements is therefore

$$\frac{0.033g}{1.117g} \times 100 = 3\%$$

When a series of measurements is precise but not accurate, the error is usually systematic. Systematic errors can be caused by faulty instrumentation or faulty technique. Use Example 2.3 for stabilization of the concept.

Significant Figures

It is important to develop the use of significant digits. Using a calculator or computer requires that students apply some rules in making calculations in order to obtain answers with reasonable significant figures. There can be some disadvantages to being too strict in assessing students' answers. It is important that they understand a number of mathematical relationships and can perform operations based on them. Being too critical of the number of digits in the answer can be frustrating for students. As a result of these limitations, help the students to comply with the rules on how to express significant figures because a calculated quantity is no more precise than the data used in the calculation.

Organize students in groups and let them discuss significant figures, exact and measured numbers. Let students also discuss in groups on ***Activity 2.4***. At the end of their discussion ask them to describe how uncertainty and precision, as well as significant figures and precision, are related. Let them also differentiate between measured and exact numbers. After the discussion, please harmonize concepts suggested by the students with the truth as follows:

(a) distance between your home and school is measured number because it is known after measuring with some degree of uncertainty

(b) Number of oranges in a sack is exact number because we can count and tell their amount with no uncertainty

(c) Number of aspirin tablet in a strip is exact number and the explanation is the same as in (b)

(d) The volume of a glass of water is measured number and explanation is the same as in (a)

Assessment

Assessment of students' active involvement students in each of the activities is important. Each of the exercises in this section should be properly used to assess the students' mastery of each concept in the sections. Your student performance record list is helpful in all your assessments. Don't forget to appreciate students working above minimum requirement level. You may assist those working below the minimum requirement level. This can be done either by arranging extra class or by giving additional exercises.

Additional Questions

1. Convert 150 μm to cm.
2. How many significant figures are there in:
   (a) 204 kg
   (b) 1.003 g
   (c) 0.0802 cm
   (d) 90560 N
3. Use scientific notations to express:
   (a) 501 kg
   (b) 0.007 g
   (c) 476395 km
   (d) 0.0603 cm

4. Express the result of adding 456.5 g and 23.77 g to the correct number of significant figures.
5. Express the result of adding 0.102 cm and 13.6 mm to the correct number of significant figures.
6. Round off each of the following to three significant figures.
   (a) 61500 g
   (b) 0.00563 mL
   (c) 6417 m
   (d) 3.456 s
7. What is the total volume produced when 5.045 L of water is mixed with 3.34 mL of water?

Answers to Additional Questions

1. Recall that 1 cm = 10^{-2} m and 1 μm = 10^{-6} m. Consequently

$$\frac{1\mu m}{1cm} = \frac{10^{-6}m}{10^{-2}m} = 10^{-4}$$ or 1 μm = 10^{-4} cm.

Therefore, $150\mu m = 150\mu m \times \frac{10^{-4}cm}{1\mu m} = 0.015cm$

2.
   (a) Three: zeros between non-zero digits are significant.
   (b) Four: zeros between non-zero digits are significant.
   (c) Three: zeros preceding the first non-zero digit are not significant and zeros between non-zero digits are significant.
   (d) Ambiguous - four or five: The final zero may or may not be significant. The first four digits, including the first zero, are significant.

3.
   (a) 5.01×10^2 kg (just count how many places to the left you have to shift the decimal to give a number between 1 and 10, and this gives the exponent)
   (b) 7×10^{-3} g (just count how many places to the right you have to shift the decimal to give a number between 1 and 10, and this gives the negative exponent)
   (c) 4.76395×10^5 km
   (d) 8.02×10^{-2} cm

4. 456.5 (significant to tenths of a gram)

  + 23.77

  480.27

The result is significant only to tenths of a gram, so you round it off to 480.27 g.

5. You can observe that the units are not identical. One of these measurements has to be converted to the units of the other. Since 1cm = 10^{-2} m and 1 mm = 10^{-3} m, you get,

$$\frac{1mm}{1cm}=\frac{10^{-3}m}{10^{-2}m}=10^{-1}$$ or 1 mm =10^{-1} cm.

therefore $13.6mm = 13.6mm \times \frac{10^{-1}cm}{1mm} = 1.36cm$ and you can add the two quantities:

  0.102 cm (significant to a thousandth of a centimeter)

+ 1.36 cm (significant to a hundredth of a centimeter)

  1.462cm

The total can be significant only to a hundredth of a centimeter, so you must report it as 1.46 cm (or 1.46 cm × 10mm /1 cm = 14.6 mm).

6. (a) 6.15×10^4 g (c) 6.42×10^{-3} m

(b) 5.63×10^{-3} mL (d) 3.46 sec

7. 5.048 L (5048 mL)

Answer to Exercise 2.1

The solution of this problem can be obtained by using the relationship d=m/V. Putting the given mass and volume in the equation, we get

$$d=\frac{m}{V}=\frac{159g}{20.2cm^3}=7.87g/cm^3$$

Since this density is the same as the density of iron from the metals given, the wire is made of iron.

Answer to Exercise 2.2

We first use the relationship $^oC = K - 273.15^o$ to convert from kelvins to degrees Celsius, then we carry out the further conversion from degrees Celsius to degrees Fahrenheit.

$$^oC=(400K-273.15K)\frac{1.0^oC}{1.0K}=127^oC$$

$$^oF=\left(127^oC\times\frac{1.8^oF}{1.0^oC}\right)+32^oF=261^0F$$

Answer to Exercise 2.3

(a)

$$\%\text{ uncertainty} = \frac{\text{absolute uncertainty}}{\text{measurement}}\times100$$

% uncertainty = (0.1 torr)/(723.5 torr) ×100 = 0.014%

Absolute uncertainty: 723.5 torr ± 0.1 torr

Percent uncertainty: 523.5 torr ± 0.014%

(b)

% uncertainty = (0.05 g)/(2.75 g)×100 =1.82%

Absolute uncertainty: 2.75 g ± 0.05 g

Percent uncertainty: 2.75 g ± 1.82%

(c)

% uncertainty = (0.0002 g)/(2.7413 g)×100 = 0.0073%

Absolute uncertainty: 2.7413 g ± 0.0002 g

Percent uncertainty: 2.75 g ± 0.0073%

(d)

% uncertainty = (0.2 °C)/(75.6 °C)×100 = 0.3%

Absolute uncertainty: 75.6 °C ± 0.2 °C

Percent uncertainty: 75.6 °C ± 0.3%

(e)

% uncertainty = (0.4 mL)/(18.6 mL)×100 = 2.2%

Absolute uncertainty: 18.6 mL ± 0.4 mL

Percent uncertainty: 18.6 mL ± 2.2%

(f)

% uncertainty = (0.4 mL)/(43.7 mL)×100 = 0.9%

Absolute uncertainty: 43.7 mL ± 0.4 mL

Percent uncertainty: 43.7 mL ± 0.9%

Answer to Exercise 2.4

a) The expected mass of a 2-carat diamond is 2 × 200.0 mg = 400.0 mg. The average of the three measurements is 457.3 mg, about 13% greater than the true mass. These measurements are not particularly accurate.

The deviations of the measurements are 7.3 mg, 1.7 mg, and 5.7 mg, respectively, which give an average deviation of 4.9 mg and a precision of

$$\frac{4.9mg}{457.3mg}\times 100 = 1.1\%$$

These measurements are rather precise.

b) The average values of the measurements are 93.2% zinc and 2.8% copper versus the true values of 97.6% zinc and 2.4% copper. Thus these measurements are not very accurate, with errors of −4.5% and + 17% for zinc and copper, respectively. (The sum of the measured zinc and copper contents is only 96.0% rather than 100%, which tells us that either there is a significant error in one or both measurements or some other element is present.)

The deviations of the measurements are 0.0%, 0.3%, and 0.3% for both zinc and copper, which give an average deviation of 0.2% for both metals. We might therefore conclude that the measurements are equally precise, but that is not the case. Recall that precision is the average deviation divided by the average value times 100. Because the average value of the zinc measurements is much greater than the average value of the copper measurements (93.2% versus 2.8%), the copper measurements are much less precise.

$$Precision(Zn) = \frac{0.2\%}{93.2\%}\times 100 = 0.2\%$$

$$Precision(Cu) = \frac{0.2\%}{2.8\%}\times 100 = 7\%$$

Answer to Exercise 2.5

Significant figures

(a) Two, because each digit is a nonzero digit.

(b) Four, because zeros between nonzero digits are significant.

(c) Three, because zeros to the left of the first nonzero digit do not count as significant figures.

(d) Two, because the number is greater than one.

Answer to Exercise 2.6

1. Arithmetic operations

In addition and subtraction, the number of decimal places in the answer is determined by the number having the lowest number of decimal places. In multiplication and division, the significant number of the answer is determined by the number having the smallest number of significant figures.

(a)

$$\begin{array}{r} 11,254.1\ g \\ +\quad 0.1983\ g \\ \hline 11,254.2983\ g \end{array}$$ ← round off to 11,254.3 g

(b)

$$\begin{array}{r} 66.59\ L \\ -\quad 3.113\ L \\ \hline 63.477\ L \end{array}$$ ← round off to 63.48 L

(c) 8.16 m × 5.1355= 41.90568 m round off to 41.9 m

(d) $\frac{0.154kg}{88.3mL} = 0.000174405436kg/mL$ round off to 0.000174 kg/mL or 1.74×10^{-4} kg/mL

(e) First we change 3.27×10^2 cm to 0.327×10^3 cm and then carry out the addition

$(2.64\ cm + 0.327\ cm)\times10^3$. Following the procedure in (a), we find the answer is 2.97×10^3 cm.

Practice Exercise Carry out the following arithmetic operations and round off the answers to the appropriate number of significant figures:

a) 26.5862 L + 0.17 L, b) 9.1 g - 4.682 g,

c) 7.1×10^4 dm × 2.2654×10^2 dm,

d) 6.54 g ÷86.5542 mL, e) $(7.55\times10^4\ m) - (8.62\times10^3\ m)$.

The preceding rounding-off procedure applies to one-step calculations. In chain calculations, that is, calculations involving more than one step, we can get a different answer depending on how we round off. Consider the following two-step calculations:

First step: A×B=C

Second step: C×D=E

Let's suppose that A= 3.66, B = 8.45, and D = 2.11. Depending on whether we round off C to three (Method 1) or four (Method 2) significant figures, we obtain a different number for E:

Method 1	Method 2
3.66×8.45=30.9	3.66×8.45=30.93
30.9×2.11=65.2	30.93×2.11=65.3

However, if we had carried out the calculation as 3.66×8.45×2.11 on a calculator without rounding off the intermediate answer, we would have obtained 65.3 as the answer for E. Although retaining an additional digit past the number of significant figures for intermediate steps helps to eliminate errors from rounding, this procedure is not necessary for most calculations because the difference between the answers is usually quite small.

2. Significant Figures

We first check to see that the quantities to be added or subtracted are expressed in the same units. We carry out the addition or subtraction. Then we follow Rule 4 for significant figures to express the answer to the correct number of significant figures.

(a)

37.24 mL
+10.3 mL
47.54 mL is reported as 47.5 mL (calculator gives 47.54)

(b)

27.87 g
−21.2342 g
6.6358 g is reported as 6.64 g (calculator gives 6.6358)

3. Significant Figures (Multiplication)

The area of a rectangle is its length times its width. We must first check to see that the width and length are expressed in the same units. (They are, but if they were not, we must first convert one to the units of the other.) Then we multiply the width by the length. We then follow Rule 5 for significant figures to find the correct number of significant figures. The units for the result are equal to the product of the units for the individual terms in the multiplication.

A= l × w = (12.34 cm)(1.23 cm) = 15.2 cm^2 (calculator result = 15.1782)

Because three is the smallest number of significant figures used, the answer should contain only three significant figures. The number generated by an electronic calculator (15.1782) implies more accuracy than is justified; the result cannot be more accurate than the information that led to it. Calculators have no judgment, so you must exercise yours.

Answer to Exercise 2.7

Volume Calculation

We use the results of Example above to calculate the volume in each of the desired units.

$$V(\overset{0}{A}{}^3) = \frac{4}{3}\pi(1.10\,\overset{0}{A})^3 = 5.58\,\overset{0}{A}{}^3$$

$$V(cm^3) = \frac{4}{3}\pi(1.10\times10^{-8}\,cm)^3 = 5.58\times10^{-24}\,cm^3$$

$$V(nm^3) = \frac{4}{3}\pi(1.10\times10^{-1}\,nm)^3 = 5.58\times10^{-3}\,nm^3$$

2.2 Chemistry as Experimental Science

(Periods allotted: 5 Periods)

Learning competencies

At the end of this section, you should be able to

- define scientific method
- describe the major steps of the scientific method
- use scientific methods in solving problems
- demonstrate some experimental skills in chemistry
- describe the procedures of writing laboratory report

Planning

This section deals with chemistry as an experimental science. A complete understanding of the scientific method, experimental skills in chemistry and writing a laboratory report is extremely important prior to presenting the topic to students. Devise, plan and carry out simple activities stated in the textbook.

Teaching Aids

Diagrams are required to show some schemes and equipment. Students need to visit the laboratory and observe the equipments available there. Read activities suggested under this topic thoroughly and prepare the materials required for yourself and let the students be ready ahead of time.

Subject Matter Presentation

The Scientific Method

The lesson can be well established if the students are actively involved in ***Activity 2.5***. You may use the following hints to facilitate the discussion.

Hold equal-sized plastic bags stuffed with different items of your interest and ask questions like.

- What things might you want to know about this bag?
- How many objects are in the bag?
- How much does the bag weigh?

Handover the palstic bag with its content for each group of students. Students will guess the number, the kinds of items in the bag, the weight, etc. Using the framework of the students guesses, you introduce scientific terminologies. For instance, during the discussion of answers to the question of how many objects (items) are in the plastic bag, the numbers put forth are hypotheses. At this point, you define the scientific term. In addition, write hypothesis on the black board, list the numbers volunteered by students underneath the word. After asking many if not all of the groups to respond with a hypothesis about how many objects are in the bag, you ask "how do you determine which hypothesis, if any, is correct?" Usually, students will ask you to open the bag.

You then introduce the concept of data collection to determine if one's hypothesis is correct, etc.

Some Experimental Skills in Chemistry

When you treat section 2.2.2, let students discuss the issues related to safety they know like traditional way of preventing any kind of danger. Then give them lecture about laboratory safety discussed in the students' text.

Classify the students in group to perform ***Activity 2.6*** to list down the laboratory equipments they know that are not in ***Figure 2.9***.

Students should come to the practical session with their prelab report and note book for collecting data. Describe how measurement and data collection is performed. Detail notes are given in student's text and read thoroughly and explain to them. Following the procedures in the student's text let students perform in group density measurement through mass and volume measurement of different objects provided.

Writing a Laboratory Report

You can inform the students that there is a formal and conventional way of writing laboratory reports. Give them some time to read their textbook and then help them to write short and precise reports about their density measurement.

Assessment

Don't forget to assess students' active involvement in each of the activities. Each of

the exercises in this section should be properly used to assess the students' mastery of each concept in the sections. Your student performance record list is helpful in all your assessments. Appreciate students working above minimum requirement level. Don't forget to assist those working below the minimum requirement level.

Additional Questions

1. Does science stand on its own without any support? Is it the only way to know anything?
2. How is a hypothesis tested?
3. What must one be able to do with a theory?
4. Can a theory be proved?
5. What is experimental science?
6. Why chemistry is considered a science for everybody?
7. Who is known as the father of experimental science?

Answers to Additional Questions

1. The answer is an unequivocal no. Since science must be prevented from being weakened by disciplines other than science, for science cannot pull itself up by its own without help from other disciplines. Science is like the second story of a house; it cannot stand without the first story and the foundation underneath.
2. You make an experimental prediction that would be true if the hypothesis is true. You do an experiment, and then conclude.
3. A scientific theory is a unified set of principles, knowledge, and methods for explaining the behavior of some specified range of empirical phenomena. By using scientific theories, one must be able to observe, sense, understand and experience the world around him and to attempt to explain how the natural world works. A scientific theory must have some logical consequences we can test against empirical facts by making predictions based on the theory.
4. The fact that a theory passed an empirical test does not prove the theory. The greater the number of severe tests a theory has passed, the greater its degree of confirmation and the more reasonable it is to accept it. However, to confirm is not the same as to prove logically or mathematically. No scientific theory can be proved with absolute certainty.
5. Science that uses what is known to try to prove ideas and concepts that are as yet untested.

6. Because chemistry is for everybody.
7. Galileo Galilee was and is sometimes referred to as "the father of experimental science." Galileo didn't take much on faith, rather, he tested his ideas through experiments.

Mass and Volume Measurement for the Determination of Density

(Formats for writing the laboratory Report

Report Name______________________Section_________

Part I: Measurements

A. Mass Measurements

	Trial 1	Trial 2	Trial 3
Mass of 50 mL beaker (assigned balance), g	______	______	______
Average mass of beaker, g		______	
Mass of 50 mL beaker (second balance), g		______	
Mass of 50 mL beaker (third balance), g		______	

Volume Measurements

Water temperature and density ______ °C ______ g/mL

	Transfer pipet	Graduated Cylinder	Beaker
Volume of water (direct reading)	______	______	______
Number of significant figures for volume	______	______	______
Mass of beaker + water, g	______	______	______
Mass of dry beaker, g (average from Part A)	______	______	______
Mass of water, g	______	______	______
Volume of water calculated from mass, mL	______	______	______

Volume Measurements

Water temperature and density ______ °C ______ g/mL

	Trial 1	Trial 2	Trial 3
Mass of flask + stopper + water, g	______	______	______
Mass of flask+ stopper, g	______	______	______
Mass of water, g	______	______	______
Pipet volume, mL	______	______	______
Average Pipet volume, mL		______	
Relative average deviation, %		______	

Report Name______________________Section_________

Part I: Density

A. Density of a Metal Bar

	Trial 1	Trial 2	Trial 3
Mass of bar, g	______	______	______
Average mass of bar, g		______	
Method I Volume:			
Final level of water, mL	______	______	______
Initial level of water, mL	______	______	______
Volume of bar, cm^3	______	______	______
Density of bar, g $/cm^3$	______	______	______
Average Density of metal bar, g $/cm^3$		______	
Method II Volume:			
Dimensions: diameter, cm	______	______	______
height, cm	______	______	______
Volume of bar, cm^3	______	______	______
Density of bar, g $/cm^3$	______	______	______
Average Density of metal bar, g $/cm^3$		______	
Type of bar (Al, Cu, brass, etc.)		______	
Relative error, %		______	

Sample Calculations (Part II. A)

In the space below, include a sample calculation of each type necessary to obtain the results in the above table. This calculation should include the equation used, substituted values, and results. Arithmetic need not be shown. In performing the calculations, please be careful to record all measured numbers to the correct number of significant figures. Check your final answers to see that they are within the expected range: The metal bar will have a density between approximately 2.7 g/mL and 8.9 g/mL.

Report Name______________________Section_________

B. **Density of a Salt Solution**

	Trial 1	Trial 2	Trial 3
1. Mass of 20 or 45 mL solution + flask, g	______	______	______
Mass of flask, g	______	______	______
Mass of 20 or 45 mL solution, g	______	______	______
Volume of solution, mL	______	______	______

Density of salt solution, g/mL	________	________	________
Average density of salt solution, g/mL		________	
Relative average deviation, %		________	
2.Mass of cylinder + solution, g	________	________	________
Mass of cylinder, g	________	________	________
Mass of solution, g	________	________	________
Volume of solution, mL	________	________	________
Density of solution, g/mL	________	________	________
Average density of salt solution, g/mL		________	
Relative average deviation, %		________	

Sample Calculations (Part II. B)

In the space below, include a sample calculation of each type necessary to obtain the results in the above table. This calculation should include the equation used, substituted values, and results. Arithmetic need not be shown. In doing the calculations, please be careful to record all measured numbers to the correct number of significant figures. Check your final answers to see that they are within the expected range: The density of the salt solution approximates 1.1–1.2 g/mL. Be sure to include the units (g, mL, cm, or g/mL) with all data.

Answers to the Review Exercise

True/False Item	Multiple Choice
1. TRUE	8. (a) 0.47
2. FALSE	9. (c) 0.86 cm^3
3. TRUE	10. (a) 7.108 cm^3
4. TRUE	11. (d) All of the above
5. TRUE	12. (a) 7.5
6. FALSE	13. (a) 4
7. TRUE	14. (a) 216 cm^3
	15. (c) 25.06
	16. (c) 100.11 g
	17. (d) 1.00×10^{-6}
	18. (b) 3

19. (a) meter (m), (b) square meter (m^2) (c) cubic meter (m^3) (d) kilogram (kg) (e) second (s), (f) Newton (N), (g) Joule (J), (h) Kelvin (K).

20. (a) 10^6, (b) 10^3, (c) 10^{-1}, (d) 10^{-2}, (e) 10^{-3}, (f) 10^{-6} (g) 10^{-9}, (h) 10^{-12}

21. The density of an object is its mass per unit volume. You can express this as

$$d = \frac{m}{V}$$

where d is the density, m is the mass, and V is the volume. Some of the units chemists use include g/cm^3, g/mL etc.

22. $^{o}C = \frac{1.0^{o}C}{1.8^{o}F}(x^{o}F - 32^{o}F) = \frac{5^{o}C}{9^{o}F}(x^{o}F - 32^{o}F)$ and $^{o}F = \left(x^{o}C \times \frac{1.8^{o}F}{1.0^{o}C}\right) + 32^{o}F = \left(x^{o}C \times \frac{9^{o}F}{5^{o}C}\right) + 32^{o}F$

23. (a) 12343.2 g
   + 0.1893 g
   12343.3893 g   round off to 12343.4 g

   (b) 55.67 L
   - 2.36 L
   53.31 L

   (c) 7.52m × 6.9232 =52.062464m round off to 52.1 m

   (d) 0.0239 kg ÷ 46.5 mL
   = 0.000513978494624 kg/mL round off to 0.000514 kg/mL
   = 5.14×10^{-4} kg/mL

   (e) 5.21×10^3cm + 2.92×10^2cm
   = 52.1×10^2 cm + 2.92×10^2 cm = (52.1+2.92) × 10^2 cm
   =55.02 × 10^2 cm round off to 55.0 × 10^2 cm

24. (a) 26.5862 L
   + 0.17 L
   26.7562 L round off to 26.76 L

   (b) 9.1 g
   – 4.682 g
   4.418 g round off to 4.4 g

   (c) 7.1 × 10^4 dm × 2.2654 × 10^2 dm
   = 1.608434 × 10^7 dm^2 round off to 1.6 × 10^7 dm^2

   (d) 6.54 g ÷ 86.5542 mL
   = 0.075559591562 g/mL round off to 0.0756 g/mL
   = 7.56 × 10^{-2} g/mL

   (e) (7.55 × 10^4 m) – (8.62 × 10^3 m) = (7.55 × 10^4 m) – (0.862 × 10^4 m)
   = (7.55-0.862) × 10^4 m = 6.688× 10^4 m round off to 6.69 × 10^4 m

25. (a) 1 km = 10^3 m therefore, $18.5m = 18.5m \times \frac{1km}{10^3 m} = 1.85\times10^{-2} km$

(b) 1km = 10^3 m therefore, $16.3km = 16.3km \times \frac{10^3 m}{1km} = 1.63 \times 10^4 m$

(c) 1 kg = 10^3 g therefore, $247kg = 247kg \times \frac{10^3 g}{1kg} = 2.47 \times 10^5 g$

(d) 1 L = 10^3 mL therefore $4.32L = 4.32L \times \frac{10^3 mL}{1L} = 4.32 \times 10^3 L$

(e) 1dL = 10^{-1}L therefore $85.9dL = 85.9dL \times \frac{10^{-1} L}{1dL} = 85.9 \times 10^{-1} dL = 8.59dL$

(f) 1L = 10^3 mL=10^3cm^3 therefore,

$$8251L = 8251L \times 10^3 mL \frac{\times 1cm^3}{1mL} = 8251 \times 10^3 cm^3 = 8.251 \times 10^3 cm^3$$

26. (a) $K = {}^o C + 273.15^o = 283 + 273.15 = 556.15K$

(b) ${}^{'}C = K - 273.15^o = 15.25K - 273.15 = -257.9^0 C$

(c) ${}^o F = \left(x^o C \times \frac{9^o F}{5^o C} \right) + 32^o F = \left(32^o C \times \frac{9^o F}{5^o C} \right) + 32^o F = 89.6^0 F$

(d) First ^{0}F has to be converted to ^{0}C and then convert from ^{0}C to K. Therefore,

1000F in 0C, ${}^o C = \frac{5^o C}{9^o F}\left(100^o F - 32^o F\right) = 37.78^0 C$ in K units,

$$K = {}^o C + 273.15^o = 37.78 + 273.15 = 310.93K$$

27. (a) ${}^o C = \frac{5^o C}{9^o F}\left(0^o F - 32^o F\right) = -17.78^0 C$

(b) First ^{0}F has to be converted to ^{0}C and then convert from ^{0}C to K. Therefore, 98.6 ^{0}F in ^{0}C,

${}^o C = \frac{5^o C}{9^o F}\left(98.6^o F - 32^o F\right) = 37^0 C$ in K units becomes

$$K = {}^o C + 273.15^o = 37 + 273.15 = 310.15K$$

(c) First K has to be converted to ^{0}C and then convert from ^{0}C to ^{0}F. Therefore, 298K in ^{0}C, ${}^o C = 298K - 273.15 = 24.85^0 C$. Convert the result in ^{0}C to ^{0}F

$${}^o F = \left(24.85^o C \times \frac{9^o F}{5^o C} \right) + 32^o F = 76.73^0 F$$

(d) ${}^o F = \left(11.3^o C \times \frac{9^o F}{5^o C} \right) + 32^o F = 52.34^0 F$

28.

(a)

Perecent error = $\frac{|\text{True value - Experimental value}|}{|\text{True value}|}$ x100

Perecent error = $\frac{|0.798\text{g/mL} - 0.802\text{g/mL}|}{|0.798\text{g/mL}|}$ x100

= 0.5%

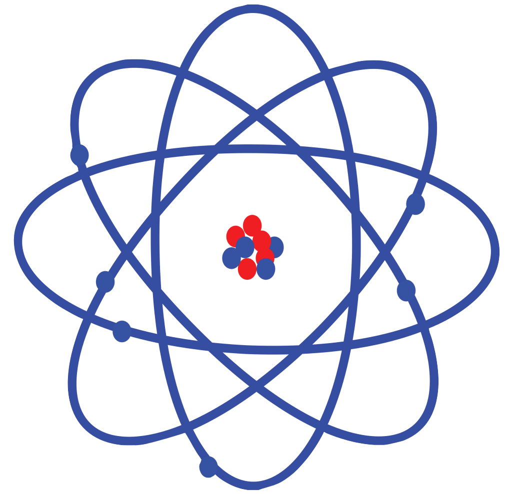
(b)

Perecent error = $\frac{|\text{True value - Experimental value}|}{|\text{True value}|}$ x100

Perecent error = $\frac{|0.864\text{g/mL} - 0.837\text{g/mL}|}{|0.864\text{g/mL}|}$ x100

= 3.1%

UNIT 3



STRUCTURE OF THE ATOM

3. STRUCTURE OF THE ATOM

Total Period Allotted 15

Unit Overview

Unit three has five sections:

Section 3.1 narrates the historical development of the Atomic Theories of Matter. Students have some understanding about the concept of matter and its properties, the particle nature of matter and the atom from their lessons in grade 7, unit 2. They also came across early thinking about the composition of matter in their grade 8, unit 2 lessons.

Section 3.2 presents the fundamental laws of chemical reactions. The Law of Conservation of Mass, the Law of Definite Proportions, and the Law of Multiple Proportions are the sub- sections discussed. In their grade 7, unit 3 lessons, students became familiar with how to write chemical formula, naming simple chemical compounds, and about simple chemical reactions and chemical equations. They covered also the definition of The Law of Conservation of Mass. In grade 8, unit 2 they were introduced about molecules as well.

Section 3.3 discusses Atomic Theories emphasizing Dalton's Atomic Theory and Modern Atomic Theory. The section presents briefly the chronological development of the Atomic Theory. It also briefly describes the merits and demerits of Dalton's Atomic Theory. Students are briefly introduced the short history of the concept of atom (Democritus' particulate nature and Aristotle's continuum) in their grade 8, unit 2 lessons.

Section 3.4 describes the discovery of sub -atomic particles. It briefly discusses J. J. Thomson's discovery of the electron and its charge-to-mass ratio, Rutherford's discovery of the proton and the nucleus, and the discovery of the neutron by James Chadwick. In addition to this, the various atomic models are covered in this section. Students will learn about the early experiments such as electromagnetic radiation, atomic spectra, and the quantum mechanical model of the atom that characterize the atom in grade 11, unit 1 lessons.

Section 3.5 deals with the composition of an atom and isotopes. The section briefly describes the electrons, protons, neutrons, atomic number, mass number, atomic mass, isotope, main energy levels, the electronic configuration on main shells, and the valence electrons of the first 20 elements in the periodic table. Students are familiar with the concept of relative mass, the charge and location of subatomic particles; atomic number and mass number; determination of electrons, protons and neutrons in an atom, for the first 10 elements of the periodic table, from their grade 8, unit 2 lessons. Writing the electronic configuration of elements using sub energy levels will be covered in grade 11, unit 1 lessons.

You are advised to encourage the students to read the student's textbook before and after class. Every section begins with activities and ends with exercise questions which will help the student to grasp the outcomes of the topic in that section or sub-section in particular and in the unit in general. It would be helpful if they read the contents and attempt to do all the activities before coming to class. Read also the teacher's guide to get guidance regarding the teaching aids needed, the methods, handling students' activities, students' assessment, and continuous evaluation. You have the responsibility to plan how to facilitate the group discussion, the presentation of the lesson, handle students' questions and time budgeting.

Assess the students' work throughout the section. Check how every student does during discussions, presentations, and answering exercise questions. Evaluate whether or not most of the students have achieved the competencies suggested for the section. Appreciate students working above the minimum required level and give them extra work. Assist those working below the minimum competency.

The methods used in this unit may include group discussion, visual-based active leaning, demonstration, collaborative learning, gapped lecture, question and answer, experimentation, and more.

Unit Outcomes

At the end of this unit, students will be able to

- discuss the development of Dalton's atomic theory and Modern atomic theory
- explain the discovery of the electron and the nucleus
- differentiate terms like an atomic number, mass number, atomic mass, isotope, energy level, valence electrons and the electron configuration
- develop skills in
  - determining the number of protons, electrons and neutrons of atoms from atomic numbers and mass numbers

- ➢ calculating the atomic masses of elements that have isotopes,
- ➢ writing the ground-state electron configurations of atoms using main energy levels and drawing diagrammatic representations of the atoms

☞ demonstrate scientific inquiry skills: observing, comparing and contrasting, communicating, asking questions, and applying concepts.

Main Contents

3.1 Historical Development of the Atomic Theories of Matter

3.2 Fundamental Laws of Chemical Reactions

3.3 Atomic Theory

3.4 Discoveries of the Fundamental Sub-atomic Particles

3.5 Composition of an Atom and the Isotopes

Structure of the Atom

Begin the unit by making students discuss the start-up activity. It is advisable to make a group of two or three for the discussion as students often sit in a group of two or three in class. You can make two to three students present their discussion points to the rest of the class. It will support learning if you give time for the whole class to discuss.

You can summarize the start-up activity discussion points as follows:
The start-up activities were designed to make students grasp the concept 'Atom' and how difficult it is to come up with its correct structure.

For question #1 students might reply 'Teff seed' or 'senafich'. It is a good attempt for we all know that these are the commonly known smallest seeds.

For question #2 briefly discuss that it is made up of solid particles compacted together. Elaborate them that if they crush the 'Teff seed', they will get a very small and uncountable solid particles known as flour. Stress how small the flour particles are.

For questions #3 and #4, it would be difficult for students to respond to the questions because it is difficult to visualize and figure out the inside and outside structure of 'Teff's seed'. It is also obvious that unless one uses a magnifying glass, no one can figure out its outside or inside structure.

Now you can associate this with the concept of the structure of the atom. Elaborate them that it took early chemists centuries to discover what the smallest particle of a substance is, and to come up with its correct structures.

3.1 Historical Development of the Atomic Theories of Matter

Total Period Allotted: 2 Periods

Competency

At the end of this section, students will be able to state briefly the history of the development of the atomic nature of substances.

Teaching Aid

Picture of the Greek philosophers Democritus, and Leucippus (from student's text, ***Figure 3.1***), the seed of '*habesha gommen*' also known as '*gommen zer*'.

Presentation of the Subject Matter

This lesson topic is designed for two periods. In the first period, you may provide students with general information regarding the topic of the unit i.e., the structure of the atom, briefly. Then you can move into the historical development of the atomic theories of matter. It would be good if you present the development of the concept that all matter is made up of four elements according to the Greek philosophers Empedocles, Plato, and Aristotle.

The methods used in this section could be group discussion, gapped lecture, visual-based active learning, question and answer.

It would support learning if you begin the section by asking students what an 'atom' is. Make sure students have their textbooks with them in the class. Following the definition of the term 'atom' you can make students discuss in groups the questions under ***Activiti 1.1***.

After the students completed the discussion, you can invite two or three groups to present their discussion points to the rest of the students. Encourage the rest of the students to add anything missing on the presentation made by the groups. Thereafter, you can summarize the activities and the lesson as follows:

Activity questions #1 and #2 are designed to challenge the students about what the smallest particle of every substance is. This will provoke thought in their mind as to how the structure of atoms was discovered.

Activity question #1 this question could be tough for students to answer correctly.

However, they might reply as, "The simplest components of wood are wood powder particles, cement for rocks and cells for a living organism." This is how they might stretch their thoughts.

Regarding Activity question #2 perhaps students might find it more difficult answering this question than the first question. This is because some of the substances are celestial and too far away to know their composition. Of course, they might respond to the components of water by saying, hydrogen and oxygen. They might also respond to the components of air saying, oxygen, nitrogen and carbon dioxide. "The composition of earth is the various minerals," they might say.

You can summarize the students' discussion points by associating it to the historical development of the atomic theories of matter. It will support learning if you narrate the historical development of the atomic theory as follows:

Brief them about the universe and how it has been changing from time to time. Following this, you can describe the fact that the world is under decay and the necessity to understand why and how it undergoes the decay. You may ask them the question, 'Is it possible to stop this change and keep our planet intact?'

At this stage, it will support learning if you consider Activity question #3 it is about the importance of knowing the nature of substances. In order to get an answer to these questions (the aforementioned and activity question #3) and others, they need to find the substance from which everything is made up of. This is where they may start and build up their understanding of the physical world. Clarify the objective of the unit.

- ☞ The main objective of this unit is, therefore, to understand the smallest particle from which everything is made up of.

At this stage, you can define the term theory and describe its importance in science. This will help you connect the term 'theory' with the term 'atom'. It will also help you clearly show the connection between scientific theories and the subject chemistry. Afterwards, you can delve directly into the historical development of the atomic theory.

Pause your mini- lecture and ask students the questions under ***Exercise 3.1***. Be inclusive and make to participate as many students as possible. Make sure that they are clear on what you have discussed so far.

Answers to Exercise 3.1

1. Air, water, earth and fire.
2. Plato (student of Socrates and teacher of Aristotle) adopted Empedocles theory and coined the term element to describe these four substances. His successor, Aristotle also adopted the concept of four elements. He introduced the idea that elements can be differentiated based on properties such as hot versus cold and wet versus dry.

The Greek Concept of Atomos

You can begin presenting this sub-topic by making students discuss the questions under ***Activity 3.2***, in groups of two or three. Let three or four groups present their discussion points to the rest of the class. Take more discussion points from other groups as well. Allow the whole class to discuss their answers to the questions.

After students finished discussing on the ***Activity 3.2*** questions, you can summarize the discussion points beginning from the activity questions. Hereunder is how you may do it:

The questions under ***Activity 3.2*** are designed to help students understand how the Greek philosophers came up with the name 'atom' or 'atomos' for the smallest indivisible particle.

For activity question #1 the most likely answer students would give will be powder for the solid non-living things, hydrogen, oxygen, or nitrogen for gaseous substances, and cell for living things. Perhaps they might also give other names.

Regarding Activity questions #2 and #3, listen to their justification and take notes. This will help you to tell them why the Greek philosophers named the smallest particle 'atom' or 'atomos'.

In your mini -lecture, describe and explain the five major points of Leucippus and Democritus.

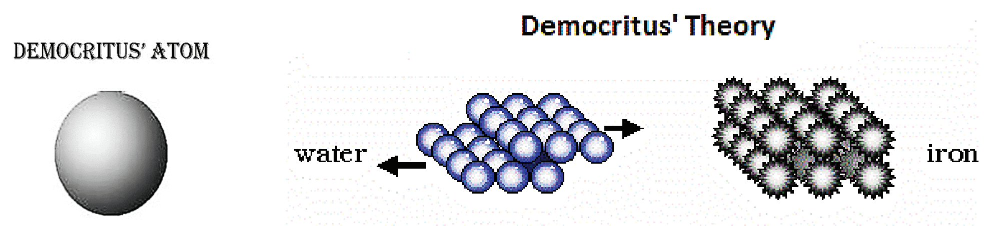
Brief the students with the opposition raised by Aristotle and other prominent thinkers on the Leucippus and Democritus atomic theory. Emphasize the contributions of John Dalton and Antony Lavoisier to the establishment of the science of modern chemistry. Describe the drawbacks of the early Greek philosophers and the reason why it took over two millennia before the theory of atoms was fully appreciated.

Accept if there is any question from students and explain them accordingly. You can ask the questions under ***Exercise 3.2*** to see students' achievement of the minimum learning competency (MLC). Clarify if still, students are not clear with some of the points discussed in the lesson. You can give a reading assignment for students to read about the fundamental laws of chemical reactions, in order to support learning.

Answers to Exercise 3.2

1. Around 440 BC, Leucippus of Miletus originated the atom concept. He and his pupil, Democritus (c460-371 BC) of Abdera, refined and extended it in future years. The work of Leucippus and Democritus was further developed by Epicurus (341-270 BC) of Samos, who made the ideas more generally known.
2. In Greek, the prefix "a" means "not" and the word "*tomos*" means "cut". The word atom therefore, comes from atomos, a Greek word meaning uncuttable.
3. i. All matter is composed of atoms, which are bits of matter too small to be seen. These atoms cannot be further split into smaller portions.
   ii. There is a void, which is an empty space between atoms.
   iii. Atoms are completely solid.
   iv. Atoms are homogeneous, with no internal structure.
   v. Atoms are different in their sizes, shape and weight.
4. Democritus even extended this theory suggesting that there were different varieties of *atomos* with different shapes, sizes, and masses. He thought, however, that shape, size, and mass were the only properties differentiating the different types of *atomos*. According to Democritus, other characteristics like color and taste did not reflect properties of the *atomos* themselves, but rather, resulted from the different ways in which the atomos were combined and connected. The generally accepted atomic model of Democritus is called "the solid sphere".

Mass of piece of paper + mass of oxygen = mass of CO_2 + mass of H_2O + mass of Ash



Seed of "*Habesha gommen*" also known as "*gommen zer*".

3.2 Fundamental Laws of Chemical Reactions

(Period Allotted 4)

Competencies

At the end of this section, students will be able to

- state the Law of Conservation of Mass and illustrate using examples.
- describe the Law of Conservation of Mass using simple experiments
- state the Law of Definite Proportions
- state the Law of Multiple Proportions

The time allotted for this section is four periods. The section is, therefore, divided into four sub- sections. The first section is about the Law of Conservation of Mass. Section two is a practical activity that deals with the application of the law of conservation of mass. It has two experiments. The first one is the reaction between silver nitrate solution and dilute hydrochloric acid while the second is the reaction between barium nitrate and sodium sulphate. The third section is about the law of definite proportions. The law of multiple proportions is in the fourth section. You may use the period allotted accordingly. It is, therefore, necessary to make the proper preparation to get the necessary the information and skills beforehand.

Presentation of the Subject Matter

The contents of these sub -sections are descriptive and experimental. The two experiments should be conducted in the laboratory. This therefore, needs your brilliance to use your time efficiently. Prepare all the suggested teaching aids before every lesson and use them at the right content. You may add more teaching aids or modify the ones suggested here as needed.

The suggested methods used in this section are group discussion, gapped lecture, visual-based active learning, question and answer, collaborative learning, and experiment (practical teaching).

3.2.1 The Law of Conservation of Mass

You might begin the presentation of this sub- section by defining the terms 'law', 'scientific law', 'chemical law', and lastly stating 'The Law of Conservation of Mass'.

You can make students to discuss the questions under ***Activity 3.3*** and make three or four groups present their discussion points to the rest of the students in the class.

Summarize the lesson as follows:

The questions under ***Activity 3.3*** are designed to help them understand the meaning of ‘law’ and the ‘Law of Conservation of Mass’.

Activity question #1 it is quite obvious that students will respond to this question by saying water flows from an area of high to low. Which of course is the right answer.
For activity question #2, students will also provide the right answer to this question. However, they may or may not justify their answer. You can agree with their answer but give more emphasis to the specific direction of water flow regardless of changing place. Briefly explain them that this is one of the ‘natural laws’ of nature. You can repeat the definition of the term ‘law’, to support learning. You can add the definition of ‘scientific law’ and ‘chemical law’. You may also need to describe the characteristics of a law to give students the right understanding of the essence of a scientific law.

Activity question #3 is about the “Law of Conservation of Mass’. Students may not be challenged too much to answer this question because it is a direct forward question. Since the sugar and the water cannot go anywhere other than forming the sugar solution. You can show them the mass balance by adding the mass of the sugar and the mass of the water being equal to the mass of the sugar solution. This is the application of ‘The Law of Conservation of Mass’ in physical change.

Activity question #4 seems obvious but students might find it difficult to answer it correctly. You may explain them that burning wood is a chemical change. In chemical change, substances undergo changes in the chemical nature and in energy. Burning wood involves releasing heat, water vapor and carbon dioxide into the atmosphere leaving ash behind. That is why the mass of the wood is not equal to the mass of the ash. Adding the mass of oxygen burning the wood, and equate it with the sum of the heat energy, water vapor, and carbon dioxide will be equal. This then demonstrates the ‘Law of Conservation of Mass’ in a chemical reaction. Now you can state the law of conservation of mass and explain its meaning briefly.

Narrate students when and by whom the law of conservation of mass is discovered. Provide the students with the alternative names of the law i.e., ‘The Law of Indestructibility of Matter’ or ‘The Law of Chemical Combination’.

Describe how the Law of Conservation of Matter eventually formed the basis of Dalton’s Atomic Theory of Matter. Support the statement of the law of conservation of mass through the examples in the student’s textbook.

At this stage, you can show students the meaning of the law in Chemistry i.e., in any

chemical change, one or more initial substances change into a different substance or substances. Both the initial and final substances are composed of atoms because all matter is composed of atoms. According to the law of conservation of matter, matter is neither created nor destroyed, so we must have the same number and kind of atoms after the chemical change as were present before the chemical change.

To show the application of the law of conservation of mass in physical changes, do the following experiment in the class. Weigh the 3 g sugar and the 50 mL water you brought as a teaching aid. Add the mass of the sugar and the mass of the 50 mL water. Dissolve the sugar in the 50 mL water. Weigh the sugar solution. Write the masses of the sugar + 50 mL water and the mass of the sugar solution on the board. Now, ask students to compare the two.

To show the application of the law of conservation of mass in chemical changes, you can do the following simple experiment (chemical reaction) in the class. The experiment is burning a piece of paper in a crucible. Here is the procedure you should follow. First weigh the piece of paper and the crucible (X g) you brought as a teaching aid, separately, using a balance. Then put the paper on the crucible and burn it using match. Now weigh the ash together (Y g) with the crucible. Subtract the mass of the crucible (X g) from the mass of the crucible and ash (Y g). This will be the mass of the ash. Write the masses of the piece of paper and its ash on the board and ask students to compare the mass of the piece of paper and the ash.

Explain the phenomena i.e., the masses of the sugar + 50 mL water and the sugar solution became equal because nothing disappeared during the formation of the sugar solution. But when burning the piece of paper; ash (in the form of powder), CO_2, and H_2O (in the form of vapor) are released into the environment. In addition to this, the mass of oxygen used by the fire during burning was not measured. Most of the reaction product dissipated into the environment. That is why the mass of the ash became low compared to the mass of the piece of paper. The law of conservation of mass would have been fulfilled if it was possible to hold the oxygen, CO_2, and water vapor, and include them all in the equation given below.

You can finish the lesson by orally asking the questions under ***Exercise 3.3***. Make sure that you avoided gender disparity and considered inclusiveness, while accepting answers from students. Explain if still, they have misunderstandings or misconceptions.

Answers to Exercise 3.3

1. Laws are generalized observations about a relationship between two or more things in the natural world.
2. Scientific laws or laws of science are statements based on repeated experiments or observations that describe or predict a range of natural phenomena.
3. The difference between a scientific law and a scientific theory: A scientific law doesn't explain why the phenomenon exists or what causes it. The explanation of a phenomenon is called a scientific theory.
4. Chemical laws are those laws of nature relevant to chemistry.
5. Antony Lavoisier discovered the law of conservation of mass.
6. The law of conservation of mass states that mass is neither created nor destroyed in chemical reactions. In other words, the mass of any one element at the beginning of a reaction will equal the mass of that element at the end of the reaction.

Experiments on the Law of Conservation of Mass

The objective of the experiments is to practically show the students the application of the law of conservation of mass in chemical reactions. These experiments also help students to develop a scientific attitude, the habit of working together, collaboration and being honest.

These are the things you need to do before students conduct the experiments in the chemical laboratory. Make sure that all the necessary materials and chemicals are available in the laboratory. Do both experiments yourself and make sure that the chemicals are still fine. Prepare a mini- prelab talk regarding the theoretical background of the experiments i.e., about the law of conservation of mass. Make a list of groups (2 to 3) for this laboratory session. Prepare enough laboratory report writing format in which students write their reports. Hereunder is the format you may use:

Laboratory Report Format

Group Number __________ Date of experiment: ______________________

Name of students:

1. ____________________________
2. ____________________________
3. ____________________________

Experiment number: ___________________

Title of experiment: ____

Materials used in the experiment: ______________________________________

Chemicals: ____

Objective of the experiment: ____

Chemical reaction: ____

Observation:

Mass of reactant: _____________

Mass of product: _____________

Colour of product: _________________

Physical state of product _________________

Conclusion: ____

____

____

____

____.

Caution: HCl and HNO_3 are corrosive. Avoid contact with the skin. If spilled on your skin, wash thoroughly with ample water, immediately. $NaNO_3$ should not be dried completely because it will cause explosion, otherwise. You should inform students about these precautions.

Answers to Observation and Analysis Questions

Begin the laboratory session by mini- prelab talk. The content of your talk includes concise information on the law of conservation of mass, the objective of the experiment, and the procedures. Advise students to take notes of their own observations while performing the experiments. Encourage them to be honest and work cooperatively. No student should be idle and do anything else other than the experimental activities. Remind them about the 'Dos' and 'Don't that they have learned in unit two. Do not leave them alone in the laboratory. Assist them all the time. Evaluate every student's performance. Inform them to do the exercise questions (*Exercise 3.4 & 3.5*) found under each experiment. Students must do both experiments in two separate laboratory sessions (periods). Students are required to bring a laboratory report a week after they experimented together with the exercise questions.

Answer to Observation and Analysis Questions of Experiment 3.1

Make sure that students measured the mass of the conical flask and its contents before and after the reaction. If the masses are closer to each other, then it is in agreement with the law of conservation of mass. Do not expect an exact mass balance between the reactants and products because there could be experimental errors.

Answers to Observation and Analysis Questions of Experiment 3.2

1. It should be closer to 2.33 g.
2. It should be closer to 1.70 g.
3. It should be closer to 200 g.
4. If the masses of the barium sulphate and sodium nitrate are closer to the theoretical results shown in answers 1 & 2 then it is in agreement.
5. Matter may not be created or destroyed.
6. The concept is a scientific law because it is based on experimentation.
7. Solution: For the reaction $KOH + CO_2 \rightarrow K_2CO_3 + H_2O$

According to the law of conservation of mass:

$$\text{Mass of } KOH + CO_2 = \text{Mass of } K_2CO_3 + H_2O$$

$$224.4\text{ g} + 88.0\text{ g} = X + 36.0\text{ g}$$

$$312.3\text{ g} = X + 36.0\text{ g}$$

$$X = 312.4\text{g} - 36.0\text{g}$$

$$\text{Mass of } K_2CO_3 = X = 276.4\text{ g}$$

You can consider the laboratory report as one of your formative assessments. You are, therefore, required to rectify it and give feedback to the students.

3.2.2 The Law of Definite Proportions

Teaching Aid

15 g of sugar; 1L distilled (bottled) water; 25, 50, and 100 mL beakers.

You can start this sub -section first by stating the 'Law of Definite Proportion' and then make students discuss the questions under *Activity 3.4*, in groups. Give time for three or four groups to present their discussion points to the rest of the class. Encourage other students to discuss the activity questions.

You can summarize the activity questions by adding more contents from the students' textbook, in your mini -lecture as follows:

The activity questions are designed to help students understand the meaning of a composition of a substance and the proportions of components in a substance. This will also help you as a springboard to discuss the 'Law of Definite Proportions.

With regard to activity question #,1 although their answers may vary, students will answer this question with little difficulty for 'shiro wot' is a common food in Ethiopia. For example, they might give the following list: onion, salt, some spices, shiro, water, etc. These are the components of 'shiro wet'.

Activity questions #2 and #3 are designed to help students to understand the meaning of the 'proportion' of a substance. For question #2 students will tell you the proportions of coffee powder and water although they might vary slightly. Similarly, students could provide the proportions of sugar/salt they are adding to the coffee before they drink it (question #3). Describe the meaning of proportion using the answers provided for the two questions. State the 'Law of Definite Proportion' and support it with the examples given in the students' textbook.

Use the local examples to elaborate the law.

- ☞ The Law of Definite Proportions illustrates that whatever the amount of water, whether it be 2 g or 54 g, the ratio of the amount of hydrogen to oxygen by weight will always be the same, just like the sugar:tea ratio in a 25 mL cup of tea should always be the same to get a tea which is consistent in colour, taste and flavour.
- ☞ Doubling the amount of sugar and tea will not change the sugar:tea ratio in order to prepare a cup of tea having the same colour, taste and flavour.

You can perform a simple experiment that gives the students the essence of the Law of Definite Proportions. Use the materials you brought as a teaching aid to do the following simple experiment in the class. Follow the following procedure.

- ☞ Take 2 g of the sugar you brought as a teaching aid, and dissolve it in 25 mL of distilled (bottled) water, in 25 mL beaker.
- ☞ Take another 4 g of sugar and dissolve it in 50 mL of distilled (bottled) water, in 50 mL beaker.
- ☞ Prepare a solution of sugar (6 g) and 75 mL distilled (bottled) water, in 100 mL beaker.

- Call five or more students to come to the front and make them taste all sugar solutions. Ask them if there is any difference in terms of the taste between the three sugar solutions.
- Explain why there is no difference in taste between the three sugar solutions by relating it to the Law of Definite Proportions. i.e.,
  - in the 25 mL beaker ,you added 2 g of sugar and 25 mL of distilled water making the sugar:water ratio 2:25.
  - In the 50 mL beaker, you added 4 g of sugar and 50 mL distilled water making the sugar:water ratio 5:50. Dividing by 5 will convert the ratio of sugar:water in the 50 mL beaker to 2:25.
  - Likewise, in the 100 mL beaker, you added 6 g sugar and 75 mL distilled water. This will provide us with a 6:75 sugar:water ratio. Dividing by 3 will give us a sugar:water ratio of 2:25. This is how the Law of Definite proportion works.

Now, you can show them how to solve a chemical problem associated with this law from the student textbook. You can use the solved problem in the student's textbook.

When you have finished your mini- lecture summary, you can question numbers 2 and 3 from ***Exercise 3.4*** as a classwork and make few students solve the problems on the board for the rest of the class. You may ask question number 1 under ***Exercise 3.4*** orally in order to check students' achievement of the MLC of the sub -section. Explain if still, students are not clear with the law.

Answers to Exercise 3.4

1. Law of definite proportions, also known as Proust's law or the law of constant composition states that every chemical compound contains fixed and constant proportions (by mass) of its constituent elements.
2. Solution:

   Mass of H_2O = 18 g; Mass of H in 18g of H_2O = 2 g; Mass of O in 18g of H_2O = 16 g

   Mass of H in 18g H_2O = 2g

   Mass of H in 25 g H_2O = ?

   Mass of H in 25 g of H_2O = (25 g x 2 g) ÷ 18 g = 2.78g

   Therefore, mass of O in 25 g H_2O = 25 g – 2.78 g = 22.22 g

   Now divide the mass of H and O by 2.78 to get the mass ratios. This will result in hydrogen to oxygen ratio of 1:8.
3. Solution:

   Mass of ethanol (C_2H_6O) = mass of C_2 + mass of H_6 + mass of O = 24 g + 6 g + 16 g = 46g

   Mass of C in ethanol 46 g = 24 g

   Mass of C in 25 g ethanol = ?

   Mass of C in 25 g ethanol = (25 g x 24 g) ÷ 46 g = 13.04 g

   Mass of H in ethanol 46 g = 6 g

   Mass of H in 25 g ethanol = ?

   Mass of H in 25 g ethanol = (25 g x 6 g) ÷ 46 g = 3.26 g

   Therefore, mass of O in 25 g ethanol = 25 g - (13.04 g + 3.26 g) = 8.7 g

   Now divide the masses of the three elements by the smallest number i.e., 3.26 to get the ratio of carbon to hydrogen to oxygen. This will result in 4:1:2.7 (C:H:O).

3.2.3 The Law of Multiple Proportions

Teaching Aid

Figure 3.4 (student's textbook).

You can start the presentation of the sub -section by stating 'The Law of Multiple Proportions'. Write the statement of the law on the board will support learning. Then you can make students to form groups of two or three and discuss the questions under ***Activity 3.5***. Allow three or four groups to present their discussion points to the rest of the class. Be fair in giving chances to present the discussion points in terms of inclusiveness and gender Allow students to discuss the activity questions for few more minutes. You can summarize the discussion points by associating with the 'Law of Multiple Proportions as follows:

The Activity questions are designed to provoke thought in the students' minds concerning the 'Law of Multiple Proportions'.

Activity question #1 is about finding two compounds that are made up of hydrogen and oxygen. This might be difficult for some students but others will respond easily. The compounds are hydrogen peroxide (H_2O_2) and water (H_2O).

Activity question #2 is about finding the mass-ratios of hydrogen and oxygen in the two compounds. This will be a bit difficult for students, but still there is a clue and smart students could answer it with ease. Explain them the mass-ratio of hydrogen to oxygen in H_2O_2 is 2:32. As ratios need to be written in a small whole number, dividing the ratios by 2 will convert the mass ratio to 1:16. Discuss the mass-ratio of hydrogen to oxygen in H_2O is 2:16, which will be converted to 1:8, likewise. In the molecules, the proportion of hydrogen remained constant, however, the proportion of oxygen varied. Consider the mass-ratio of oxygen in H_2O and H_2O_2 which is 8:16. Divide the ratios by the smallest number of the two i.e., 8 and this will convert the ratio to 1:2.

Activity question #3 is about the meaning of a small whole number. It will not be difficult for students to answer this question because they have learned about whole numbers in the preceding grade mathematics subject. The ratio of hydrogen to oxygen obtained in question #2 is a small whole -number ratio.

Now you can state the 'Law of Multiple Proportions' and discuss it with more examples from the student textbook. You can use ***Figure 3.4***, prepared as teaching aid to illustrate the first example. Describe how one gram of carbon combines with two different masses of oxygen in order to give CO and CO_2. Discuss the second example as well.

You can give students the diagram shown below as a classwork together with ***Exercise 3.7***. For ***Exercise 3.7***, give them the table given below the diagram. Let them fill the empty boxes for the diagram below and the empty columns in the table. You can give them in groups and allow three to four groups to present their answers to the class. Encourage students to ask questions if in case they are not yet clear.

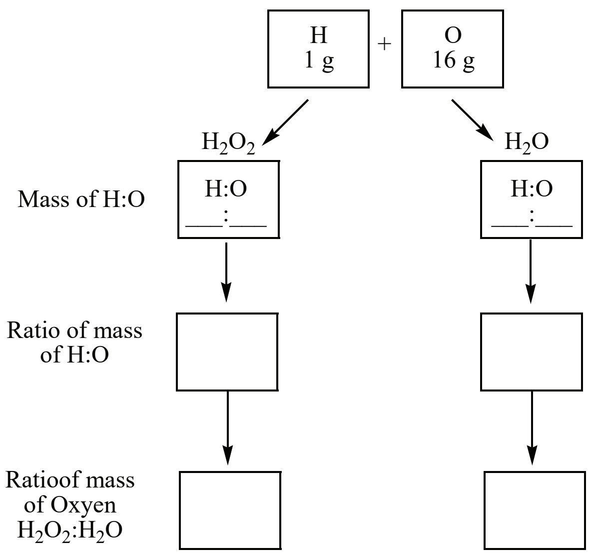


Table for *Exercise 3.5*

//	NO	NO_2	N_2O	N_2O_4	N_2O_5
1. Ratio of molar masses N:O					
2. Grams of oxygen combining with 1g of N					
3. Ratio of small whole numbers of O:N					

Answer for the diagram:

//	H_2O_2	H_2O
Mass of H:O	2:32	2:16
Ratio of mass of H:O	1:16	1:8
Ratio of mass of O that combines with 1 g of H	2	1

Answers to Exercise 3.5

//////////////////////////////////	NO	NO_2	N_2O	N_2O_4	N_2O_5
Ratio of molar masses N:O	14:16	14:32	28:16	28:64	28:80
Mass of oxygen combining with 1g of N	16/14 = 1.14	32/14 = 2.29	16/28 = 0.571	64/28 = 2.28	80/28 = 2.86
Ratio of small whole numbers of O:N	1.14/0.571 = 2	2.29/0.571 = 4	0.571/0.571 = 1	2.28/0.571 = 4	2.86/0.571 = 5

3.3 Atomic Theory

Period Allotted 3

Competencies

At the end of this section, students will be able to

- describe Dalton's atomic theory
- describe the modern atomic theory
- compare and contrast Dalton's atomic theory and the modern atomic theory.

The time allotted for this section is three periods. The section is, however, divided into two sub- sections. The first section is about Dalton's Atomic Theory. Section two deals with Modern Atomic Theory. You may use the period allotted following the Activity questions. It is, therefore, necessary to make the proper preparation to get the necessary information and skills beforehand.

Presentation of the Subject Matter

The contents of these sub- sections are descriptive and narrative. Prepare all the suggested teaching aids under each sub -section before the presentation of every lesson and use them for the right content. You may add more teaching aids or modify the suggested ones as needed.

The suggested methods used in this section include group discussion, gapped lecture, visual -based active learning, question and answer, collaborative learning, narration and description through mini- lecture, and classwork.

3.3.1 Dalton's Atomic Theory

Teaching Aids

A big picture of John Dalton (***Figure 3.5*** student's textbook); a bead (ዶቃ), a big picture of Dalton's symbols of elements and compounds (***Figure 3.6,*** student's textbook).

You can start the presentation of the sub -section by defining the terms 'Theory', 'Scientific Theory', and 'Atomic Theory'. Writing the definitions on the board will support learning. Then you can give the questions under ***Activity 3.6*** to the students to discuss in groups of two or three. You may give three or four groups the opportunity to present their discussion points to the rest of the students. Encourage the whole class to discuss the activity questions. In the end you can summarize the discussion points by answering the activity questions and adding more from the students' textbook.

This is what you may do in the mini summary lecture:

The activity questions are designed how to make a simple theory and to give an appropriate title for the theory.

Activity question #1 is about describing an orange for a friend who doesn't know orange at all. Inform them to consider the size, inside and outside shape, content, taste, and use of orange, in their description. You may also ask also what an orange is.

Activity question #2 is about describing the two colours of orange. Orange has two colours, green and orange. It is green when it is not ripe and becomes orange when ripe.

Activity question #3 is about giving an appropriate title for the description of the orange they have made. You may say 'The Theory of Orange'. Perhaps you may consider a better and more appropriate title from students as well. This is how to make a simple theory about orange. Then associate this to the concept 'Theory', 'Scientific Theory', and 'Atomic Theory'. You may need to redefine these terms and then move to 'Dalton's Atomic Theory'.

Briefly narrate the historic gap between the discovery of the atom by Democritus and the emergence of Dalton's atomic theory. You can put the picture of John Dalton on one side of the board so that all students could see it properly. Then describe the general tenets of John Dalton's Atomic Theory. Encourage students to do such significant work that they will be recognized nationally as well as internationally. Remind them that they are the ones whom our country is expecting to be heroes and become a Nobel Prize winner in Chemistry, sometime in future, just like the Prime Minister of Ethiopia, Dr Abiy Ahmed. He won the Nobel Prize for securing peace in the Horn of Africa in 2020.

You can show them a bead (ዶቃ) as a local example of Dalton's Atomic Model assuming that the bead is indivisible.

You may ask them the questions under ***Exercise 3.6*** to stabilize them with the lesson. Be aware of gender disparity and disability while putting questions to the students in the class. Make sure that they have achieved the MLC. Explain if there is confusion or misunderstanding.

Answers to Exercise 3.6

1. Dalton's findings were based on experiments and the laws of chemical combination whereas Democritus' discovery of an atom was a mere speculation.
2.
   - Elements are made of small particles called atoms.
   - Atoms can neither be created nor destroyed.
   - All atoms of the same element are identical and have the same mass and size.
   - Atoms of different elements have different masses and size.
   - Atoms combine in small whole numbers to form compounds.
3. From his experiments and observations, as well as the work from peers of his time, Dalton proposed a new theory of the atom. His experiments include; i) studies of the weights of various elements and compounds; from which he noticed

that matter always combined in fixed ratios based on weight, or volume in the case of gases. ii) He also noticed that chemical compounds always contain the same proportion of elements by mass, regardless of amount, iii) Dalton also observed that there could be more than one combination of two elements.

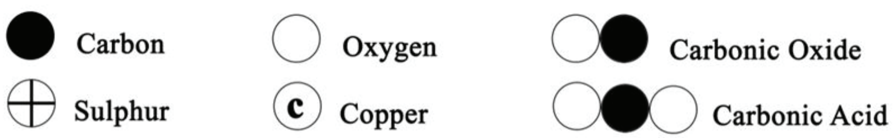
Describe the merits of Dalton's Atomic Theory. Show them some of the chemical symbols proposed by Dalton (***Figure 3.6,*** student's textbook).

To stabilize students in the day's lesson,you can ask the questions under ***Exercise 3.7***. Involve as many students as you can. Maintain gender balance and inclusiveness. Make sure that students achieved the MLC. If still there is misunderstanding or misconception, you need to elaborate more.

Answers to Exercise 3.7

1. Successes of Dalton's Atomic Theory:
   - The atomic theory explains the laws of chemical combination (the Law of Constant Composition and the Law of Multiple Proportions).
   - Dalton was the first person to recognize a workable distinction between the fundamental particle of an element (atom) and that of a compound (molecule).

2.



3. Because they are difficult to remember and draw.
4. The discovery of particles smaller than atoms doesn't mean that we should scrap the entire theory. Atoms are still known to be the smallest particles of elements that have the properties of the elements. Also, it is atoms-not particles of atoms-that combine in fixed proportions in compounds. Instead of throwing out Dalton's theory, scientists have refined and expanded on it.

3.3.2 Modern Atomic Theory

Teaching Aid

A big picture of J.J. Thomson, Robert Millikan, Goldstein, Ernest Rutherford, Niels Bohr, and James Chadwick.

You may start this section with students' group discussion. You can form group of two or three students and make them discuss the questions under ***Activity 3.8***. Allow three

to four groups to present their discussion points to the class. Encourage the whole class to discuss the activity questions.

When the students' presentation and discussion is over, you can summarize the lesson by starting with the students' answers to the activity questions. You can also add more information from the student's textbook.

The activity questions are designed to help them understand the long and tedious journey that scientists travelled to come to the modern atomic theory.

Regarding activity question #1 probably students will answer saying no. Listen to their justification and take note of their misconceptions for your later explanation.

Regarding activity question #2 they may answer the question based on their previous knowledge because they were taught about the atom and the subatomic particles (protons, neutrons and electrons).

Regarding activity question #3 some students might suggest the names of scientists who discovered some of the subatomic particles although not accurately. This question will help you lead to the day's lesson directly.

You can narrate the chronological development of the Atomic Theory beginning from the ancient Greeks.

Inform students of the fact that the detailed discussion of all the aforementioned discoveries of the sub -atomic particles is presented in Section 3.4. The discoveries by the aforementioned scientists proved Dalton's Atomic Theory wrong.

Describe the drawbacks of Dalton's atomic theory and then move into the postulates of modern atomic theory.

Inform them that they will learn in detail about isotopes and isbars in the near future. You can ask students the questions under ***Exercise 3.10*** to see if students achieved the MLCs.

Answers to Exercise 3.8

1. Comparison of Dalton's and Modern atomic theories.

Dalton's atomic theory	Modern atomic theory
Matter consists of small indivisible particles called atoms.	Atom is no longer indivisible, but consists of neutrons, protons and electrons.
Atoms of same element are alike in all respects.	All atoms have isotopes. It means some of the atoms of same element have different atomic weights..
Atoms of different elements are different in all respects.	Atoms of different elements are sometimes similar in some respects. For example, atoms of argon and calcium have same atomic weight.
Atoms combine in small whole numbers to form compound atoms (molecules).	Atoms in organic compounds do not combine in small whole number ratio. The molecules of proteins are highly complex.
Atoms can neither be created nor destroyed.	
Similarity: Atom is the smallest unit of matter that takes part in a chemical reaction.	

2. The postulates of modern atomic theory:

- Elements are made of small particles called atoms.
- Atoms cannot be created or destroyed during ordinary chemical reactions.
- All atoms of the same element have the same atomic number but may vary in mass number due to the presence of different isotopes.
- Atoms of different elements are different.
- Atoms combine in small whole numbers to form compounds.

3. D

4. i) divisibility of atoms into the three sub -atomic particles known as protons, neutrons and electrons; ii) the concept of isotopes is not considered; iii) the concept of isobars is not considered; iv) in complex molecules like sugar ($C_{12}H_{22}O_{11}$) and protein molecules, atoms combine in high whole number ratios; v) the theory fails to explain the existence of allotropes.

3.4 Discoveries of the Fundamental Sub-atomic Particles and the Atomic Nucleus

Period Allotted 3

Competencies

At the end of this section, students will be able to

- explain the discovery of electrons.
- explain the discovery of protons.
- explain the discovery of the nucleus
- explain the discovery of the neutron

The time allotted for this section is three periods. The section is, however, divided into four sub- sections. The first section is about the discovery of protons. The second sub -section deals with the discovery of electrons. The discovery of the nucleus and neutron are in the third and fourth subs sections respectively. You may divide the content into three parts based on the Activity questions. It is, therefore, necessary to make the proper preparation to get the necessary information and skills beforehand.

Presentation of the Subject Matter

The contents of these sub -sections are experimental but presented through description and narration. Prepare all the suggested teaching aids under each- sub section before the presentation of every lesson and use them at the right content. You may add more teaching aids or modify the suggested ones as needed.

The suggested methods used in this section include group discussion, gapped lecture, visual -based active learning, question and answer, narration, and description through mini- lecture.

3.4.1 Discovery of the Proton

Teaching Aid

Goldstein's perforated cathode ray experiment set up picture (***Figure 3.7***) and Goldstein's picture.

Starting this sub-section by making students discuss the questions under ***Activity 3.8***, in groups of two or three, would support learning. You can make three or four groups present their discussion points to the class. Encourage the whole class to discuss the questions. You can summarize the discussion points by associating them with the discovery of the proton.

The activity questions are designed to brainstorm them about how the negatively charged electrons of J. J. Thomson coexisted in his atomic model. This will provoke thought in the students; mind and rethink Thomson's atomic model. Which then would help you associate this with the discovery of the proton by Goldstein.

Activity question #1 is about the existence of repulsive force between objects having the same charge when they come close to each other. Students might have an understanding of the existence of repulsive forces between similar charges from their physics lessons.

Activity question #2 is about showing the basic problem of J. J. Thomson's Atomic Model. At this point, students realize the difficulty of the co-existence of electrons in an atom unless something holds them together. Challenge them so that they should think critically. Describe to them about the neutral nature of atoms. Inform them that they should have asked this question while discussing about Thomson's Atomic Model, if in case they did not.

Activity question #3 is a leading question to the discovery of the proton. Students cannot answer this question unless they have already read the contents of this sub -section before coming to class.

You may begin with the information that initiated scientists to discover protons. Following this you can explain how Goldstein discovered the anode rays or canal rays which are known today as protons. You can use the perforated cathode ray picture (***Figure 3.7***) at this point, as a teaching aid.

List down and discuss the properties of anode rays, based on the experimental findings. You may ask students the questions listed under ***Exercise 3.9***, to check whether they achieved the MLC's or not. Explain if still students are not clear with some points.

Answers to Exercise 3.9

1. Anode rays or canal rays were found in a stream of positively charged particles in contrast to cathode rays.
2. Protons.
3. i. Anode rays travel in straight lines. ii. They consisted of material particles. iii. They are deflected in electric and magnetic field in opposite to that of cathode rays. iv. The nature or e/m ratio of anode rays depends upon the nature of gas present in the cathode ray tube. v. They are (particles of anode rays) simply positively charged gaseous ions..

3.4.2 Discovery of the Electron

Teaching Aid

A big picture of ***Figures 3.8-3.15*** (from student's textbook).

You can begin the lesson by defining 'electron' and informing them who discovered them. Writing these on the board will support learning. Then you can give the questions under ***Activity 3.9*** to the students to discuss in groups of two or three. Allow three or four groups to present their discussion points to the class. Encourage the whole class to further discuss the discussion points for few more minutes.

You can summarize the discussion points beginning by answering the activity questions as follows:

The activity questions are designed to help them understand electric bulbs give light as a result of the movement of electrons through the gas in fluorescent lumps. It also shows the movement of electrons through filaments inside some bulbs that give light by glowing.

Activity question #1 it is obvious that the electric bulb gives light when the switch is on. Activity question #2, the electric bulb gives light as a result of the movement of electrons through the bulb. The type of light produced depends on the type of bulb used.

Activity #3, yellow lights result from those bulbs whose filaments glow because of the resistance against the movement of electrons. Essentially, the lightbulb is a very thin filament of hard-to-melt metal – tungsten, usually – encased in a glass bulb filled with inert gases so that the filament doesn't oxidise and disintegrate. The electricity (movement of electrons) causes the wire to glow and a portion of that energy is turned into light. A fluorescent lamp generates a white light from collisions in a hot gas ('plasma') of free accelerated electrons with atoms– typically mercury.

You can associate this with the discovery of electrons by J. J. Thomson. Crook is the first scientist who discovered the discharge tube. Describe the Crook's discharge tube or cathode ray tube. A very good example of the cathode ray tube would be a fluorescent bulb found in their home. You can show them the picture of the discharge tube (***Figure 3.8***) and the fluorescent bulb prepared as a teaching aid in addition to ***Figure 3.9***.

It is also necessary to let them know the danger associated with the mercury present in fluorescent bulbs.

Discuss Thomson's discharge tube experiments that led him to the discovery of the electron, briefly. You can use the figures of each experiment in your discussions. Describe the conditions used in the discharge tube experiments, as well.

Summarize J.J. Thomson's discoveries from his experiments. You may finish the presentation by asking the questions listed under ***Activity 3.10***. Make sure that students achieved the MLC of the lesson.

Answers to Exercise 3.10

1. In order to have less intermolecular attraction.
2. J. J. Thomson's second experiment was performed by placing a light paddlewheel between cathode and anode in order to study the particulate nature of the cathode rays. The movement of the paddle wheel proved the particulate nature of the cathode rays.
3. Upon passing through an electric field, the cathode rays bent towards the positive plate. Passing cathode rays in a magnetic field resulted in the deflection of the cathode rays perpendicular to the applied magnetic field. This proved that cathode rays are negatively charged particles.

J. J. Thomson's Atomic Model

Teaching Aid

A big picture of J.J. Thomson's atomic model (***Figure 3.14,*** student's textbook) and his picture, watermelon, knife, Millikan's oil drop experiment design (***Figure 3.15,*** student's textbook) and his own picture.

You may begin presenting the lesson by making students discuss the questions under ***Activity 3.10,*** in groups of two or three. You can make three or four groups present their discussion points to the rest of the class. Encourage the whole class to further discuss the discussion points.

After listening to the students' presentation on the discussion points, organize a mini-lecture, to summarize the lesson. You can begin the summary by answering the activity questions and associating them with Thomson's Atomic Model. The activity questions are designed to help them understand the concept 'model'.

Activity question #1 is about giving proper and enough description about orange. Students might answer by saying orange is a spherical, green or orange coloured fruit. It has thick skin. Its inside is watery and with compartments and several small seeds imbedded.

Activity question #2 is about drawing the inside and outside picture of the orange described in question #1. It would be good if students use colour to draw a good picture of an orange. The picture is a model of an orange. It is not a real orange, however, it gives a good impression of what an orange looks like.

Activity question #3 is about practicing what the atomic model of Democritus looks like by considering his atomic descriptions.

Activity question #4 would associate the activity questions with the J. J. Thomson's Atomic Model. Now describe Thomson's 'plum pudding. Atomic model. You can use the picture of the plum pudding and Thomson's model at this stage. Cut the watermelon into two halves and show them the seeds embedded in the reddish watery pulp would mimic the electrons and the watery soft reddish palp mimics the positive matter. Describe to students about the validity of Thomson's atomic model.

Now present how Millikan discovered the charge and mass of the electron. Put Millikan's oil drop experiment picture in a place where students can see properly. Narrate how he did the oil drop experiment using the picture. Brief students with Millikan's observations, from his oil- drop experiment. Summarize the properties of cathode rays.

You can finalize this part of the sub- section by asking students the questions under ***Exercise 3.11.*** Stabilize them with misconceptions and misunderstandings.

Answers to Exercise 3.11

1. Charge (e) and charge to mass ratio (e/m)
2. i. Balancing of oil drop, ii. Calculation of the velocity of the drop, iii. Calculation of mass, iv. Basic charge of an electron
3. i. uniformly distributed positive charge, ii. Electrons embedded.
4. Thomson's model

3.4.3 Discovery of the Nucleus

Teaching Aid

Apicture of cannonballs (***Figure 3.16***, student's textbook), a big picture of Rutherford and his apparatus (***Figure 3.17***, student's textbook), Rutherford's atomic model (***Figure***

3.18, student's textbook), Bohr's atomic model (*Figure 3.19*, student's textbook) and his picture. Print out pictures from students' textbook. You may download from the internet the ones absent in the students' textbook.

You may begin the presentation of the lesson by making students discuss the questions under *Activity 3.11*, in groups of two or three. Allow three or four groups to present their discussion points to the rest of the class. Encourage the whole class discuss the activity questions.

After facilitating the presentation and the discussion followed, you can summarize the main points raised by the students. Add your answers to the activity questions and more information from the textbook.

The activity questions are designed to help students understand the presence of empty space between the nucleus and the electrons and the probability of the collision of α-particles and the positively charged nucleus.

Activity question #1 is to show that the small stone will have a small probability of hitting the Sun or the other planets. Since there exists a large space between the Sun and the planets through which the stone could pass through. This mimics the empty space between the electrons (in this case the planets) and the positively charged nucleus (in this case the Sun) in the atomic structure (in this case the Solar System model).

Activity question #2 is about increase in probability of the stone(s) hitting the sun. This mimics the probability of the α-particles hitting the positively charged protons inside the nucleus.

Activity question #3 helps them predict how the α-particles scatter when they collide with the protons inside the nucleus. Therefore some of the stones might collide directly with the Sun and bounce back, while others deflect in certain angles. After dealing with these questions you can now move on to the discovery of the nucleus.

Describe the model that Rutherford came up with. You can show students *Figure 3.18*, to support learning. Compare Rutherford's atomic model with the planetary motion. Now challenge students why Rutherford's model of an atom is also called the planetary model. .

Discuss the reason why Rutherford's atomic model, nowadays, is known as the nuclear model.

Discuss the reason why Rutherford's atomic model, nowadays, is known as the nuclear model.

Summarize the legitimacy and the objections concerning Rutherford's atomic model. Inform students that for this and other insights, Rutherford was awarded the Nobel Prize in Chemistry in 1908. Encourage students to be like Rutherford to receive a Nobel Prize in their lifetime. Encourage them to become brave like Rutherford.

You can finalize the lesson by asking students the questions under *Exercise 3.12*. Make sure students achieved the MLC. Then move on to the next part of the lesson i.e., the Niels Bohr atomic model.

Answers to Exercise 3.12

1. Because Rutherford discovered the nucleus.
2. Goldstein discovered protons in the Discharge tube experiment.
3. i. Proton is located at the centre of the atom, ii. The electron is located on the extra nuclear part.
4. i. Continuous radiation of energy by electron, ii. Spiral path of electron towards nucleus, iii. The collapse of an atom.
5. i. Mostly empty space, ii. Nucleus, iii. Electrons revolve around the nucleus in circular paths.
6. i. An accelerating charged particle loses energy, ii. Spiral path of electron, iii. The collapse of the atom.

The Niels Bohr Atomic Model

Using *Figure 3.19*, you can describe the Niels Bohr Atomic Model. In 1913, a Danish scientist, Niels Bohr was able to overcome the limitation of Rutherford's atomic model effectively based on the Quantum Theory of Radiation proposed by Max Planck. The concept of Quantum Theory is, however, beyond the scope of this subject. Inform them that they will learn about it in grade 11. At this level, only present and discuss the principles associated with Bohr's Atomic Model.

When you have finished the summary, you can ask students the questions under *Exercise 3.13* to stabilize students with Bohr's atomic model. Make sure that students are clear with Bohr's atomic model. Then move on to the last portion of the section i.e., the discovery of the neutron.

Answers to Exercise 3.13

1. A. The Bohr Model.
2. Orbits or shells.
3. Based on Plank's Quantum theory.
4. i. Specified paths of electrons, ii. Energy remains constant.
5. i. Specified paths of electrons orbit, ii. A definite amount of energy, iii. Increase in the energy of orbit with an increase in distance from nucleus, iv. Stationary orbits, v. Change in the energy of electron during movement from one orbit to another.

3.4.4 The Discovery of Neutron

Teaching Aid

Picture of James Chadwick's experiment set up (***Figure 3.20***, student's textbook) and his picture (***Figure 3.21***, student's textbook), Chadwick's Atomic Model (***Figure 3.22***, student's textbook).

You can start presenting this sub-section by defining the following terms: α-rays or α-radiation, α-decay, and γ-rays. Following this you can make students discuss the questions under ***Activity 3.12***, in groups of two or three. You may give three or four groups the chance to present their discussion points. Facilitate the whole class discussion. Summarize the discussion points by giving answers to the activity questions and associating them with the discovery of the neutron.

The activity questions are designed to provoke thought in the minds of students about the coexistence of positively charged protons. The questions also provoke thought on the reason why the negatively charged electrons do not collide with the positively charged protons.

Activity question #1 is about the existence of the positively charged protons inside the tiny nucleus. Rutherford's discovery proved the existence of protons in the tiny nucleus. The question provokes thought because like charged protons exist in a tiny nucleus and the question is how? The answer to this question is again the presence of another sub-atomic particle that shields the repulsive force between the positively charged protons inside the nucleus.

Now you can narrate how the experiment performed by Irene Joliot-Curie led James Chadwick to the discovery of the neutron. Following this you can describe James Chadwick's beryllium bombardment experiment using ***Figure 3.20***. Write the reaction between beryllium and helium on the board and relate it to Chadwick's experiment.

Describe the new tool that James Chadwick's contribution brought to the atomic model. You can show students ***Figure 3.22***. You can ask students the questions under ***Exercise 3.14*** to sum up the lesson. Make sure that they achieved the MLC.

Answers to Exercise 3.14

1. James Chadwick.
2. α-particles.
3. The difference in the predicted mass and actual mass,
4. Bombardment of beryllium nucleus with α-particles.

3.5 Composition of an Atom and the Isotopes

(Period Allotted 3)

Competencies

At the end of this section, students will be able to

- write the relative charges of an electron a proton and a neutron.
- tell the absolute and relative masses of an electron, a proton and a neutron.
- tell the number of protons and electrons in an atom from the atomic number of the element.
- determine the number of neutrons from given values of atomic numbers and mass numbers.
- explain the terms atomic mass and isotope.
- calculate the atomic masses of elements that have isotopes.
- describe the main energy level
- define electronic configuration.
- write the ground- state electronic configuration of the elements.
- draw diagrams to show the electronic configuration of the first 20 elements.
- write the electronic configuration of the elements using noble gas as a core.
- describe valence electrons

The section is divided into six sub- sections. The first sub -section is about the electrons, protons, and neutrons. The second sub -section deals with the calculation of atomic numbers and mass numbers. Atomic mass and isotope is the third sub- section. Main energy levels and electronic configuration on main shells are entertained in the fourth and fifth sub -sections respectively. The last -subs section is about valence electrons. The time allotted for this section, however, is three periods. It is, therefore, advisable to reorganize them it into three. The first sub- section covers electrons, protons, neutrons, atomic number and mass number. The second sub- section deals with atomic mass and isotope. The third sub -section treats about main energy levels, electronic configuration on main shells, and valence electrons. It is, therefore, necessary to make the proper preparation to get the necessary information and skills beforehand.

Presentation of the Subject Matter

The contents of these sub -sections mainly involves numerical calculation. Some of the contents are dealing with physical properties of the sub-atomic particles and others are mainly concerned with the arrangement of electrons in atoms. Prepare all the suggested teaching aids under each sub -section before the presentation of every lesson and use them for the right content. You may add more teaching aids or modify the suggested ones as needed.

The suggested methods used in this section include: group discussion, gapped lecture, visual- based active learning, question and answer, calculation, and description through mini- lecture.

3.5.1 Electrons, Protons and Neutrons

Teaching Aid

Figure 3.23 (student's textbook) or an inflated football and a bead, ***Figure 3.24***.

You may start this sub-section by defining electrons, protons and the neutrons. Then you can students discuss the questions under ***Activity 3.13***, in groups of two or three. Allow three or four groups to present their discussion points. Facilitate a discussion that participates the whole class. Summarize the discussion by answering the activity questions and adding more information from the students' textbook.

The activity questions are designed to give a good impression of the size and masses of three sub-atomic particles and their co-existence in an atom.

Activity question #1 is about providing local examples that mimic the three sub-atomic particles based on their previous knowledge. Show them that in terms of size, proton and neutron are like a football in comparison to the electron which is like a bead.

Activity question #2 is about the electrostatic attraction force that exists between the heavy protons inside the nucleus and the very light electrons revolving around the nucleus. Describe the individual sub- atomic particles (electrons, protons and neutrons) in terms of size, weight and charge, briefly. You can use the teaching aids prepared in their proper context, to support learning.

Describe how electrons, protons and neutrons interact with each other. Compare the masses of electrons, protons and neutrons. Summarize the physical properties of the sub-atomic particles using ***Table 3.1***. Pause your lecture at this juncture and ask students the questions under ***Exercise 3.15*** to see if they have achieved the MLCs. Elaborate if still there is a misunderstanding or misconception. Then move into the second sub -topic of the lesson, which is given below.

Answers to Exercise 3.15

1. Electron: mass (kg) = 9×10^{-31} or 5.4858×10^{-4} amu; charge (in coulombs) = -1.59×10^{-19} or -1.
2. The masses of protons and neutrons are fairly similar, although technically, the mass of a neutron is slightly larger than the mass of a proton.
3. Electrons have an electric charge of −1, which is equal but opposite to the charge of a proton, which is +1.
4. Because they are neutral.
5. Because the mass of electrons is too small.

3.5.2 Atomic Number and Mass Number

Teaching Aid

Table 3.2 and a big picture of the nuclear symbol of an element.

You may begin this sub-section by defining the terms 'atomic number' and 'mass number'. Write the definitions on the board, to support learning. You can make students discuss the questions under ***Activity 3.14***, in groups and give chance for three or four groups to present their discussion points to the rest of the class. Allow few minutes for the whole class to discuss the questions. Summarize the main points obtained from the discussion and add more information from the students' textbook by associating to the activity questions.

You may begin your summary by answering the activity questions. The activity questions are designed to remind students about the atomic number, the sub-atomic particles that make up the mass of an atom, and how atomic number is useful in the differentiation of individual elements.

Activity question #1 reminds students the way how elements are arranged in the periodic table. The question appears to be answered by almost all students. If there is a misunderstanding remind them that elements are arranged based on their atomic number, in the periodic table. Remind them also about the relationship between atomic number, number of protons, and number of electrons. In a neutral atom they are equal.

Activity question #2 is a reminder of the masses of the sub-atomic particles that contribute to the mass of an atom. This question seems also less difficult for students to respond to. Since the mass of an atom is concentrated on protons and neutrons, they are the ones we will consider to calculate the mass number. Explain to them about the difference between atomic mass and mass number. Atomic mass is the weight of an atom whereas the mass number is simply the sum total of the number of protons and neutrons in an atom.

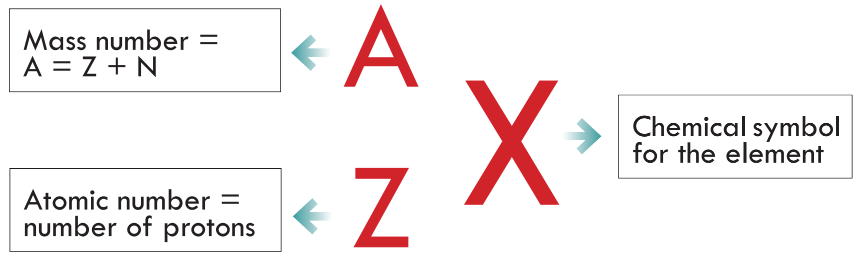
Activity question #3 is about distinguishing the individual elements by using one of the sub-atomic particles. We have seen in Dalton's Atomic Theory that some elements have a different number of neutrons. The number of protons, however, remains constant always. The number of protons or atomic number is the tool one can use to distinguish the elements.

You can use ***Table 3.2*** and the picture of the nuclear symbol of and element to supplement your discussion. You can give more examples on how to calculate the atomic number, number of protons, electron numbers, and mass number, from the student textbook. Briefly explain how scientists represent the mass number and atomic number in a chemical symbol of an element.

Mass number A = (number of protons) + (number of neutrons)

The nuclear symbol of an element.

Average atomic mass = (% 1) (mass 1) + (%2) (mass 2) + ⋯



You may ask students the questions under ***Exercise 3.16*** and stabilize them with the day's lesson. Briefly explain any ambiguity observed from students understanding. You can give a reading assignment i.e., about atomic mass and isotope, to support learning the next lesson.

Answers to Exercise 3.16

1. D
2. 27
3. 14
4. 17
5. $_{13}Al^{27}$, $_{14}Si^{28}$, $_{17}Cl^{35}$

3.5.3 Atomic Mass and Isotope

Teaching Aid

A big picture of isotopes of hydrogen (***Figure 3.25,*** student's textbook).

You can start this sub- section by defining the terms 'Atomic mass', 'Average atomic mass', and 'isotope'. Let students discuss the questions under ***Activity 3.15***, in groups. Make them present their discussion points to the rest of the class. Summarize the discussion points after facilitating the discussion of the whole class. Begin your summary by answering the activity questions and associating it to the main contents of the sub-section.

The activity questions are designed to remind students about the concept of the isotope and the variation of the atomic mass of an element from their previous lessons.

Activity question #1 is mainly focused on the concept of isotope. Atoms of the same element are not always alike because of the differences in their atomic mass. This is because of the differences in the number of neutrons. You may define the term isotope at this stage and illustrate it with examples. You can use the figure that shows the isotopes of hydrogen as a teaching aid. Discuss briefly also about the stability of isotopes, radioactive nuclei, radioactive decay, and radioisotopes. Explain how

Dalton missed the difference in the atoms of an element but used the correct atomic mass of elements.

Activity question #2 is about calculating the atomic mass of elements. As we can recall from the previous lesson, the atomic mass of an element could be calculated by considering the mass of protons and neutrons. This, however, needs standardization and defining the atomic mass unit.

Activity question #3 is about the differences in the atomic masses between different isotopes. Show them how to calculate the mass number of isotopes by using the examples in the students' textbook.

Using examples, briefly discuss how the masses of atoms of an element are measured. Explain how the carbon-12 nuclide is used as the reference standard by which all other masses would be compared. Define the terms 'atomic mass unit' and show its relation to carbon-12. Explain to them why the 'atomic mass unit' is also called the Dalton (Da).

Define 'average atomic mass' and describe its importance. Show how to calculate it using the examples in the students' textbook.

$$\text{Average atomic mass} = (\%1)\ (\text{mass } 1) + (\%\ 2)\ (\text{mass } 2) + \ldots$$

Activity question #4 is about differentiating mass number and atomic mass. Stabilize the lesson by explaining the difference between mass number and atomic mass. You can ask students the questions under ***Exercise 3.17***. You can give four different questions for four students so that the four of them could do the questions on the board, simultaneously. Make sure they have achieved the MLCs.

Answers to Exercise 3.17

1. The neutron is different while electrons and protons remain unchanged in an element that has isotopes.
2. a. $_{27}Co^{60}$: Protons 27, electrons 27, neutrons 33; b. Na-24: Protons 11, electrons 11, neutrons 13; c. $_{20}Ca^{45}$: Protons 20, electrons 20, neutrons 25; d. Sr-90: Proton 38, electrons 38, neutrons 52.
3. The average mass of copper: Cu-63, 69.15% & Cu- 5, 30.85%.
   $[(63 \times 69.15) \div 100] + [(65 \times 30.85) \div 100] = \mathbf{63.61}$
4. Calculate the average mass of chlorine: Cl-35, 75% & Cl-37, 25%.
   $[(35 \times 75) \div 100] + [(37 \times 25) \div 100] = \mathbf{35.5}$

3.5.4 Main Energy Levels

Teaching Aid

A big picture of main energy levels (***Figure 3.26,*** student's textbook).

You may begin the sub-section by defining 'energy level'. Inform students the alternative name for 'energy level' is 'shell'. Then you can let students discuss the questions under ***Activity 3.16***, in groups. You may give chance for three or four groups to present their discussion points to the class. Let the whole class discuss for few minutes. Summarize the discussion points by adding more information from the students' textbook. It would be a wise approach to begin the summary by addressing the activity questions and associating them with the contents of the sub- section.

The activity questions in this section are designed to remind students about Bohr's atomic model in which the arrangement of electrons is roughly proposed.

Activity question #1 is a reminding question about the discovery of energy levels or shells. It is Bohr who came up with the concept of energy levels or shells on which the electrons are orbiting around the nucleus of an atom. Remind them about the different energy levels and their names.

Activity question #2 is about the existence of the repulsive force between electrons in an atom. The electrons repel each other and hence disperse around the nucleus of an atom. This dispersion, however, is not random, according to Bohr, they follow a certain pattern.

Activity question #3 is about how the electrons disperse around the nucleus of an atom in a certain pattern known as the arrangement of electrons or the electronic configuration. The electrons will arrange themselves in the main energy levels or sometimes called orbits. They are also known as the principal energy levels. The electronic configuration will be dealt with in the next sub -section. The energy levels are called 'main' because of the presence of another energy level known as an orbital. The concept of orbital, however, is not part of this syllabus.

Revise Bohr's atomic model briefly and show the main energy levels and the principal quantum numbers using ***Figure 3.26***.

Summarize this sub-topic by asking questions under ***Exercise 3.18***. Stabilize students with the difficulties they face, through more explanations. Then move into the next sub-topic of the day's lesson.

Answers to Exercise 3.18

1. The main energy level of an electron refers to the shell or orbital in which the electron is located relative to the atom's nucleus.
2. H & He only one energy level; Li, Be, B, C, N, O, F, Ne two energy levels; Na, Mg, Al, Si, P, S, Cl, Ar three energy levels, K, Ca four energy levels

3.5.5 Electronic Configuration on Main Shells

Teaching Aid

Electronic configuration of some elements (***Figure 3.27,*** student's text book).

You may begin this sub- section by defining the term, 'electronic configuration', 'valence shell', 'penultimate shell', and 'anti-penultimate shell'. Then move to the students' group discussions. You can make students discuss the questions under ***Activity 3.17***, in groups. Allow three or four groups to present their discussion points to the rest of the students. Summarize the discussion points after the discussion by the whole class. You may begin the summary by answering the activity questions followed by the association of the contents of the sub-section.

The activity questions in this sub -section are designed to demonstrate how the arrangement of electrons would take place by using general and simple examples.

Activity question #1 is a mimicking example of the electronic configuration of electrons on the main energy levels. The 35 students will take seats as follows: 2 on the front seat, 8 on the second row, 18 on the third row and 7 on the back seats.

Activity question #2 follows the same procedure as activity question #1 except electrons are replaced by students and the seats by the shells. Therefore, the answer to the question would be 2 electrons on the K-shell, 8 electrons on the L-shell, and 10 electrons on the M-shell. This however, is not the perfect way of arranging electrons on the main energy levels. Now, briefly explain the maximum number of electrons an orbit can hold and the rules atoms follow to fill their shells. There are only seven main energy levels which can hold any of those elements known thus far.

Now, you may define the electronic configuration again and elaborate it using examples.

Define the different types of shells in an atom, again, to support learning. You can draw the following table on the board and show the students the maximum number of electrons on each shell

Table

Shell	$2n^2$
K	2
L	8
M	18
N	32
O	50

You can also draw and use the table indicated below to describe the electronic configuration rules.

The filling of electrons till atomic number 30 follows the following pattern.

Table

K	L	M	N
2			
2	8		
2	8	8	
2	8	8	2
2	8	18	2

Now you can clarify the rule using more examples.

Describe the other alternative way (the energy diagram) in which the electronic configuration of elements can be written. You can show ***Figure 3.27*** to elaborate on this.

Inform them of the existence of a third way of writing electronic configuration which considers the noble gas elements as the core. This, however, needs the understanding of the concept of orbitals. Orbitals are sub -energy levels in which electrons spent most of their time around the nucleus. The concept of orbital, however, is beyond the scope of this syllabus.

You can stabilize this sub -topic by asking students the questions under ***Exercise 3.19***. Make sure that students achieved the MLCs.

Answers to Exercise 3.19

1. The electron configuration of an element describes how electrons are distributed in their energy levels or shells.
2. See the table below.

Table: Electronic configuration of the first 20 elements.

Atomic Number	Name of the Element	Electronic Configuration
1	Hydrogen (H)	1
2	Helium (He)	2
3	Lithium (Li)	2, 1
4	Beryllium (Be)	2, 2
5	Boron (B)	2, 3
6	Carbon (C)	2, 4
7	Nitrogen (N)	2, 5
8	Oxygen (O)	2, 6
9	Fluorine (F)	2, 7
10	Neon (Ne)	2, 8
11	Sodium (Na)	2, 8, 1
12	Magnesium (Mg)	2, 8, 2
13	Aluminum (Al)	2, 8, 3
14	Silicon (Si)	2, 8, 4
15	Phosphorus (P)	2, 8, 5
16	Sulphur (S)	2, 8, 6
17	Chlorine (Cl)	2, 8, 7
18	Argon (Ar)	2, 8, 8
19	Potassium (K)	2, 8, 8, 1
20	Calcium (Ca)	2, 8, 8, 2

3. It is very difficult to draw all of the energy diagrams due to limited space. Please check for yourself according to the examples given in the student's textbook.

3.5.6 Valence Electrons

Teaching Aid

An energy diagram showing the valence electrons of Silicon (***Figure 3.28***, student's textbook), and an energy diagram showing the valence electrons of Argon (***Figure 3.29***, student's textbook).

You can begin the presentation of this sub- section by defining the term 'valence electron'. Let students discuss the question under ***Activity 3.18*** in groups. You can allow three or four groups to present their discussion points to the rest of the students. Summarize the discussion points raised by students. Add more information from the textbook on top of the students' discussion points in your mini- lecture. It is advisable to begin the summary by answering the activity questions.

The activity questions under this -sub section are designed to associate the names

discussed in the previous sub -section with electrons on the shells. This will directly lead you to the main content of this sub -section. The electrons arranged in the outermost shell are called valance electrons. The electrons on the penultimate shell are known as penultimate electrons and the ones on the anti-penultimate shell are called the anti-penultimate electrons. It, however, is a common practice to call the penultimate and the anti-penultimate electrons, the inner shell electrons. Elaborate the valence electrons using the examples given in the students' textbook. You can use ***Figures 3.28*** and ***3.29*** to make visual aided active learning.

Explain how valence electrons and the energy needed to remove them in the course of a chemical reaction are related.

You can summarize this sub -section by asking students the questions under ***Exercise 3.20***. Make sure that students have achieved the MLC.

Answers to Exercise 3.20

1. Valence electrons are the electrons found in the outermost shell of an atom.
2. Understanding the number of valence electrons of an atom will help us know how it reacts with other atoms.
3. Teacher refer to ***Exercise 3.17*** answer #2 (Table).
4. The inner electron is held by the positively charged nucleus due to strong electrostatic force and hence difficult to remove it from a neutral atom.

You can use the review exercises found at the end of the unit to give students assignments, quizzes, tests or examinations as part of your formative assessment. The answers to the review exercise questions are given hereunder.

Answers to the Review Exercise

Part I: Answers for the basic level questions

Multiple choice questions.

1.	B	6.	C	11.	C
2.	A	7.	A	12.	D
3.	A	8.	C	13.	A
4.	D	9.	B		
5.	A	10.	B		

Part II: Answers for the intermediary level questions

True or False items.

14. False
15. True
16. True
17. False

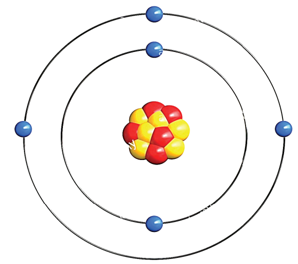
Fill in the blanks.

18. positively charged
19. positively charged
20. less

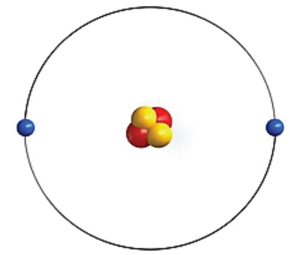
Part III: Answers for the challenge level questions

Short answer type questions.

21. Atoms are the tiniest particle of matter that take part in the chemical reaction.
22. The discovery of isotopes.
23. Laws of chemical combination.
24. All matter is composed of atoms; atoms of the same element are the same, and atoms of different elements are different; atoms combine in whole-number ratios to form compounds.
25. Atoms are composed of electrons and a nucleus. The electrons are revolving around the nucleus. The nucleus consists of a positively charged proton and a neutral neutron bound together in nuclear energy.
26. Less intermolecular attraction.
27. electron: -1.6×10^{-19}c and 9.1×10^{-28} g; proton: 1.6×10^{-19}c and 1.673×10^{-24} g; neutron: 0 and 1.675×10^{-24} g
28. A proton is larger than an electron.
29. Neutron is larger
30. Arrangement of the fundamental particles.
31. Goldstein, Discharge tube.
32. The mass of an atom is located in the nucleus.
33. Increases
34. Doubly ionized helium ion.
35. i) Uniformly distributed positive charge; ii) electrons embedded
36. i) Formation of shadow-travel in straight lines. ii) Rotation of paddle wheel-mass and kinetic energy. iii) Bending of rays in electric and magnetic field-charged particles. iv) Properties do not depend on the nature of gas and cathode.

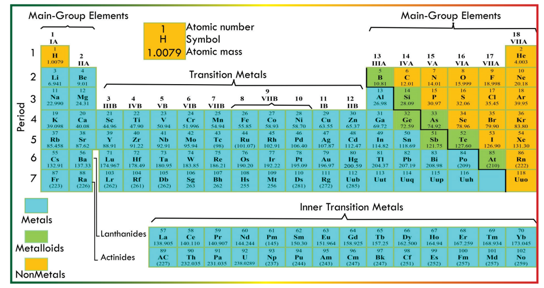


37. A diagram of boron atom:



38. A diagram of helium atom:
39. The atomic number is the number of protons in a nucleus. Boron has an atomic number of five.
40. The atomic number of helium is two.
41. Isotopes are atoms of the same element but with different numbers of neutrons. $_1H^1$ and $_1H^2$ are examples.
42. Deuterium has two neutrons and tritium three neutrons. So, they have different masses.
43. A. isotopes, E. isotopes; F. isotopes
44. A. $_8O^{16}$; B. $_{19}K^{39}$; C. $_3Li^7$, D. $_{12}Mg^{12}$; E. $_{12}Mg^{13}$; F. $_{54}Xe^{77}$
45. $_{95}Am^{241}$
46. $_6C^{14}$

UNIT 4



PERIODIC CLASSIFICATION OF ELEMENTS

Unit Overview

Total Period Allotted 14

In this unit, based on early attempts to classify the elements the concept of periodic law and the periodic table are discussed. The modern periodic table, periodic law and the general trends of the periodic properties of elements in the periodic table are emphasized in the unit.

Section 4.1 deals with the historical development of the periodic classification of the elements.

Section 4.2 deals with the Mendeleev's classification of the elements. Moreover, the periodic law and periodicity will be explained briefly.

Section 4.3 Deals with the modern classification of elements as representative, transition and rare earth elements, and also in terms of s, p, d, f - blocks of elements, are explained briefly.

Section 4.4 Deals with the Major trends in properties of the elements such as atomic size, ionization energy, electron affinity, and electronegativity across a period and down a group of the periodic table.

Unit outcomes

After completing this unit students will be able to

- explain the historical development of the periodic classification of the elements
- describe the periodic classification of the elements.
- develop the skills of correlating the electron configuration of elements with the periodicity of the elements, predicting the trends of periodic properties of elements in the periodic table.
- acquire skills of classifications based on patterns in chemistry.
- demonstrate scientific inquiry skills: observing, inferring, predicting, classifying, comparing and contrasting, making models, communicating, measuring, asking questions, interpreting illustrations, drawing conclusion, applying concepts and problem solving.

4.1 Historical Development of Periodic Classification of the Elements

Periods Allotted 1

Learning Competencies

At the end of this section, you will be able to

- describe periodicity.

Forward Planning

Read thoroughly the contents about this section from the students' text to help you make appropriate preparation. Read the contents in the teacher's guide as well to get clear information about the methodologies you implement to teach this section and the suggested start-up activity and ***Activity 4.1***. Make a plan how you can manage students during discussion and presentation, so that the teaching-learning process becomes attractive and interesting. Prepare a plan to budget your time for group discussion, presentation, harmonizing concepts and other activities you perform during each period.

Subject Matter Presentation

In order to teach the contents of this section, it is desirable to use group discussion and inquiry as apprpriate teaching methods. After briefly initiating the learning of the topic of this section, it is good to ask the students to suggest repeating events in their daily lives. Some examples are day and night, months of the year or days of the week etc. Such daily-life examples will help the students to understand periodic events and periodicity.

Allow the students to discuss the start up activity for a few minutes. In the start-up activity, periodicity is shown to the students, using the Ethiopian calendar. This is a periodic table of days of the week. At the end of the start-up activity, students are expected to associate what they have seen from the periodic table of days of the week with the periodic table of the elements. They are expected to have a clear idea of the periodic table of the elements.

The students should be able to see that the calendar consists of families of days repeating after the seventh day and rows of weeks. The calendar that is given to is incomplete so that they can predict repeating events. What days are missing in a row and what name is given to columns of days?

You can guide students in constructing the table and encourage them to predict the missing days and names of columns. When they complete their group presentation, inform them the missing days in columns 3(X) is 13, and columns 4(Y) is 14. They should be able to name columns 3 as Wedensday.

You should also inform them that inclusion of X and Y completes columns 3 and 4. Inclusion of X and Y also completes row 3, which consists of days (10, 11, 12, 13, 14, 15, 16). In your further explanation, help them to see the previous month ended on Friday, and that the 25th of that month was Sunday and that it would have appeared in the fourth row.

Dear teacher please give students a similar understanding about the construction of the periodic table of the elements in your harmonizing session. Immediately after the start–up activity, let the students discuss ***Activity 4.1*** for a few minutes in groups and then invite some groups present their opinions to the class and following the presentation session, try to harmonize concepts.

In ***Activity 4.1***, students should try to relate how repetition of sound observed in musical instruments and let them relate this to the Newlands law of octaves. Similar kind of explanation can be given to the case of Ethiopian notes of musical instruments except Ethiopian music notes are pentatonic. Let students appreciate the fact that the modern periodic table is a result of many attempts. In this activity, group discussions and group presentations are directed to the historical development of the modern period table. During your explanation, let the students suggest what they already know about the early attempts of the classification of the elements. Inform them about the attempts made by Dobereiner and Newlands and explain how they made the classifications.

Reading Check: This checking in needed to motivate students to read other related reference materials, analyze information, summarize and write reports.

Assessment

Assess how every student is doing throughout Section 4.1. Record the performance of each student in the performance list you already have related to:

- participation of each student in discussing the start-up activity and ***Activity 4.1***.
- participation in presenting the ideas of the group after discussion.
- answering questions you may ask during harmonizing concepts or stabilization

You may appreciate students working above the minimum requirement level and encourage them to continue working hard. You can give them the additional questions suggested in the guide. For students working below the minimum requirement level, you can set questions on Dobereiner's triads and Newland's law of octaves and give them additional exercise to assist them catch up with the rest of the class.

Additional Questions

1. Explain the contribution of Newland's law of octaves to the development of the modern periodic table.
2. What are the similarities between the Dobereiner's triads and Newland's law of octaves in the classification of elements?

Answers to Additional Questions

1. Because he proposed for the first time the periodicity in the properties of elements.
2. Both Dobereiner's and Newland's classified the elements on the basis of the atomic masses of elements.

4.2 Mendleev's Classification of the Elements

Periods allotted 2

Learning competencies

At the end of this section, you should be able to

- state Mendeleev's Periodic law

Planning

Read the contents on the Mendleev's periodic table thoroughly to familiarize yourself with the ideas in the section. Prepare a plan that demonstrates the topics and activities you will treat during each period so that you can cover the entire content of the section within two periods. In addition read the teacher's guide to get information about the methodologies you need to implement and about the activities suggested in this section. In your plan, show the time allotted for every activity you perform during each period, such as group discussion, presentation, harmonizing concepts, gapped lectures etc. Make sure that your school has a short form of Mendeleev's periodic table chart (***Figure 4.4*** of student text). If not prepare the chart yourself.

Teaching Aids

- The short form of Mendeleev's Periodic Table chart.

Subject Matter Presentation

The periodic law

It is better to apply group discussion, followed by lecture and visual-based active learning methods of teaching for this lesson.

You are advised to begin the lesson with *Activity 4.2*. Have the students perform and discuss it in their groups. Then invite some students to present their answers to the class. After their presentations, make a class room discussion. After the discussion, please harmonize concepts suggested by the students with the truth as follows:

According to the given activity, the group will use a blank table as shown below to fill the letters A-R on the boxes on increasing order of atomic weight.

There are 3 horizontal rows of elements that are filling the same valence shell. In the first row, 2 elements, A and B, in the second 8 elements, C to J and in the third also 8 elements K to R are grouped. When students replace the letters A-R by the chemical symbol corresponding to their atomic weight, they should understand the regular patterns in forming sets of vertical and horizontal boxes. Elements in the same set of vertical boxes have the same property.

After this you may continue explaining the concepts of Mendeleev's periodic table. First, by letting students to explore the Mendeleev's periodic table ask the students to suggest the basis for the classification of elements in this table. After their responses, guide them to understand that elements are classified based on their atomic masses. State Mendeleev's periodic law. You explain them why Mendeleev left some blank spaces in his table. Identify the elements for which Mendeleev left blank spaces. Finally, explain the defects of Mendeleev's periodic table and continue by dealing with the modern periodic table. Then, give students information about the contribution of Henry Mosely to the modern form of the periodic table. Be sure students are familiar with the basis for the classification of elements in the modern periodic table and the modern periodic law.

Assessment

Assess how every student is doing throughout section 4.2. Record the performance of each student in the performance list you already have related to:

- participation of each student in discussing the start-up activity and *Activity 4.2*.
- participation in presenting the ideas of the group after discussion.
- answering questions you may ask during harmonizing concepts or stabilization

It is good to appreciate students working above the minimum requirement level and to encourage them to continue working hard. You can ask them to do *Exercise 4.1* as additional question.

4.3 The Modern Periodic Table

Periods allotted 3

Learning Competencies

At the end of this section, you should be able to

- state modern periodic law
- describe period
- describe group
- tell the number of groups and periods in the modern Periodic table
- tell the number of elements in each period
- predict the period and group of an element from its atomic number

Forward Planning

Read the contents on the modern periodic table carefully to familiarize yourself with the concepts in the section. Set a plan that shows the topics and activities you will treat during each period so that you can cover the entire content of the section within five periods. In addition read the teacher's guide to get information about the methodologies you need to implement and about the activities suggested in this section. In your plan, show the time allotted for every activity you perform during each period, such as group discussion, presentation, harmonizing concepts, gapped lectures etc. Make sure that your school has a periodic table chart. If not prepare the chart yourself.

Teaching Aids

The Modern Periodic Table.

Subject Matter Presentation

The Periodic Law

It is preferable to implement group discussion, gapped lecture and visual-based active learning methodologies methods of teaching for this lesson.

You are advised to begin the lesson with ***Activity 4.3***. Form groups and let students discuss it in their groups. Then request some students to present their conclusions to the class. After their presentations, perform a whole-class discussion. After the discussion, please harmonize concepts suggested by the students with the truth as follows:

According to the given activity, students should list the 18 elements in increasing order of atomic number and write their electronic configurations and arrange them in sets of vertical boxes and horizontal boxes. There are 3 sets of horizontal boxes of elements that are filling the same valence shell. In the first set, 2 elements (H and He), in the second set, 8 elements (Li to Ne) and in the third set also 8 elements (Na to Ar) are grouped. The students should understand the regular patterns in forming sets of vertical and horizontal boxes. Elements in the same set of vertical boxes have the same outer electron configuration while those in horizontal boxes have the same number of shells. Here is the drawing of sets of horizontal and vertical boxes. Regular pattern is observed. Elements filling the same shell fall in the same ro and elements having similar valence shall electrons fall in the same group.

IA							VIIA
$_{1}H$	IIA	IIIA	IVA	VA	VIA	VIIA	$_{2}He$
$_{3}Li$	$_{4}Be$	$_{5}B$	$_{6}C$	$_{7}N$	$_{8}O$	$_{9}F$	$_{10}Ne$
$_{11}Na$	$_{12}Mg$	$_{13}Al$	$_{14}Si$	$_{15}P$	$_{16}S$	$_{17}Cl$	$_{18}Ar$

Groups and Periods

It is preferable to use gapped lecture as methodology in teaching this lesson. Begin the lesson by asking students questions to suggest their opinion. After getting answers to the questions, tell them the basis for the classification of elements and define periods. By hanging the modern periodic table chart explain the number of periods and also the number of elements classified in each period. After that, show them how they can determine the period number of an element from its electron configuration. Give them an activity and practice have them determining the period number of some elements. Check how well they are doing and give them corrections. Then, define groups and introduce the common features of elements in the same group. Show them how to determine the group number of an element form its electron configuration. To help students decide the position of an element in the modern periodic table, give them the following activity at the end.

The atomic numbers of four elements, W, X, Y and Z, are 11, 14, 8 and 16, respectively.

a. Determine the period and group number of each element.

b. Which elements are in the same period?

c. Which elements are belong to the same group?

When you are checking their work, make sure that the answers of the students are as follows.

a. W is in period – 3 and group I, X; in period – 3 and group IV; Y period – 2 and group VI and; Z in period – 3 and group VI

b. W, X and Z

c. Y and Z

Assessment: Assess how every student is doing throughout section 4.3 in the activity and examples. Record the performance of each student in the performance list you already have related to:

- participation of each student in discussing the ***start-up activity*** and ***Activity 4.3***.
- participation in presenting the ideas of the group after discussion.
- answering questions you may ask during harmonizing concepts or stabilization

It is important to motivate and appreciate students working above the minimum requirement level and to encourage them to continue working hard.

Classification of the Elements

Periods allotted 4

Learning competencies

At the end of this section, you should be able to

- explain the relationship between the electronic configuration and the structure of the modern Periodic table
- describe the three classes of the elements in the modern Periodic table
- give group names for the main group elements
- classify the periods into short, long and incomplete periods
- tell the block and group of an element from its electronic configuration

Assessment

Assessment has to be done for each student's work. This can be done by using students' performance list recording how eac h and every student:

- participates in discussing ***Activity 4.4***

- presents ideas after discussion
- answers questions raised during harmonizing concepts, stabilization and gapped lectures
- does the activity suggested in this guide related to classification of elements.

Based on the cumulative record, see whether or not the competencies suggested for this section are achieved by most of the students. Appreciate students working above the minimum requirement level. Give them the additional questions suggested for this section.

With regard to students working below the minimum requirement level, give them the necessary assistance in class and arrange additional lesson time when over required. You can also set questions of your own in accordance with the suggested competencies and give them additional exercise to help them catch up with the rest of the class.

4.4 The Major Trends in the Periodic Table

(atomic size, ionization energy, electron affinity and electro negativity)

Periods allotted 4

Learning competencies

At the end of this section, you should be able to

- describe the four major trends (atomic size, ionization energy, electron affinity and electro negativity) in the periodic table

Planning

For your preparation first read the contents on the periodic properties in the periodic table from the students' text. Set a plan of your own that shows the contents and activities (4.5 – 4.8) which you treat during each period in such a way that you can cover the whole section within six periods. Your plan should also include the time allotted for every activity you perform during each period. Read the teacher's guide on this section to get information about the methodologies you implement for the section and to gain more ideas about each activity.

Teaching Aid

Modern Periodic Table.

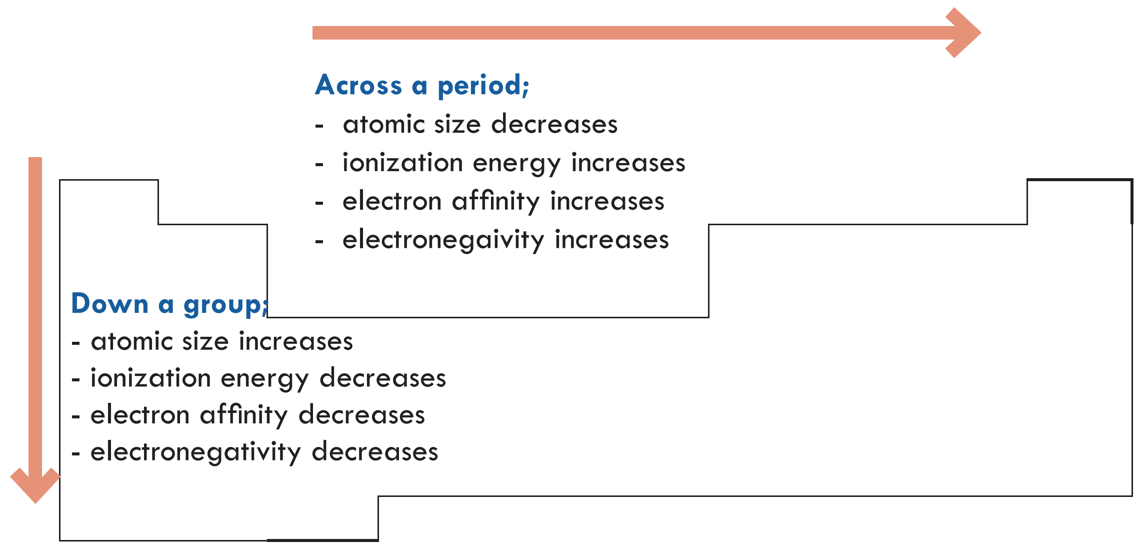
Subject Matter Presentation

Periodic Properties within a Group

You can apply group and gapped lecture methodologies to teach this topic.

Please hang up a periodic table containing values of ionization energy, atomic size, electron affinity and electronegativity for doing activities in this section. Have them fill in these values and observe the trends in the properties of the elements across a period and down a group. After they fill the values, have the students discuss in groups.

Following their group discussion, have them present their findings and analyze any trend in the properties of the elements in a group and across a period. After the presentations, harmonize concepts. Tell them that they should come up with trends like the one shown below.



Next, you can proceed by introducing ***Activity 4.5***. This activity is designed to help students realize concepts related to nuclear charge, effective nuclear charge and the shielding effect. So, have the students perform the suggested task in ***Activity 4.5*** in groups for a few minutes. Encourage one or two groups to present their findings to the class. After the presentations, harmonize concepts as follows:

1. Elements in the same group have similar chemical properties because they have the same number of valence electrons in their outer most shell.
2. Elements in the same period have different chemical properties because of regular increase in valence electrons in all the elements in the period.

Order of radii is B < C < A. Since atomic size generally decreases along a period, as the atomic number (effective nuclear charge) increases thus, the element with smaller radii, has the highest atomic number. Hence, B has the highest atomic number followed by C and A

Next do ***Example 4.3*** and let them do ***Exercise 4.2*** in groups for a few minutes and discover the trend in atomic radius in a group. Then, have some groups presented their findings to the class.

Then, continue by explaining ionization energy. Start by asking them to define ionization energy. After getting their answers, give them the right definition of ionization energy and also explain the difference between first and second ionization energy. Tell them what ionization energy measures.

Before discussing the trend atomic size of elements across a period let students first do ***Activity 4.6***. Give time for students in group to explore the variation in atomic size across the period by and ask them what they observe about the trend on the variation of atomic size of elements across a period. Encourage some groups to present their findings to the class. After the presentations, harmonize concepts as follows:

From left to right in a given period, nuclear charge or atomic number increases progressively, by one, for every succeeding element, as an increasing number of valence electrons is added to the same shell. This results in an increase in effective nuclear charge. Due to this, the valence electrons are pulled closer to the nucleus. As a result, atomic size of the elements decreases across a period.

Next, you can have students discuss ***Activity 4.6*** in groups for a few minutes and identify the trend in ionization energy of elements in a group. Have one or two groups present their findings to the class. After they complete their presentations, harmonize concepts, using the following information.

Generally, with increasing atomic number, the first ionization energy of the elements decreases down a group. Let students explore the trends in ionization energy across a period and down a group by looking ***Tables 4.6*** and ***4.7*** of the student's text. Do ***Example 4.4*** to show the trend in first and second ionization energy as it is explained in the example and let students do ***Exercise 4.3*** and check whether they understood the concept or not and try to help them by giving more of similar exercises of your own.

Before discussing the trend in ionization energy, across a period let first students do ***Activity 4.7*** in group. Give time for students to explore the variation in ionization energy, across the and ask them what they observe about the trend on the variation of ionization energy of elements across a period. Encourage some groups to present their findings to the class. Then, continue by presenting ionization energy. First, have the students recall what factors affect it's ionization energy. After the presentations, harmonize concepts as follows:

1. Across a period, ionization energy increases. Two factors account for this effect. First, across a given period, nuclear charge increases steadily from left to right. Also, the nucleus increasingly attracts each additional valence electron which, in effect, increases the effective nuclear charge and decreases the atomic size. These results cause increase in ionization energy from Na to Ar.
2. However, for various reasons, some irregularities are observed across a period.
   i. Al - $1s^2 2s^2 2p^6 3s^2 3p^1$ and Mg- $1s^2 2s^2 2p^6 3s^2$

The first ionization energy of Mg > Al. This is due to completely-filled sublevel stability.

   ii. S – $1s^2 2s^2 2p^6 3s^2 3p^4$ and P - $1s^2 2s^2 2p^6 3s^2 3p^3$

The ionization energy of S < P. This is because of half-filled sublevel stability in the case of phosphorous, P. Tell your students that it is difficult to remove an electron from an atom possessing half-filled or completely filled outermost subshell, and hence such atoms have higher ionization energies.

Then you can proceed to discuss electron affinity. Begin by asking the students to define electron affinity. After their responses, define it yourself and tell them what it measures. Let them discuss in groups ***Activity 4.7*** for a few minutes and ask some groups present their views to the class. After the presentations, try to harmonize concepts, using the following information:

Electron affinity depends on the size of the atom and effective nuclear charge.

a. Down a given group, although nuclear charge increases, the effective attraction of the nucleus for an added electron decreases. This is due to the increased shielding effect of the inner electrons. Therefore, electron affinity decreases down a group. The following table shows the electron affinity of the halogens.

The electron affinity of Sodium is lower than that of Lithium, due to smaller size of Lithium. The smaller the size of the atom, the greater the force of repulsion between the electron being added to the atom and the electrons already present on the atom, so that the smaller the electron affinity of the element would be,

b. Noble gases have extremely low (almost zero) electron affinity, due to their stable electron configuration and low tendency to accept an additional electron.

c. Halogens have the highest electron affinities (highest negative values). Halogens need only one electron to be stable. Therefore, they have a high tendency to gain an electron and form stable negative ions.

To discuss the trend electron affinity of elements across a period you tell to the students to do ***Activity 4.8*** in groups. Give time for students to explore the variation in electron affinity across the period and ask them what they observe about the trend on the variation of electron affinity of elements across a period and discuss in groups for a few minutes. Encourage some groups to present their findings to the class. After the presentations, harmonize concepts as follows:

From left to right in a given period, nuclear charge or atomic number increases progressively, by one, for every succeeding element, as an increasing number of valence electrons is added to the same shell. This results in an increase in effective nuclear charge. Due to this, the valence electrons are pulled closer to the nucleus. As a result, atomic size of the elements decreases across a period.

Then, you may continue by introducing electronegativity. Start this, by asking students to define electronegativity. After their attempt, tell them the correct definition of electronegativity and inform them of its relationship with ionization energy and electron affinity. Have them discuss ***Activity 4.8*** in groups for a few minutes and discover the trend in electronegativity. Invite one or two groups to present their findings. After the presentations, harmonize concepts, using the following information:

Electronegativity decreases down a given group, due to increase in atomic size. Generally, high electronegativity is characteristic of nonmetals, and low electronegativity is characteristic of metals.

The decreasing order of electronegativity for each set of elements is:

a. Be > Mg > Ca > Ba
b. C > Si > Pb > Ge
c. F > Cl > Br > I

Next, you can discuss the trend in electronegativity. Before you deal with present the details, have students discuss ***Activity 4.9*** in groups for a few minutes to discover the trend in electronegativity of elements across a given period. Then ask some groups present their findings. After the presentations, continue by harmonizing concepts as follows:

1. The following table shows the electronegativity values of Period 3 elements.

Table 4.1 Electronegativity values of Period-3 elements

Period-3 Element	Na	Mg	Al	Si	P	S	Cl
Electronegativity	0.9	1.2	1.5	1.8	2.1	2.5	3.0

2. Generally, across a period, electronegativity increases because of the gradual increase in effective nuclear charge and also the decrease in atomic size.

Project work: Students should be encouraged to use locally available materials to make this model of a section of the periodic table. Using their model, they are also expected to fill in this section of the periodic table with the appropriate elements position.

Students should think of reasons for changes in size and the patterns from Li to F, Na to Cl, and from Li to Cs, using the data in the table.

$_3$Li	$_4$Be	$_5$B	$_6$C	$_7$N	$_8$O	$_9$F	$_{10}$Ne
$_{11}$Na	$_{12}$Mg	$_{13}$Al	$_{14}$Si	$_{15}$P	$_{16}$S	17Cl	$_{18}$Ar
$_{19}$K							
$_{37}$Rb							
$_{55}$Cs							

i. For the decrease in size from Li to F and Na to Cl, students should understand that it is due to an increase in the nuclear charge attraction for the extra added electrons filling the same valence shell.

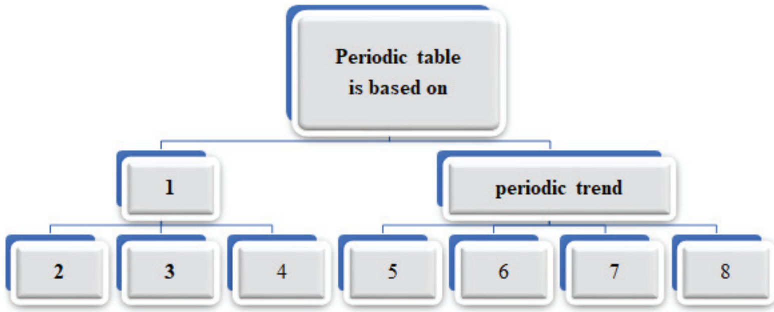
ii. The increase in size from Li to Cs is accounted for by the increase in the number of energy levels.

Concept Mapping

After you introduce the classification of the elements (the periodic table), list the following terms on the blackboard and let some volunteer students try to complete the concept map using the terms:

- electronegativity
- electron configuration
- atomic radius
- group number
- ionization energy
- period number
- block

- electron affinity



Appreciate their attempts in constructing the concept map and harmonize by drawing the concept map on the blackboard. Let the students compare the concept map with their attempts.

1. Electron configuration
2. Group number
3. Period number
4. Block
5. Electronegativity
6. Ionization Energy
7. Electron Affinity
8. Atomic radius

Assessment

You are advised to assess each student's work throughout Section 4.3 and 4.4. This can be done by recording the performance of every student. You can record the performance of each student by taking into consideration how the student:

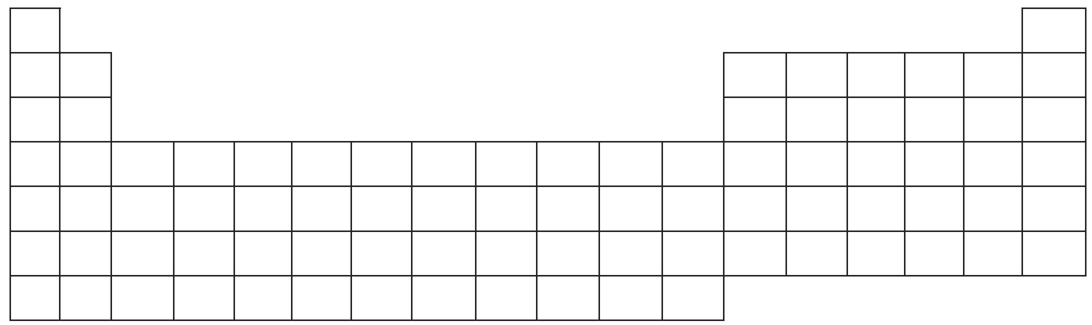
- takes part in discussing ***Activities 4.3 – 4.9***.
- involves in presenting concepts after discussion.
- answers questions raised during: discussions, harmonizing concepts, stabilization and gapped lectures.
- attempts to construct the concept map suggested in this section.

Give them ***Exercises 4.2 to 4.4*** as class work or homework. Check their work and record their performances.

From the record, make sure that the suggested competencies for the section are achieved by most of your students. Praise students working above the minimum requirement level and recognize their achievements. In case of students working below the minimum requirement level, give them assistance in class and arrange additional lesson time. You can also give them exercise from the additional questions recommended to them and prepare others related to the contents in this section. This will help them to catch up with the rest of the class.

Additional Questions

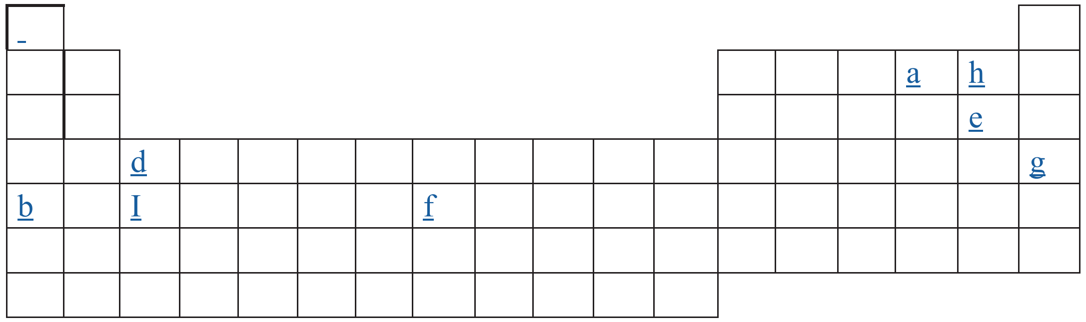
1. How many inner electrons and valence electrons are present in an atom of the following elements?
   - i. Ca
   - ii. Br
   - iii. O
   - iv. Cs
   - v. Kr
2. Which element is described by each of the following descriptions? Place the correct letter of the question (a, b, c, etc) in the box given below.
   - a. Smallest atomic radius in Group VIA
   - b. Largest atomic radius in Period 5
   - c. Highest first ionization energy in Group IA
   - d. The transition metal with the lowest atomic number
   - e. Extremely high election affinity in Period 3
   - f. The element with the electron configuration [Kr] $5s^2 4d^6$
   - g. Period-4 element with a completely filled outer energy level.
   - h. The most electronegative element
   - i. Period-5 transition element with the lowest ionization energy



Answers to Additional Questions

1. First, write the electron configurations of each element and then you can determine the number of inner shell electrons and valence electrons.

	Element	Inner shell electrons	Valence electrons
i	Ca	18	2
ii	Br	28	7
iii	O	2	6
iv	Cs	54	1
v	Kr	28	8



Answers to Exercises

Exercise 4.1

1. Because their electornic configuration finshes 1f oribitals and 1f oribitals accomodares a maximum of two electorns.

2.

a. Group IV Period 2

b. Group VIII Period 2

c. Group III Period 3

d. Group I Period 4

e. Group II Period 4

f. Group VI Period 3

Exercise 4.2

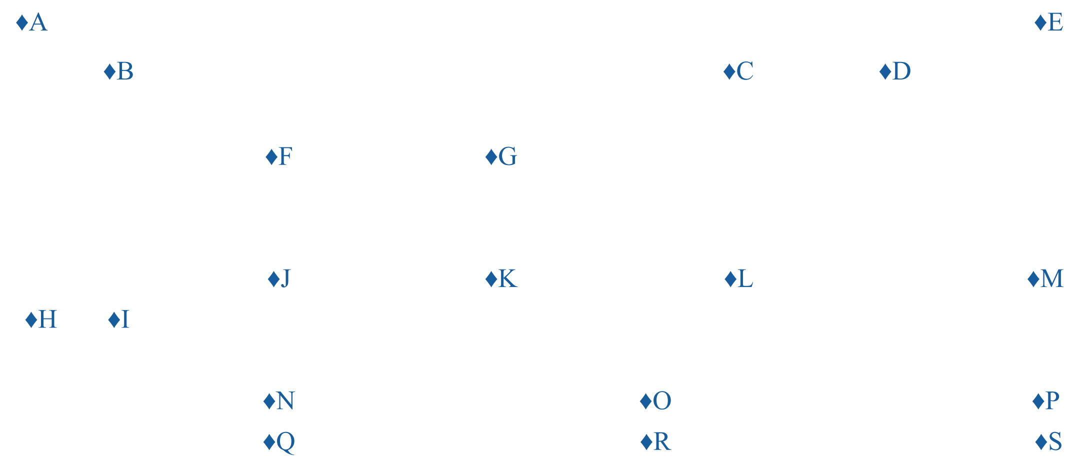
Use group discussion, visual-based learning and question and answer methodologies for this topic.

After reviewing the main points of the previous lesson, continue by presenting the classification of the elements. First, have the students perform the task given in ***Activity 4.4*** in groups for a few minutes and then have some groups present their conclusions

to the class. After the presentations, harmonize concepts. Use the following table for this purpose:

Element	Atomic Number	Electron Configuration	Valence electron	Block
Nitrogen	7	$[He]2s^22p^3$	5	p
Sodium	11	$[Ne]3s^1$	1	s
Silicon	14	$[Ne]3s^23p^2$	4	p
Iron	26	$[Ar]3d^64s^2$	2	d
Zinc	30	$[Ar]3d^{10}4s^2$	2	d
Krypton	36	$[Ar]3d^{10}4s^24p^6$	8	p
Cerium	58	$[Xe]4f^15d^16s^2$	2	f

Then, proceed by introducing the classifications of elements as representative, transition and rare-earth elements. Give a gapped-lecture on the relationship between electron configuration and classification of the elements. To help students understand the concepts in your explanation, hang a big periodic table chart on the side of the black board. Let the students conduct group discussions about groups, periods, and the relationships between group and period number and electron configurations of elements, by using the chart as a teaching aid. Finally, check whether or not the students have realized the blocks of elements classified as representative, transition and rare-earth elements. Use the following information.



Without referring to the periodic table, let students join the points given by the letters and draw a modern periodic table. After that let them identify the regions that bound.

a. s - block elements

b. p - block elements

e. representative elements.

f. transition elements

c. d - block elements
g. f - block elements.

d. rare - earth elements.

Harmonize concepts as follows:

a. ABIH
b. CDEML
c. FGKJ
d. NOPSRQ
e. Refer a,b
f. FGKJ
g. NOPSRQ

Reading check - This reading check is designed to help students to refer to additional materials, analyze information and write a short report.

Exercise 4.3

From Figure 4.8 we see that C, Li, and Be are in the same period (Period 2). Therefore, the radius of Li is greater than that of Be and atomic radius of Be is greater than that of C (atomic radius decreases as we go across a period from left to right). Thus, the order of decreasing radius is Li >Be>C.

Exercise 4.4

Generally, with increasing atomic number, the first ionization energy of the elements decreases down a group. Based on this:

a. IE1(Be) > IE1(Mg) > IE1(Ca) > IE1(Sr)
b. IE1(Li) > IE1(Na) > IE1(K)> IE1(Rb)
c. IE1(F) > IE1(Cl) > IE1(Br)> IE1(I)

Exercise 4.5

a. Nitrogen and phosphorous are members of Group 5A. They have the same valence electron configuration (ns^2np^3), but the 3p electron in phosphorous is farther from the nucleus and experiences less nuclear attraction than the 2p electron in nitrogen. Thus, we predict that phosphorous should have a smaller first ionization energy than nitrogen.

b. The electron configurations of Na and Mg are $1s^22s^22p^63s^1$ and $1s^22s^22p^63s^2$, respectively. The second ionization energy is the minimum energy required to remove an electron from a gaseous unipositive ion in its ground state. For the second ionization process we write

$$Na^+(g) \rightarrow Na^{2+}(g) + e^-$$
$$1s^22s^22p^6 \qquad 1s^22s^22p^5$$
$$Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$$
$$1s^22s^22p^63s^1 \qquad 1s^22s^22p^6$$

Because 2p electrons shield 3s electrons much more effectively than they shield each other and the 2p electrons are all paired, we predict that it should be easier to remove a 3s electron from Mg^+ than to remove a 2p electron from Na^+

Exercise 4.6

Electron affinity depends on the size of the atom and effective nuclear charge.

1. Down a given group, even though nuclear charge increases, the effective attraction of the nucleus for an added electron decreases. This is due to the increasing shielding effect of the inner electrons. Therefore, electron affinity decreases down a group. The following table shows the electron affinity of the halogens. The electron affinity of chlorine is higher than that of fluorine, due to smaller size of fluorine. The smaller the size of the atom, the greater the force of repulsion between the electron being added to the atom and the electrons already present on the atom, so that the smaller the electron affinity of the element would be,
2. Noble gases have extremely low (almost zero) electron affinity, due to their stable electron configuration and low tendency to accept an additional electron.
3. Halogens have the highest electron affinities (highest negative values). Halogens need only one electron to be stable. Therefore, they have a high tendency to gain an electron and form stable negative ions.

Exercise 4.7

Electronegativity decreases down a given group, due to increase in atomic size. Generally, high electronegativity is characteristic of nonmetals, and low electronegativity is characteristic of metals.

The decreasing order of electronegativity for each set of elements is:

a. Be > Mg > Ca > Ba
b. C > Si > Pb > Ge
c. F > Cl > Br > I

Answers to the Review Exercise

Part I: True or False Items

1. True
2. True
3. False
4. False
5. True

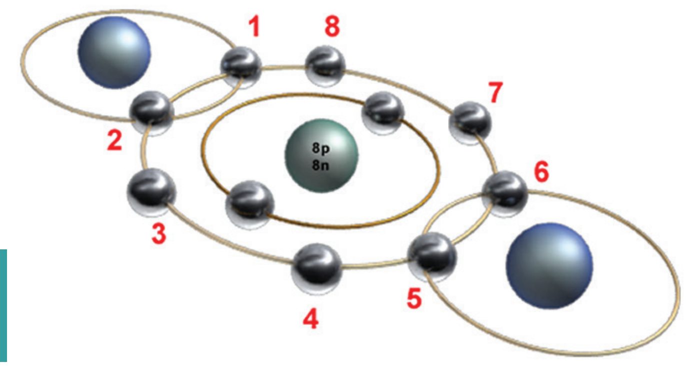
Part II Multiple choice

6. A
7. A
8. C
9. B
10. B
11. C
12. B
13. C

Part III:

Group	Period	Block type
IIA	3	s
VA	3	p
VIIIA	4	p
VIIB	4	d
IB	6	d
IA	4	s

UNIT 5



CHEMICAL BONDING

UNIT OVERVIEW

CHEMICAL BONDING

Total Period Allotted 13

This unit has four sections.

Section 5.1 deals with the definition of chemical bonding. It describes why atoms form chemical bonds. In their grade 7, unit 2 lessons, students covered the portions; elements and their representation, valence number, meaning of chemical formula, writing the formula of binary compounds, writing chemical formulas, polyatomic ions, writing and balancing chemical equations. In addition to this in grade 8, unit 2 they covered the lessons about mono, di, and polyatomic molecules of homoatomic nature.

Section 5.2 discusses the formation of ionic bonding, Lewis's formula of ionic compounds, and the general properties of ionic compounds.

Section 5.3 describes the formation of covalent bonding, Lewis's formula of covalent molecules, polarity in covalent molecules, formation of a coordinate covalent (dative) bond, and general properties of covalent compounds. Intermolecular forces in covalent compounds and The Valence Bond Theory will be covered in grade 11, unit 2 lesson.

Section 5.4 briefly presents the formation of metallic bonding and the properties of metallic bonds. Only the electrical and thermal conductivity of metals is covered in this section. The general properties of metals will be covered in grade 10, unit 5.

Dear teacher, read the student's textbook to get a good understanding of chemical bonding. Make sure that you are clear about the contents of the lesson before presenting it to the students. Read also the teacher's guide to get guidance regarding the teaching aids needed, the methods, handling students' activities, students' assessment, and continuous evaluation. It is your responsibility to plan how to facilitate the group discussion, the presentation of the lesson, handle students' questions and time budgeting.

You are advised to encourage students to read the student textbook before and after class. Every section begins with activities and ends with exercise questions which will help the student to grasp the outcomes of the topic in that section or sub-section in particular and in the unit in general. It would be helpful if they read the contents and attempt to do all activities before coming to class.

The methods used in this unit include group discussion, visual-based active learning, demonstration, collaborative learning, gapped lecture, question and answer, experimentation, and more.

Assess the students' work throughout each period. Check how every student does during discussions, presentations, and answering exercise questions. Evaluate whether or not most of the students have achieved the competencies suggested for each lesson. Appreciate students working above the minimum required level and give them extra work. Assist those students working below the minimum competency.

Unit Outcomes

At the end of the unit, students will be able to

- discuss the formation of ionic, covalent and metallic bonds
- explain the general properties of substances containing ionic, covalent and metallic bonds
- acquire the skills of drawing the electron dot or Lewis' structures for simple ionic and covalent compounds
- describe the origin of polarity within molecules.

Main Contents

5.1 Chemical bonding
5.2 Ionic bonding
5.3 Covalent bonding
5.4 Metallic bonding

Begin the unit by making students discuss the start-up activity. It is advisable to make a group of two or three for the discussion as students often sit in a group of two or three in the class. It would support learning if two to three students present their discussion points to the rest of the class. It is also good if you give time for the whole class to discuss.

The start-up activities are designed to help students understand the essence and importance of chemical bonding. The activities show the necessity of a 'bond' among the celestial bodies, between human beings and the Earth, and among elements existing on Earth.

You can summarize the start-up activity discussion points as follows:

Activity question #1 is about the bond between the Sun and the other planets that revolve around it. The relatively massive Sun has a gravitational force that attracts the planets towards itself. The gravitational force is the 'bond' or the type of energy that held the Sun and the planets, together. If it had not been for this, the 'bond' between the Earth and the Sun, life would have not survived on Earth. Plants need sunlight to undergo the light assisted reaction known as photosynthesis so that they could prepare their own food.

Activity question #2 deals with the importance of the Earth's gravitational force for the survival of the human race on Earth. If there is no gravity, then all of us will begin to float in the atmosphere. This will make cultivation difficult. If we cannot cultivate our land properly, then we will not have enough food to eat and this puts the human race in danger. Therefore, the Earth's gravitational force is another example of an essential 'bond' between human beings and the Earth.

Activity question #3 links the idea of 'bond' that we have discussed thus far to the topic of the unit, 'chemical bonding'. Except for few elements, all elements exist as mixtures. This reveals the inability of most elements to exist by themselves. In other words, they are not sufficiently stable to stand on their own just like we have seen the importance of gravitational force for the survival of the human race on Earth. So, the atoms of elements will also form a type of 'bond' that brings them together. We call this a 'chemical bond'. The main focus of this unit is discussing the different types of 'chemical bonds'.

5.1 Chemical Bonding

Period Allotted 1

Competencies

At the end of this section, students will be able to

- define chemical bonding
- describe why atoms form chemical bonds

Teaching aids: A chart that shows the electronic configuration of Group IA-VIIA, periodic table of the elements.

The suggested methods used in this section include: group discussion, gapped lecture, visual -based active learning, question and answer.

Presentation of the Subject Matter

You can begin the section by asking students what a 'chemical bond' is. Make sure that students have their textbooks with them in the class. Following this you may need to define the term 'chemical bond' and make students discuss in groups the questions under ***Activity 5.1***. After the students have completed the group discussion, you can invite two or three groups to present their discussion points to the rest of the students. Allow Encourage the rest of the students to add anything missing on the presentation made by the groups. Thereafter you can summarize the activities and the lesson as follows:

The activity questions in this section are designed to brainstorm students as to why the atoms of elements do not exist in their atomic form, what binds the atoms of elements together, and how atoms form a chemical bond.

Activity question #1 is about the inability of most elements to exist in their atomic form. If something cannot exist by itself, it is possible to deduce that the substance is unstable. To become stable, it must associate itself with the environment in which it exists. The same logic works for the atoms of the elements. Discuss why most atoms are unstable by comparing the electronic configuration of the atoms with the most stable elements called noble gases.

Activity question #2 is about what atoms need to do to become stable. If an atom is unstable, one way through which it becomes stable is associating itself with other atoms. This association is what we call chemical bonding. It is the chemical bond that binds atoms together to form compounds or molecules. Briefly, explain the fact that atoms need to have the nearest noble gas electronic configurations. Define the Octet rule and brief them with the exceptions to this rule using specific examples. Mention the specific elements in the periodic table obey the Octet Rule. Define and explain the Duet rule with examples.

Activity question #3 is about how the unstable atoms associate themselves with other atoms to form compounds or molecules and become sufficiently stable. In other words, it is about how atoms could satisfy the Octet rule. At this stage you may briefly explain the three possible ways through which atoms can fulfill the Octet or in some cases the Duet rule. Describe with examples how metals fulfill octet or duet rule. Do the same for non-metals. Finish your summary by explaining the energy changes accompanied in the course of gaining, losing, and sharing of electrons.

You can use the questions under ***Exercise 5.1*** as needed in your summary. Make sure that you have asked the questions to make sure students achieved the minimum learning competencies.

Answers to Exercise 5.1

1. The electronic configuration of a noble gas is the configuration wherein the number of electrons in the valence shell is eight, or two.
2. The noble gas configuration is important to determine the stability of an atom.
3. Octet rule: Atoms tend to form compounds in ways that give them eight valence electrons and thus the electron configuration of a noble gas.
4. Metals lose the valence electrons to obey the octet rule.
5. Non-metals obey the octet rule by gaining electrons. Sometimes they obey the octet rule by sharing electrons.
6. Only most of the second raw elements follow the octet rule.
7. Hydrogen can fill its outermost shell by gaining or sharing one electron, which will make the number of valence electrons two. Hydrogen will become stable with this number of electrons rather than eight according to the octet rule. This is how hydrogen violets the octet rule.

5.2 Ionic Bonding

Period Allotted 3

Competencies

At the end of this section, students will be able to

- explain the term ion
- elucidate the formation of ions by giving examples
- define ionic bonding
- describe the formation of an ionic bond
- give examples of simple ionic compounds.
- draw Lewis' structures or electron-dot formulas of simple ionic compounds.
- describe the general properties of ionic compounds.
- investigate the properties of given samples of ionic compounds.

In the previous section, we have discussed that atoms need to gain, lose or share electrons to become stable. This losing, gaining or sharing of electrons will lead atoms to chemical bonding. The result of the chemical bonding will be the formation of molecules or compounds having different chemical and physical properties. In this

section, we are going to discuss first the formation of ionic bonding. This will be followed by the discussion how to write ionic compounds using the Lewis' formula. The sub- topic will also cover the discussion of the general properties of ionic compounds. You, therefore, need to prepare yourself accordingly.

The suggested methods used in this section include: group discussion, gapped lecture, visual- based active learning, experimentation, and question and answer.

5.2.1 Formation of Ionic Bonding

Teaching Aids

Table 5.1 (student's textbook), ***Figures 5.2*** and ***5.3*** (student's textbook).

You may start this section by defining the terms 'ionization', 'ions', 'anions', 'cations', 'zwitterions', 'monoatomic ion', 'polyatomic ion', and 'ionic bond'. Make sure students have their textbooks with them in the class. You can support learning by making students discuss in groups the questions under ***Activity 5.2***. After the students have completed the group discussion, you can invite two or three groups to present their discussion points to the rest of the students. Allow Encourage the rest of the students to add anything missing on the presentation made by the groups. Thereafter you can summarize the activities and the lesson as follows:

The activity questions in this section are designed to give an illustration of the formation of ions, cations, anions, and ionic bonds, in a simplified way. Now answer the activity questions sequentially. Bring the contents of the section in line with the questions and briefly discuss them with examples.

Activity questions #1 to #3 deal with the formation of ions, more specifically, with cation and anion. If an atom gains extra electrons on its valence shell, it will have more electrons than the protons. If the number of electrons in an atom exceeds the number of protons, then the atom will have a negative charge. This is known as an anion. Therefore, atom 'A' will be an anion. But if an atom loses one of its valence electrons, the number of protons exceeds the number of electrons. This will result in a positively charged atom called a cation. Therefore, atom 'B' will be a cation. At this stage you can define the term 'ionization'. Illustrate this by supporting with examples. Classify elements into metals and non-metals and justify why metals lose electrons whereas non-metals gain electrons in the process of ionization, by associating with electronegativity and electro positivity. Associate this with the types of ions each main group element in the periodic table forms. Describe the formation of monoatomic and polyatomic ions. Explain the behaviors of ions. Explain how ions are written using ***Table 5.1***.

Activity question #4 is about the formation of ionic bonds. In questions #1 to #3, we have seen that atom 'A' became an anion A^- and atom 'B' became a cation B+. Since an anion is a negatively charged atom and a cation is a positively charged atom, by the rule 'unlike charges attract each other', the anion A^- and the cation B^+ are held by an electrostatic attractive force. At this stage define the term 'ionic bond'. The whole process is known as ionic bonding. The compound formed from A^- and B^{+}' is called ionic compound and it is represented as $A^- B^+$. You may associate this with the formation of ionic bonds in NaCl and $CaCl_2$, using ***Figures 5.2 and 5.3***. Briefly explain the driving force for the ionic bond formation is the tendency of the atoms to become stable. Inform them also that ionic bond is formed between metallic and non-metallic elements.

Explain to them the other or an alternative way through which Na and Cl could attain the Octet rule., , Inform them however why this alternative doesn't work actually.

You can pause and ask students the questions under ***Exercise 5.2*** at a relevant point of discussion throughout your mini-lecture. You can use some of them as a classwork exercise. Make sure that students achieved the minimum learning competencies.

Answers to Exercise 5.2

1. A cation is a positively charged atom or a group of atoms. Anion is an atom or a group of atoms having a negative charge.
2. Cations are formed when an atom loses its outermost electrons. Anions are formed when an atom gains electron to its outermost shell.
3. A chemical bond is a force that binds atoms or a group of atoms together.
4. Ionic bonds are formed by the attraction between oppositely charged ions.
5. It is relatively easy for aluminium to lose three valence electrons than to gain five electrons to its valence shell. This is because it needs large ionization energy for aluminium to gain five electrons than to lose three electrons.
6. It is relatively easy for iodine to gain one electron to its valence shell than to lose its seven valence electrons for it requires large ionization energy.
7. Potassium loses its valence electron and becomes K^+. Iodine accepts the electron released by potassium and becomes I-. In doing so, both potassium and iodine will attain an octet and become stable. The electrostatic attraction between the potassium cation and iodide ion will form the ionic bond in potassium iodide (KI).

5.2.2 Lewis' Formulas of Ionic Compounds

Teaching Aid

A big picture of Gilbert N. Lewis (***Figure 5.1***, student's textbook), Lewis' symbols of second-period elements (***Tables 5.2*** and ***5.3***, student's textbook), atomic diagrams of NaCl and $CaCl_2$ (***Figures 5.2 and 5.3***, student's textbook), a table showing some ionic compounds and their naming (***Table 5.4***, student's textbook).

You can begin presenting the sub-section by defining the terms 'chemical formula' and 'Lewis' dot formula'. Make sure students have their textbooks with them in the course of the teaching-learning process, to support learning. You can make students discuss in groups the questions under ***Activiti 5.3***. After the students have completed the group discussion, you can invite two or three groups to present their discussion points to the rest of the students. Encourage the rest of the students to discuss further the questions. Thereafter you can summarize the activities and the lesson as follows:

The activity questions in this section are designed to show the importance of using formulas to communicate substances in chemistry. Give answers to the activity questions as follows:

Activity question #1 is about the importance of representing an orange using anything that is commonly accepted by everybody who knows orange. One way is drawing a picture and painting it with a green color that resembles the real orange. If he/she is shown this picture and then made to go to the market to buy it, no doubt, he/she will buy an orange even if he/she does not know the real orange. It is in this way that students will be taught about formulas of ionic compounds. Bear in mind that they have no clue about how to write the formula of ionic compounds.

Activity question #2 is about the importance of having a common name for chemical substances. Chemistry is not only a local subject. It is taught globally and several researchers are using chemical substances. Therefore, the need for international chemical names and chemical languages is crucial. Unless we use a standard chemical name, there is no way we could understand each other. Chemistry students and researchers living in Ethiopia and South Africa should equally understand the chemical name of substances.

Activity question #3 is about the importance of having a common formula for ionic compounds. As we have said in question #2 above, the same justification works for having common formula for ionic compounds. One general way of representing ionic compounds is by using Lewis' dot formula. Briefly and with sufficient examples from the textbook, describe how to write the dot formula of the American chemist Gilbert N. Lewis.

Use ***Table 5.2*** to discuss the Lewis' dot formula of the third-period elements. Write on the board to show how Lewis' symbols can be used to illustrate the formation of cations and anions from atoms as shown below:

$$Na\cdot \longrightarrow Na^{+} + e^{-} \qquad \cdot Ca \cdot \longrightarrow Ca^{2+} + 2e^{-}$$

Likewise, they can be used to show the formation of anions from atoms for chlorine and sulphur:

Show students examples of how Lewis' dot formula is used in the formation of ionic compounds using ***Table 5.3***.

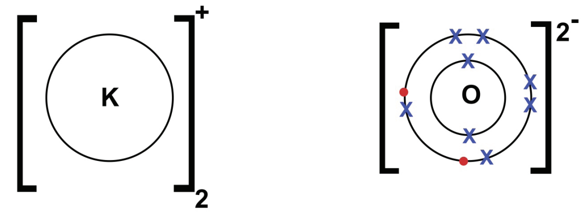
Describe how an atomic diagram is used as an alternative way of Lewis' dot formula to show ionic bond formation using ***Figures 5.2*** (about the formation of NaCl) and ***Figure 5.3*** (about the formation of $CaCl_2$).

There are seven questions under ***Exercise 5.3***. You can use these questions in your mini- lecture whenever necessary. You can use some of the questions as a classwork or homework exercise. Make sure that students achieved the minimum learning competencies.

Answers to Exercise 5.3

1. The valence electron configuration for aluminium is 3. So, it would have three dots around the symbol for aluminium, two of them paired to represent the 3s electrons (or three single dots around the atom):
   The valence electron configuration for selenium is 6. In the valence shell, there are six electrons. Its electron dot diagram is as follows:
2. Column IIA.
3. Column VIA.

4. Formula: K_2O; name: Potassium oxide.



5. The atomic diagram of K_2O:
6. A group of eight elements namely, sodium (Na), magnesium (Mg), aluminium (Al), silicon (Si), phosphorous (P), sulphur (S), chlorine (Cl) and argon (Ar) that belong to the third period of the periodic table are called third-row elements. The formula:
   a. $MgCl_2$ b. $AlCl_3$ c. Na_2S d. Al_2S_3

7. Lewis' symbols

Ionic compound	Lewis' symbol (formula)
a. MgS	$Mg^{2+}:S:^{2-}$
b. Al_2O_3	$Al^{3+}:O:^{2-}$
c. $GaCl_3$	$Ga^{3+}:Cl:^{-}$
d. K_2O	$2K^{+}:O:^{2-}$
e. Li_3N	$3\ Li^{+}:N:^{3-}$
f. KF	$K^{+}:F:^{-}$

5.2.3 General Properties of Ionic Compounds

Teaching Aids

The crystal structure of sodium chloride (***Figure 5.4*** and ***5.5*** , student's textbook), a picture of an electric circuit in ionic solution (***Figure 5.6***, student's textbook).

You may begin presenting this sub-section by defining the 'physical property of a substance' and 'chemical property of a substance'. Make sure students have their textbooks with them in the course of the teaching-learning process, to support learning. You can make students discuss in groups the questions under ***Activity 5.4***. After the students have completed the group discussion, invite two or three groups to present their discussion points to the rest of the students. Allow the rest of the students to discuss the questions further. Thereafter you may summarize the activities and the lesson as follows:

The activity questions in this section are designed to demonstrate the physical and chemical properties of substances. Therefore, begin your summary by answering them as follows:

Activity question #1 is about some human being's behavior emanating from hormonal actions. In other words, it is the behavior stemmed from the chemical reactions inside the body. It could also emanate from the genetic make-up of individuals. It is also about the physical properties of human beings. Human behavior refers to the way humans act and interact. It is based on, and influenced by several factors such as genetic make-up, culture a, individual values, and attitudes. In this specific question, you need to focus on the behaviors associated with hormonal actions and genetic make-ups. For example, a person who is in a dangerous situation can jump more than when he/she is under normal conditions due to the work of the hormone called adrenalin. Similarly, the genetic make-up of a person is responsible for most of the behaviors of a person. Genes, via their influences on morphology and physiology, create a framework within which the environment acts to shape the behavior of an individual. Therefore, the person's physical appearance is associated with his/her genetic make-up. Genes at the molecular level are organic bases. This is a very good example to show students how physical and chemical properties are tied together.

Activity question #2 is about using taste as the physical property. You can identify the three juices by their tastes. Lemon has a strong sour taste, orange is a relatively milder sour mixed with the sweet test, and grape juice has a sweet test if of course, it is fresh. The sour taste in the case of lemon and orange is due to citric acid. Acids have a sour taste in general.

Activity question #3 is about the properties of ionic compounds that make them different from other compounds. Now you can delve into the content of the sub-section, general properties of ionic compounds. Discuss briefly the six general properties of ionic compounds. You can use the figures mentioned as a teaching aid to support learning. Provide enough examples in each case.

The experiment mentioned in this sub-section of the student's textbook needs to be performed in the chemistry laboratory. Schedule a laboratory session outside the

normal lesson periods to make students experiment. Experiment yourself before making the students do it. Prepare all the necessary materials and experiment. Tell the students to use the format in unit 3 for reporting the observations and the answers to ***Exercise 5.4***. You can consider this as one of the formative assessments.

The following are the activities you are going to do in this laboratory session:

- Inform them of the laboratory precautions
- Brief them about the solubility of ionic compounds
- Brief them about the experimental procedures
- Make available all the necessary materials for students
- Follow every student's participation and performance
- Move around and make sure that students have understood what is expected of them in this laboratory session
- Do not leave the laboratory until the experiment is completed by students

Answers to Observation and Analysis Questions

1. The salt solution will light the electric bulb when the circuit is on.
2. Distilled water has no ions to transport the electric charge. The sodium chloride crystal is packed with cations and anions that did not move. If there is no charge moving through the electric circuit, then the bulb will not light
3. A water solution of sodium chloride will conduct electricity. It is an ionic compound as well.

Use NaCl as a common household example to summarize the properties of ionic compounds. You can give more examples using Table 4 as well.

Sugar being a crystalline solid and soluble in water just like sodium chloride does not conduct electricity in solution form. This would make the students to become curious to know about the reason. In contrast, sugar is a crystalline covalent compound (will be discussed in the proceeding section). It has a lower melting point (186 °C) than salt. It dissolves in water but doesn't dissociate into ions so its solution doesn't conduct electricity. Do not tell them the reason why sugar solution does not conduct electricity, at this stage. Inform them that they will be taught about it in the lessons ahead.

You can use the questions under ***Exercise 5.5*** whenever necessary in your mini-lecture. Some of the questions could be used as classwork or homework to support students understanding. Make sure that students achieved the minimum learning competencies.

Answers to Exercise 5.4

1. The general properties of ionic compounds are
   a. They form crystals.
   b. They're hard and brittle.
   c. They have high melting points and high boiling points.
   d. They conduct electricity when they are dissolved in the water and in the molten state.
   e. They have high density.
2. Ionic compounds are formed from cationic and anionic species that are strongly held by electrostatic force which makes the ions to have a regular packed structure known as crystal.
3. No. Because some non-ionic compounds are also soluble in water. For example, sugar.
4. This is because when they are in the molten state or an aqueous solution, the ions become free to move and hence, they carry an electric charge. This is not true when they are in the solid-state i.e., the ions are strongly held together in the crystal lattice and cannot move freely.

5.3 Covalent Bonding

Period Allotted 8

Competencies

At the end of this section, students will be able to

- define covalent bonding.
- describe the formation of a covalent bond.
- draw Lewis' structures or electron-dot formulas of simple covalent molecules.
- give examples of different types of covalent molecules.
- make models of covalent molecules show single, double and triple bonds using
- sticks and balls or locally available materials.
- discuss the polarity in covalent molecules
- distinguish between polar and non-polar covalent molecules
- define coordinate covalent (dative) bond.
- elucidate the formation of a coordinate covalent bonds using suitable examples.
- explain the general properties of covalent compounds.
- Investigate the properties of given samples of covalent compounds.

We thoroughly discussed that to become stable, atoms of elements need to fulfil the octet rule. Except for the noble gases, all the second raw elements obey the octet or duet rule either by gaining, losing or sharing electrons. In this section, we shall discuss the second type of bonding known as covalent bonding, the Lewis' dot formulas of covalent molecules, polarity in covalent molecules, coordinate covalent bond, and general properties of covalent compounds. The period allotted for this section is eight and therefore needs your preparation ahead.

The suggested methods used in this section include: group discussion, gapped lecture, visual- based active learning, and question and answer.

5.3.1 Formation of Covalent Bond

Teaching Aids

The atomic diagram of the formation of H_2 molecule (*Figure 5.8* , student's textbook), the schemes showing the electrostatic attraction force between the electrons and the nuclei in hydrogen molecule (*Figures 5.9*, student's textbook), atomic diagrams showing the formation of a chlorine molecule (*Figure 5.10*), oxygen molecule (*Figure 5.11*, student's textbook), and nitrogen molecule (*Figure 5.12*, student's textbook).

You can start presenting the lesson by defining the terms 'covalent bond', 'covalent molecule', 'single bond', 'double bond', 'triple bond', and 'multiple bond'. Make sure students have their textbooks with them in the class. Make students discuss in groups the questions under ***Activiti 5.5***, to support learning. After the students have completed the group discussion, you can invite two or three groups to present their discussion points to the rest of the students. Encourage the rest of the students to add anything missing on the presentation made by the groups. Thereafter, you can summarize the activities and the lesson as follows

The activity questions in this section are designed to provoke thought in the minds of the students in relation to having the possibility of forming a chemical bond between atoms other than through electron transfer. Therefore, you may begin your summary by answering the activity questions as follows:

Activity question #1 is designed to challenge the students to think the possibility of forming a bond between two non-metallic elements. In the case of ionic bonding, a metallic atom and a non-metallic atom form an ionic bond. In this case, it is a different scenario. As we have discussed in ionic bond formation, non-metallic elements do not tend to lose their electrons because of their high electronegativity. So, you may ask students the question 'how could it be possible to form a bond between two non-metallic elements?' Remind them of the three possibilities through which unstable atoms can become stable. Now you can give them the answer, it is through sharing their valence electrons that non-metallic elements form a bond. At this stage you can define covalent bonding. The molecules formed through sharing of electrons are known as covalent molecules.

Activity question #2 is about the origin and type of force that holds the bonded non-metallic atoms. Remind them about the electrostatic attraction force that is responsible to hold the cation and anion in ionic bonding. Challenge students at this stage regarding this attraction force since there are no charged species if the atoms share their valence electron(s). Describe the origin of the force that holds the two atoms. It is the electrostatic attraction force between the shared electrons and the two nuclei that holds the atoms together. Explain to them, however, there is the presence of an optimum distance between the nuclei of the bonding atoms. When the nuclei become closer than the optimum distance, they will repel each other. If they are far away from the optimum distance, they cannot share electrons hence, no bond will be formed. You can use ***Figure 5.9*** to illustrate this.

Activity question #3 is about the formation of a covalent bond between the same atoms and between different atoms. In other words, the discussion of the way how covalent bonding forms will be dealt with under this question. Therefore, describe the formation of different covalent bonds in detail through examples from the textbook.

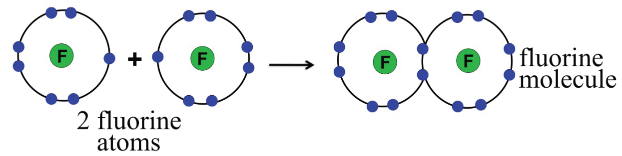
You can begin with the formation of singly bonded homoatomic covalent molecules H_2 and Cl_2. Then move to the singly bonded heteroatomic molecules HCl and H_2S formation.You can support learning by using the teaching aids while discussing each molecule. Define the term 'lone pair electrons'. Show the lone pair electrons in Cl_2, H_2S, and HCl molecules.

Pause your mini-lecture here and ask questions 1 to 3 found under ***Exercise 5.5*** and receive answers orally. You can give question number 4 under ***Exercise 5.5***, as classwork and make them do in groups. Encourage four or five groups to present their answers. Revise any misconception or misunderstanding observed.

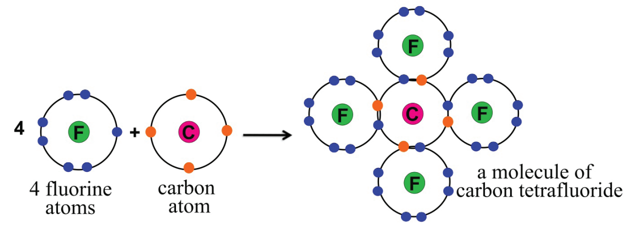
Answers to Exercise 5.5

1. A covalent bond is a type of chemical bond formed by sharing of electrons between two same or different atoms.

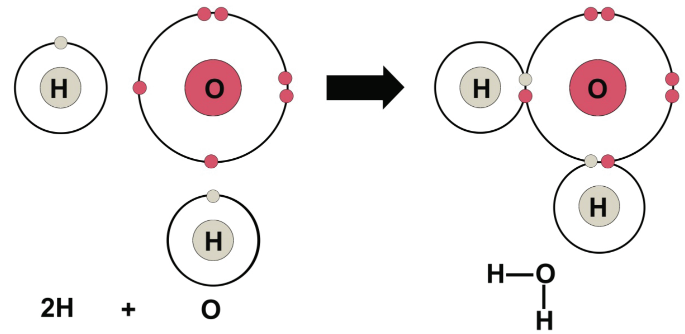
2. In covalently bonded atoms, the two atoms are held together by an electrostatic attraction force between the shared electrons and the nuclei of the two atoms.
3. This is because of two reasons: i) the valence electrons that are found on the two covalently bonded atoms possess negative charge hence, they repel each other, and ii) the nuclei of the two atoms possess a positive charge and hence there is electrostatic repulsion between them. There is an optimum nuclear distance for the two atoms to exist as a molecule.
4. Formation of F_2 =



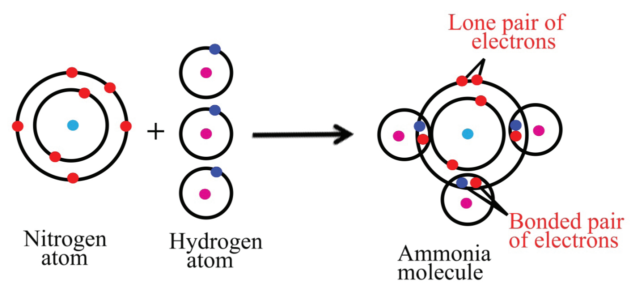
Formation of CF_4 =



Formation of H_2O =



Formation of NH_3 =



Now, move to the formation of multiple bonds. Make students discuss the questions under *Activity 5.5* in groups and present their discussion points to the rest of the class. Summarize the discussion points as follows:

The activity questions are designed to show students the other possible way through which two non-metallic atoms form a bond other than a single bond. It is about double and triple bonds formation. You can begin your summary by answering the activity questions.

Activity question #1 is a question that provokes students to think other possibilities of covalent bond formation other than a single bond. Explain how a single covalent bond is formed between any two atoms. At this stage ask them what if the two atoms share two electrons each. Then move to question number 2

Activity question #2 answers the aforementioned question. Let us consider atom 'A'. The total electrons of atom 'A' are eight. Its electronic configuration will be 2,6. To fulfil the Octet rule and becomes stable, it needs two more electrons. However, atom 'A' must bond with itself to form the molecule 'A_2'. The only way A_2 would be formed is if both atoms share two electrons each. Therefore, the total number of valence electrons for both atoms will become eight. The number of shared electrons will be two pairs and this will make a double bond. Atom 'B' has a total of seven electrons and its electronic configuration will be 2, 5. Atom 'B' needs three more electrons to become stable. To form B_2, both atoms must share three electrons each, which makes the number of shared electrons three pairs. Such a type of covalent bond is known as a triple bond.

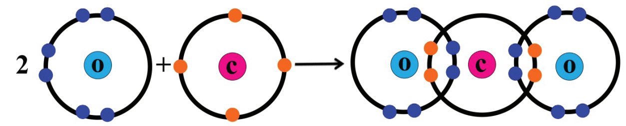
Now you can describe the formation of multiple bonds. You can begin by explaining the covalent bond formation in the doubly bonded homoatomic molecule O_2 (use ***Figure 5.11***). Following this, you can discuss the formation of triple bond in N_2 (use ***Figure 5.12***).

You can give question number 2 as classwork. Encourage three students (one molecule each) discuss their answers with the class. Encourage and give the opportunity to the slow learners. Maintain gender balance. Clarify any ambiguity or misconception observed.

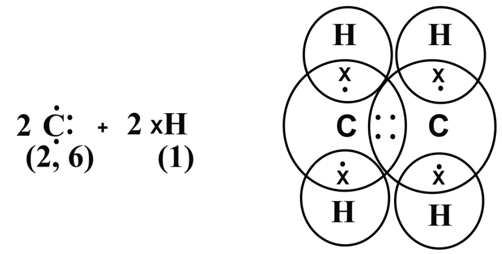
Answers to Exercise 5.6

1. There are three types of covalent bonds: single bond, double bond, and triple bond.

2. Formation of CO_2 =

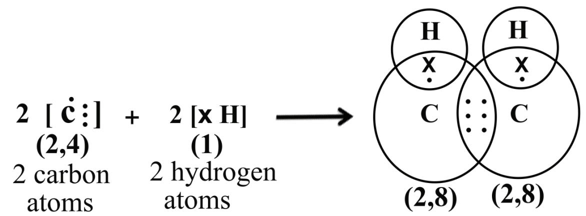


Formation of H_4C_2 =



Ethylene molecule

Formation of H_2C_2 =



Acetylene molecule

Activity question #4 is meant to check whether students have understood the concept of multiple bond. Therefore, let them do this as homework.

5.3.2 Lewis' Formula of Covalent Molecules

Teaching Aid

The Lewis' formula of some simple covalent molecules (***Table 5.5,*** student's textbook).

You can begin presenting the lesson by reminding the use of Lewis formula in representing ionic compounds. Inform them that Lewis' formula is also used to represent covalent bonds in covalent molecules. You can give ***Activity 5.7*** for students to discuss in a group. Encourage three or four groups to present their discussion points to the rest of the students. After the discussion of the whole class, you can summarize the contents of the section through mini-lecture. You may begin by answering the activity questions.

The activity questions are designed to adapt the Lewis' dot formula discussed in ionic compounds to the various types of covalent molecules. In addition to this, they will help students differentiate between bonding and lone pair electrons, single bonds, double bonds, and triple bonds from Lewis' formula of a covalent molecule.

Activity question #1 is a challenging question that provokes thought in students minds as to how to adopt Lewis' dot formula used in ionic compounds for covalent molecules. The rule to write Lewis' dot formula still works. The only difference between the Lewis' formula of ionic compounds and covalent molecules is the absence of positive and negative charges in t Lewis' formula of covalent molecules. All the valence electrons will be represented as 'dot' or 'x'.

Activity question #2 is applying the understanding revealed in question number 1. The molecule HCN, however, is a little bit complex and needs serious thinking. We know that hydrogen needs to fulfil the Duet rule. It does so by sharing its one electron with carbon's one electron (H∶C). Nitrogen on the other hand, shares its three electrons with the carbon's three electrons to fulfil octet (H:C⁝⁝N:). Carbon being the central atom shares its one electron with hydrogen and the remaining three electrons with nitrogen to fulfil the Octet rule. Lewis' did not only propose a dot formula but also did a line formula. According to Lewis, a single line represents a pair of electrons. Hence, HCN could be written by a line formula as H-C≡N. Sometimes the dot and line Lewis' formulas are used being mixed. For example, HCN could be written as H-C≡N:.

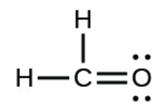
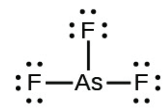
Elaborate Lewis' dot or line formula writing by giving examples from Group IVA, VA, VIA, and VIIA elements. You may show them Lewis' formula of CCl_4 and SiH_4 for Group IVA (can also be an example for group VIA), NH_3 for group VA, CH_2O (formaldehyde) and C_2H_4 (ethene) for group VIA, and Cl_2 for group VIIA. The double bond between carbon and oxygen in formaldehyde (CH_2O), and the triple bond in N_2 could be used as representative examples of Lewis' formula for multiple bonds. You may also use Table 5 to show Lewis' formula of some covalent molecules including the ones described above.

Activity question #3 is meant to help students differentiate between bonding and lone pair electrons from Lewis' formula of a covalent molecule. In HCN as we can see from the line and dot mixed Lewis' formula, there are four lines (one between carbon and hydrogen and three between carbon and nitrogen) each line representing a pair of electrons. All of these are bonding electron pairs whereas the two dots on the nitrogen represent one lone pair of electrons.

Activity question #4 is meant to help students differentiate single, double, and triple covalent bonds from Lewis' formula. As we can see the dot and line mixed Lewis' formula of HCN, there is one single bond (between hydrogen and carbon), no double bond, and one triple bond (between carbon and nitrogen).

You can stabilize this lesson by asking some questions that would help you summarize the lesson. You can give the questions under ***Exercise 5.7*** a homework. Each student needs to come up with his/her models for the molecules given in question number 3. Make students describe their models to the class.

Answers to Exercise 5.7

1. P_2: :P≡P:
2. The Lewis structures are as follows:
   a. O_2: :Ö=Ö:
   b. H_2CO: 
   c. AsF_3: 
3. Make sure that students made the models of the given molecules from locally available materials.

5.3.3 Polarity in Covalent Molecules

Teaching Aid

Linus Pawling's electronegativity values of some common non-metallic elements (***Table 5.6,*** student's textbook).

Although the terms 'electronegativity' and 'electron affinity' were defined in section 3.5.1, it is good if you begin presenting the lesson by defining them in addition to defining the new terms like 'dipole', 'polarity', 'polar molecules', 'polar covalent bond', 'non-polar molecules' and 'non-polar covalent bond'. s

Make students discuss the questions under ***Activity 5.8***, in groups and present their discussion points to the rest of the class. Give time for the whole class to discuss further and then summarize the discussion points by associating them with the contents of the section. It will be a good approach to start by answering the activity questions because they are the leading questions of the lesson.

Activity question #1 is a challenging question for students to give the right answer. However, all of them are aware of the fact that table salt is soluble in water but not in oil. Probably students could reason out by saying, "oil is a thick liquid and water is thin". This however is not the reason. Leave without answering this question for a moment. Tell them you will answer it sometime later but before the period ends. Then move to question number two.

For Activity question #2, students might give the correct answer if they understood the concept of electronegativity. You may need to clarify the concept 'electronegativity' because without its clear understanding, it is not possible to answer this question in a way student would understand it. You can use Table 6 to elaborate on the concept of electronegativity. In covalently bonded molecules, the electrons are distributed in such a way that the more electronegative element attracts the shared electrons towards itself creating a partial negative charge (δ-) around itself. This pull of the shared electrons towards the more electronegative atom will create a partial positive charge (δ+) on the less electronegative atom. Now, you can define the term 'pole', 'polarity', and 'polar covalent molecule'. Explain why all ionic compounds are polar.

Describe the general rules that help distinguish between the polar covalent bond and ionic bond. Provide the answer for the first activity question i.e., the reason why table salt (NaCl) is soluble in water but not in oil. You may need to describe the principle 'like dissolves like' so that it will be easy for them to understand the answer. Explain why water is a polar covalent molecule and table salt (NaCl) is an ionic compound. Because water and table salt are polar, salt dissolves in water easily. Oil on the other hand is more of a hydrocarbon organic molecule and is non-polar. So, a non-polar molecule cannot dissolve a polar ionic compound.

You may describe the more polar molecules with examples from the textbook (HF, H_2O, NH_3, SO_2, H_2S, CH_4O, and C_2H_6O). Solving the problem given in the textbook, supports learning, as well.

Activity question #3 is about the electron distribution (polarity) of a covalent bond formed from two atoms having similar electronegativities. At this stage, it is very clear that if the two atoms have similar electronegativities, then this means they have similar power to attract the bonding electrons towards themselves. This will result in a net-zero charge development and the bond will be non-polar. Now you can briefly discuss the non-polar covalent molecules categorically i.e., homonuclear diatomic molecules (H_2, O_2, N_2 and Cl_2) and heteronuclear molecules (CH_4, C_2H_6, C_6H_6, CO_2).

You can also discuss heteronuclear non-polar molecules whose specific bonds are polar but the net polarity is zero with examples from the textbook (CCl_2, CO_2).

You can give ***Exercise 5.8*** as classwork or homework. Check their work, record their results in your students' performance list, and evaluate how many of the students achieved the minimum learning competencies.

Answers to Exercise 5.8

1. Polar covalent bond: NH_3; ionic bond: CsCl; non-polar covalent bond: N-N bond in H_2NNH_2.
2. The H-N bond in NH_3 is polar because the electronegativity difference between H (2.1) and N (3.0) is 0.9 and since this is greater than 0.5, it qualifies to be polar. The N-N bond is non-polar covalent bond because there is no electronegativity difference between the nitrogen atoms. CsCl is an ionic compound because i) the electronegativity difference between Cs (0.7) and Cl (3.0) is 2.7 and qualifies to be an ionic bond. ii) Cs is metal and Cl is a non-metal, hence the bond between metallic and non-metallic elements is ionic.
3. Although both C-O and S-O bonds are polar, in CO_2 the two oxygen atoms arrange themselves linearly and this cancels out each other the partial charges. In SO_2, however, the oxygens arrange themselves in a bent shape, and the partial charges will not cancel out each other.

5.3.4 Coordinate Covalent Bond (Dative Bond)

Teaching Aid

Atomic diagram that shows the formation of a coordinate covalent bond between atoms 1 and 2 (***Figure 5.13***, student's textbook).

To connect the previous lessons to this lesson, you may begin by revising the previous lessons as follows:

Remind students that in the previous sections they have discussed the formation of ionic and covalent bonding. In ionic bonding, a metallic element loses and a non-metallic element accepts electron(s). Covalent bond on the other hand results from the equal sharing of electrons between two atoms. Tell students that in this sub-section they are going to learn about the third possibility that atoms can form a bond known as a coordinate covalent bond also known as a dative bond.

Following the introductory remark, you canmake them discuss the questions under ***Activity 5.9***, which would be followed by the presentation of the discussion points by three or four groups. Allow some time for the discussion of the whole class and then summarize their discussion points in your mini -lecture. The activity questions are the leading questions of the lesson and it is advisable to begin by answering them.

Activity question #1 is an illustration of coordinate covalent bond formation. Here is the explanation: person 'A' has a total of 200 birr and bought three "doro wet" by sharing 40 birr with his/her friends. So, person 'A' is left with 160 birr (200-40 = 160) in his/her pocket. Since person's 'A' friend had no money in his/her pocket, the only way they can eat dinner together is if person "A" buys "Tibs" for both of them since he/she has enough money to buy two "Tibs". Remind students about the dinner cost coverage by person 'A' and the zero contribution his/her friend made.

Activity question #2 is thought-provoking and makes them associate the illustration given in question #1 so that they could come up with an answer. If they are not in a position to answer question #1 , then ask them to associate it to question #1. Now, they may answer the question properly. If not, inform them two atoms can form a bond by sharing electrons and the sharing being from one atom alone. Such type of bond is called a coordinate covalent bond or dative bond.

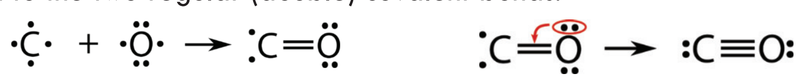
Describe briefly the conditions required for the formation of a coordinate covalent bonds using ***Figure 5.13***. Then illustrate coordinate covalent bond formation with examples from the textbook (between NH_3 and BF_3, NH_3 and H^+, and in Al_2Cl_6).

Inform them that although the properties of a coordinate covalent bonds do not differ from those of normal covalent bonds (because all electrons are alike no matter what their source), the distinction is useful for keeping track of valence electrons.

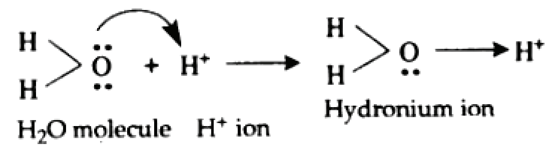
You can give ***Exercise 5.9*** as a classwork. Move around and checkout whether students' answer to the questions is correct. Help those who lack full understanding. Make sure that students achieved the minimum learning competencies.

Answers to Exercise 5.9

1. Carbon (C) has four electrons in its valence shell, and oxygen (O) has six. Both carbon and oxygen share their two electrons. While the Octet rule is satisfied with oxygen, there is still a deficit of two electrons on the carbon. So, oxygen shares its two electrons with carbon to form a coordinate covalent bond, in addition to the two regular (double) covalent bonds.



2. When hydrogen chloride (HCl) gas dissolves in water to make hydrochloric acid (HCl aq.), a coordinate covalent bond is formed in the hydronium ion. The hydrogen (H) nucleus is transferred to the water (H_2O) molecule, which has a lone pair of electrons to form hydronium. So, H does not contribute any electrons to the bond.



Or $H_2O \longrightarrow H^+$ Or H_3O^+

5.3.5 General Properties of Covalent Compounds

Teaching Aids

Hydrogen bonding in HF molecules (***Figure 5.14***, student's textbook), an immiscible mixture of water and oil (***Figure 5.15***, student's textbook), melting and boiling points of halogens (***Table 5.7***, student's textbook), Intermolecular forces and boiling points (***Table 5.8***, student's textbook).

You may begin the presentation of this section by defining 'the physical property of a substance' and 'the chemical property of a substance. Then you may move to make students discuss the questions under ***Activity 5.10*** in groups. Give time for three or four groups to present their discussion points to the rest of the class. Then summarize the discussion points in your mini- lecture beginning from the activity questions.

Activity question #1 is intended to show the difference in the properties between ionic and covalent compounds. It would not be difficult to answer most of the questions indicated under question number one. For example, they can tell that the water is liquid and table salt is solid at room temperature, and the melting point of water is less than the melting point of table salt. However, they might not compare properly the boiling point of water and table salt because they might not have the correct information of this previously. It is therefore at this juncture you should give them some general information regarding the bond strength difference between ionic and covalent bonds. As you know water is a polar covalent molecule whereas table salt is an ionic compound. Generally, ionic bonds are stronger than the intermolecular forces that exist in polar or non-polar covalent molecules. Regarding conductivity of electricity, students might not answer at first glance because they might have forgotten

Experiment 5.1. You need to remind them of ***Experiment 5.1*** which is about the test for the electrical conductivity of distilled water, solid table salt, and water solution of table salt. Then they will give you the correct answer. You don't need to waste time explaining this because they have seen it practically.

Activity question #2 is a leading question towards the core of the section i.e., the general properties of covalent compounds. Now give them the list of the general properties of covalent compounds. Do not discuss the reasons behind at this stage. You will discuss the detailed reasons later on.

You can stabilize the lesson by asking the questions under ***Exercise 5.10*** and make them answer orally. Participate as many students as possible. Keep gender balance and consider inclusiveness. Make sure that students achieved the minimum learning competencies relevant to the content discussed so far.

Answers to Exercise 5.10

1. The physical properties of covalent compounds:
   a) Most covalent compounds are gases or liquids at room temperature. Some are soft solids.
   b) Most covalent compounds have low melting and boiling points.
   c) Most covalent compounds are poor conductors of electricity.
   d) Most covalent compounds are soluble in non-polar solvents and are insoluble in polar solvents like water.
   e) Reactions of covalent compounds are slow compared to that of ionic compounds.
   f) They have low density.
2. Comparison of ionic and covalent compounds:

Table: Comparison of ionic and covalent compounds:

Property	Ionic compound	Polar covalent compound	Nonpolar covalent compound
Physical state	Crystalline solids. The constituent particles of the crystals are ions, not molecules.	Generally, liquids or gases. The constituent particles are molecules.	
Melting and boiling points	Have high melting and boiling points as a result of the need of considerable heat energy requirement to overcome the electrostatic force between ions.	Have low melting and boiling points because a small amount of energy is sufficient to overcome the weak electrostatic force of attraction and hydrogen bonding between the polar molecules.	Have low melting and boiling points because a small amount of energy is sufficient to overcome the weak intermolecular forces acting between the molecules.
Solubility	Generally soluble in polar solvents like water, but insoluble in nonpolar organic solvents.	Soluble in polar solvent due to the presence of partial charges. Also soluble in nonpolar covalent liquids, due to similar forces between the molecules.	Insoluble in polar solvents like water because they don't ionize, but soluble in nonpolar covalent liquids like benzene, CCl_4, due to similar forces.
Density	The opposite charged ions in an ionic compound are held closely by an electrostatic force of attraction. Hence the number of ions per unit volume in an ionic compound is more and thereby their density is high.	Generally, they exist in the form of liquid or gaseous states due to weak intermolecular forces. Hence the number of molecules per unit volume is less, thereby leading to low density.	
Electrical conductivity	Electrovalent compounds conduct electricity either in the fused state or in their aqueous solutions due to the presence of molten ions.	These compounds ionize in water and the ions help in conducting electricity.	These compounds do not ionize and hence do not conduct electricity.

Forces that hold molecules together and their effect on physical properties of covalent compounds will be covered in grade 11, unit 2.

5.4 Metallic Bonding

Period Allotted 1

Competencies

At the end of this section, students will be able to

- discuss the formation of metallic bond
- explain the electrical and thermal conductivity of metals in relation to metallic bonding.
- make a model to demonstrate metallic bonding

In the previous sections, we have discussed the three types of bonding known as ionic, covalent and coordinate covalent. In ionic bonding, metals form a bond with non-metallic elements. In covalent bonding, non-metals share electrons. In coordinate covalent bonding, non-metallic elements share electrons but the sharing comes from one atom. These, however, are not the only types of bonding that elements can form. There is a fourth type of bonding that occurs between metallic atoms. This bond unlike other types of bonds will only occur between atoms of the same metallic elements. This section therefor, deals with the formation of metallic bonding and its properties.

Teaching Aids

The Electron Sea Model (***Figure 5.14***, student's textbook), the electron sea model of magnesium metal (***Figure 5.15***, student's textbook), conductivity in metallic bond (***Figure 5.17***).

The suggested methods used in this section are group discussion, gapped lecture, visual- based active learning, question and answer, and collaborative learning.

5.4.1 Formation of Metallic Bond

Make students discuss the questions under ***Activity 5.11*** in groups of two or three. Let three or four groups present their discussion points to the rest of the class. Summarize the discussion points raised by the students. You may add the missing information in your mini lecture. The activity questions are intended to lead the teaching-learning process by provoking thought, providing hints and as an illustrative example of the contents to be covered in the lesson. It is, therefore, advisable to begin by answering the activity questions.

Activity question #1 is intended to show the major difference between ionic compounds and covalent molecules. Students might not know the difference between the two. It is therefore essential to clarify the difference. There are no ionic molecules but ionic compounds. We cannot say an ionic compound 'ionic molecule' because ionic compounds do not exist in molecular form. They rather do exist in a crystal lattice of ions. Covalent molecules, however, can be called covalent compounds or covalent molecules. This is because covalent molecules exist in molecular form. Both ionic and covalent compounds can be called compounds because the term compound means a substance that is composed of two or more elements.

Activity questions #2 and #3 would lead you to metallic bonding. Of course, students might not give the correct answer to this question. Explain them why there are no metallic molecules and discuss metallic bonding. Metals can only form a sea of metallic cations in which electrons move freely. They cannot exist in molecular form just like ionic compounds. Metals exist in a form known as "an array of positive ions in a sea of electrons".

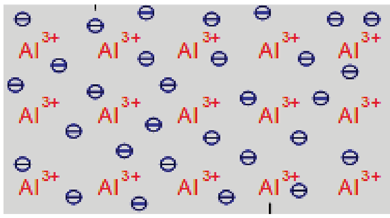
You can discuss the formation of metallic bonds in sodium and magnesium metals using the Electron Sea metallic bonding model (***Figure 5.14***).

Compare the metallic bond strengths of sodium and magnesium. Discuss why the strength of the attraction force between the nuclei and the free electrons in terms of ionic size in magnesium is stronger than that of sodium. Describe why transition metals have strong metallic bonding in relation to the number of electrons.

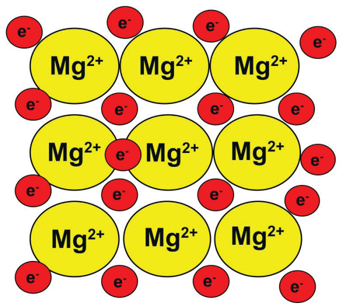
You can give ***Exercise 5.11*** a classwork to be carried out in groups. Encourage three groups present their answers to the class. Clarify any misunderstanding or misconception before you move to the next sub-section.

Answers to Exercise 5.11

1. The force of attraction that exists between the mobile electrons and the metal ions is known as a metallic bond.
2. The electronic configuration of aluminium is 2, 8, 3. The three valence electrons in every 12 atoms of aluminium will be freed to move among the pool of 13 protons containing a positively charged aluminium nucleus. The attraction force between the positively charged aluminium nuclei and the shared free electrons makes the metallic bonding in aluminium.



3. The size of Al^{3+} is smaller than Mg^{2+}. There are more free electrons in aluminium metal than in magnesium. The free electrons in aluminium metal are, therefore, closer to the positively charged nucleus thereby forming a strong electrostatic attraction. On the other hand, the size of Mg^{2+} is relatively large and the number of free electrons is smaller compared to that of aluminium. The attraction force between the freely moving electrons and the nucleus in magnesium is not as strong as that between aluminium the nucleus and the electrons.
4. The electron sea model of magnesium metal. The dots in the red circle represent the electrons.



5.4.2 Properties of Metallic Bond

You can make students discuss the questions under ***Activity 5.12*** in groups. Following the discussion encourage three or four groups present their discussion points to the class briefly. Allow the whole class to discuss further. Finally, you can summarize the discussion points by adding more information from the textbook. You can begin your summary by answering the activity questions because they will lead you to the main content of the lesson smoothly.

Activity question #1 is intended to identify one property of metals. Students can answer this question easily. Of course, the answer to this question is that a piece of metal is the only substance that conducts electricity.

Activity question #2 is intended to challenge students to relate it to their previous knowledge regarding conductivity. If they found it difficult, remind them about how a substance conducts electricity by considering water solutions or molten ionic compounds.

Now, students may respond to the question partly with the correct answer. Explain to the students that metals form a metallic bond and metallic bond is simply an 'array of positive ions in a sea of electrons'. It is the sea of ions full of free electrons that made metals good conductors of electricity (***Figure 5.15***). All the other substances do not have either free electrons or ions and hence, cannot conduct electricity.

Activity question #3 is intended to let students find another property of metals. Students for sure will find the answer to this question easily because they know this from their day-to-day experience. However, they will be challenged to reason out. Remind them about the relationship between intermolecular forces and melting or boiling point. This might give them a clue. If not, then go directly to the discussion of the bulk and physical properties of metals with a brief explanation of each property.

Ask students the questions under ***Exercise 5.12*** and make them respond orally. Involve as many students as possible keeping gender balance and inclusiveness. Make sure students achieved the minimum learning competencies of the lesson.

You can also give the unit summary a reading assignment. You may use the review exercise questions to give them assignments, quizzes, tests or examinations.

Answers to Exercise 5.12

1. Properties of Metals:
   - the ability to conduct electricity and heat,
   - a low ionization energy
   - a low electronegativity (so they will give up electrons easily to form cations).
   - a lustrous (shiny) appearance,
   - they are malleable and ductile,
   - have a crystal structure but can be easily deformed.
2. The strength of a metallic bond depends on three things:
   - The number of electrons that become delocalized from the metal.
   - The charge of the cation (metal).
   - The size of the cation.
3. Metallic bonds are strong and require a great deal of energy to break, and therefore metals have high melting and boiling points.

Answers to the Review Exercise

Part I: Answers to the basic level questions.

Multiple choice questions

1. A
2. C
3. B
4. C
5. A

Part II: Answers to the intermediary level questions.

True-False questions

6. True
7. True
8. False
9. True
10. False
11. False
12. False
13. True
14. True
15. True
16. False
17. False

Fill in the blank

18. Sharing, transferring
19. energy changes
20. metals
21. anion
22. ionic bond
23. Lewis symbol
24. "like dissolves like"
25. multiple covalent bonds
26. Covalent bonds
27. pure covalent
28. electronegativity
29. non-polar
30. coordinate covalent bond or dative bond

Part III. Answers to the challenge level questions.

Short answer type questions

31. There are four types of chemical Bonds. These are ionic bond, covalent bond, coordinate covalent bond, and metallic bond.
32. A solvent in which most of the ionic compounds dissolve in is water.
33. Ionic compounds conduct electricity in the molten state and solution form.

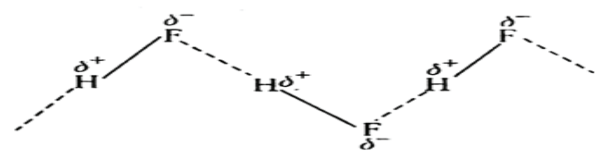
34. The non-polar covalent compounds do not conduct electricity because the net charge formed during chemical bond formation is zero. In the absence of a charge carrier, electricity conduction is impossible.
35. The type of chemical bonds found in each of the following compounds is
    a) Potassium chloride -ionic
    b) Carbon dioxide - covalent
    c) Hydrogen chloride - covalent
    d) Water - covalent
    e) Magnesium oxide - ionic
    f) Calcium fluoride - ionic
    g) Methane - covalent
    h) Sodium chloride - ionic
    i) Ammonia - covalent
    j) Phosphorus pentachloride - covalent
    k) Sulphur hexachloride - covalent
36. According to the principle, "Like dissolves like" a) The polar compounds dissolve in polar solvents b) The non-polar compounds dissolve in non-polar solvents.
37. Molecules are more stable than atoms because the atoms that make molecules attained octet. In other words, the valence shell of the atoms in molecules is filled either with two or eight electrons and this makes them stable. All atoms except for the noble gas elements have a valence electron short of 8, and are not stable.
38. A covalent bond becomes non-polar whenever the atoms forming the bond are identical, meaning homoatomic, or when the electronegativity difference between the atoms is low (less than 0.5). The covalent compound becomes polar when the electronegativity difference between the combining atoms is large (between 0.5-2.0).
39. In a polar covalent molecule, a partial positive and negative charges develop because the shared electrons distribute unevenly between the bonding atoms. This is because of the electronegativity difference between the atoms. In other words, the one with high electronegativity will attract the shared electrons towards itself more than the one with low electronegativity hence uneven electron distribution.
40. A coordinate covalent bond is a type of bond formed by sharing of electron pairs between two atoms but the sharing comes from one atom.
41. The weak forces which exist between the covalent molecules are known as van der Waal's forces. It is an electrostatic force of attraction between the nucleus of one molecule and the electrons of the other.
42. Polar covalent compound is a compound in which there exists a net partial positive and negative charge in the covalent bond of the molecule. Non-polar

covalent compound is a compound in which there is no net partial positive and negative charge in the overall covalent bond of the molecule.

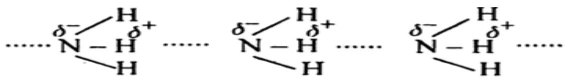
43. Examples of molecules or ions in which coordinate covalent bond formation takes place are the following: H_3O^+, NH_4^+, NH_3BF_3, Al_2Cl_6, and CO.
44. Metals lustre or shine because they can reflect the light ray falling on their surface.
45. Examples of compounds in which hydrogen bonds exist: water-H_2O, hydrogen fluoride-HF, ammonia-NH_3, methanol-CH_4O, and ethanol-C_2H_6O.
46. The Lewis' dot formula of the given molecules/compounds is given in the table below:

Element/molecule	Dot formula
NaCl	$Na^+[:\ddot{Cl}:]^-$
CaF_2	$Ca^{2+}[:\ddot{F}:]^-_2$
H_2	H:H
O_2	$\ddot{O}::\ddot{O}$
N_2	:N ⋮⋮ N:
H_2O	$H:\ddot{O}:H$
NH_3	N N :C: N
CH_4	H H:C:H H

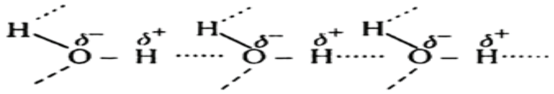
47. The factors responsible for the formation of covalent bonds and ionic bonds are ionization potential and electron affinity.
48. The noble gas elements do not take part in a chemical reaction because they fulfil the Octet and Duet rules. This means they have a stable valence shell electronic configuration and hence, they are sufficiently stable.
49. A type of bond formation that takes place between a) metal and a non-metal is an ionic bond and b) two non-metals is a covalent bond.
50. The reason that most of the ionic compounds exist in a solid state is because of the strong electrostatic force that exists between the compounds. Covalent compounds have a weak electrostatic or van der Waal's force between the molecules hence liquids or gases in most cases.
51. Large ionization potential difference between the atoms results in the formation of ionic bond whereas having high ionization potentials in both atoms results in a covalent bond. A large electron affinity difference between two atoms results in ionic bonding whereas a small difference in electron affinity between the two atoms results in a covalent bond.
52. The oppositely charged ions in an ionic compound are held closely by the electrostatic force of attraction. Hence the number of ions per unit volume in an ionic compound is more making their density high. In covalent molecules, the attraction force between molecules is either hydrogen bond or dipole-dipole interaction and is not comparable to that of the electrostatic attraction between ions. Hence, most covalent compounds are liquids or gases and it is known that liquids and gases have low density.
53. Why are the melting points and boiling points of the ionic compounds high and those of covalent compounds low? The strong electrostatic force between ionic compounds needs high energy. This high heat energy is associated with high temperature. Hence ionic compounds need a high temperature to melt or boil. In covalent compounds, the relatively weak dipole-dipole, the hydrogen bonding or van der Waal's force needs relatively less energy which in turn needs low temperature to melt or boil.
54. Pure covalent compounds have zero net charges. In the absence of charge, electricity cannot be conducted. In other words, pure covalent compounds do not ionize.
55. Both ionic compounds and water are very polar and since like dissolves like, polar compounds dissolve in a polar solvent. Ionic compounds exist in the form of ions and dissolve in the highly polar water molecule.
56. Polar covalent compounds dissolve in water because they have a partial positive and negative charge that can interact with the partial negative and positive charges in the water molecules.
57. Hydrogen bond formation with the help of a diagram for
    a. hydrogen fluoride



b. ammonia



c. water



33. Types of bonds exist in a) ammonium ion – the covalent bond between three hydrogens and nitrogen and a coordinate covalent bond between the fourth hydrogen and nitrogen; b) hydronium ion – covalent bond between two hydrogens and oxygen and coordinate covalent bond between the third hydrogen and oxygen.

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