Based on National Curriculum of Pakistan 2022-23

Model Textbook of

CHEMISTRY

Grade 11

National Curriculum Council
Ministry of Federal Education and Professional Training

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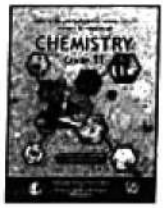
Islamabad

Model Textbook of **Chemistry**
for Grade 11



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PREFACE

In a historic footstep, the national curriculum of Pakistan 2022-2023 has introduced a new era for schooling in the country, This is the first-ever core curriculum in the 75-year history of Pakistan. It is in line with the protected right to school education by Article 25-A.

Chemistry might be a difficult subject for someone, but it holds significance for those who embrace a systematic approach to understanding its concepts.

This new Textbook has been developed as a model Textbook for Pakistan. The book consolidates critical thinking methodologies, guiding scientific reasoning, and thinking abilities. The book incorporates problem-solving strategies, which will guide students toward analytical thinking and skills. These skills would be invaluable for both academic as well as practical life.

The book also inspires concept assessment exercises in every unit, which have been designed to evaluate acquired knowledge and promote critical thinking and analyzing data..

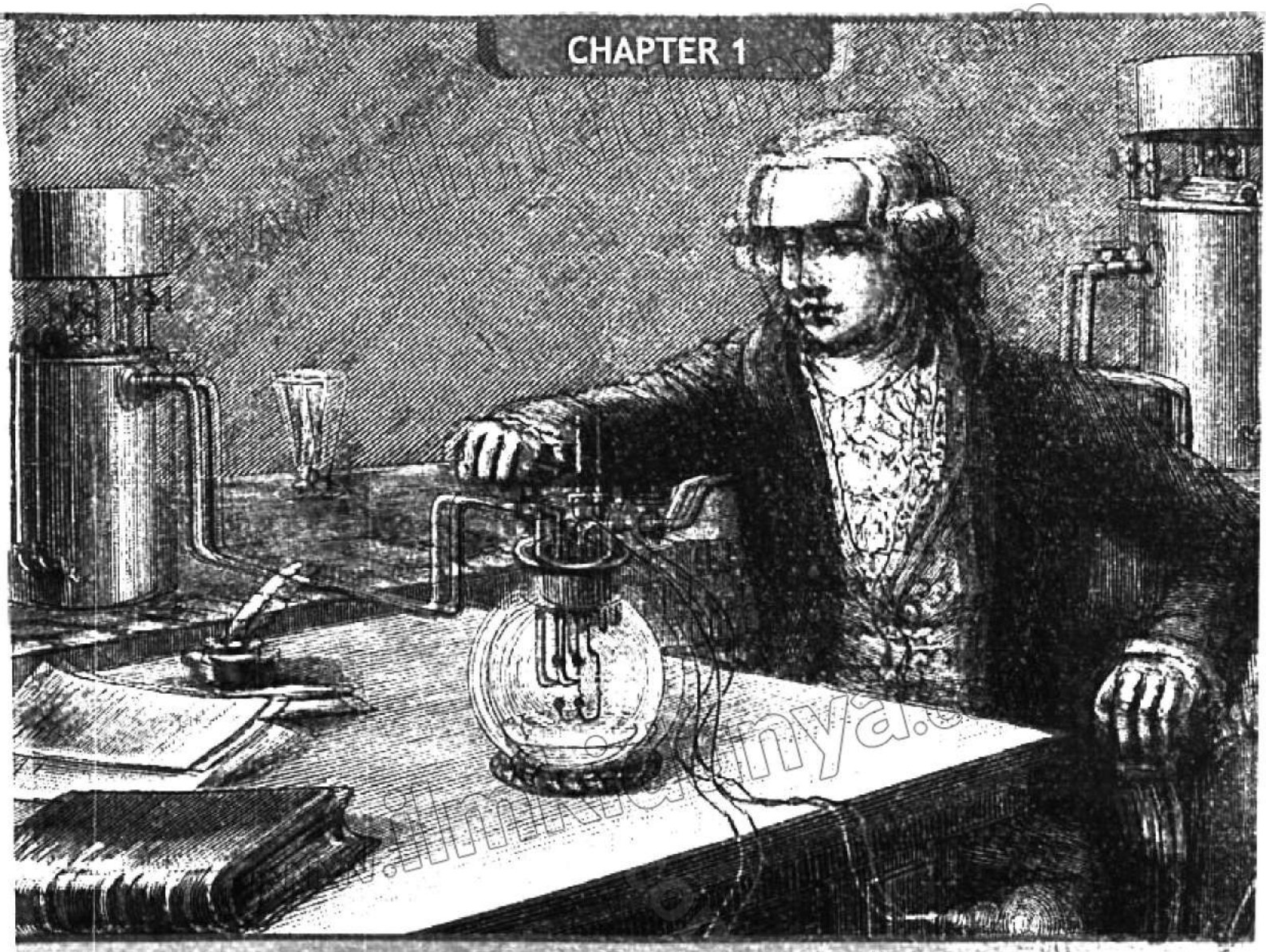
One of the book`s distinctive features is the key points at the end of each unit, which serve as a quick reference to reinforce the salient features of each unit.

Dr. Raja Mazhar Hameed

Managing Director

Contents

CHAPTER 1



HISTORY OF CHEMISTRY

SLOs: After completing this lesson, the student will be able to:

1. Describe how Al-Ghazali's burning cotton thought experiment highlight the challenges of inductive reasoning. Examples of deductive reasoning with respect to chemistry.

THOUGHT EXPERIMENTS

The experiment that is performed in the laboratory of human mind is called thought experiment. We study a specific situation, then observe what happens in that situation and finally reach at some conclusion. The difference between thought experiment and real experiment is that the former is done in mind whereas the later one in real world. Thought experiments play vital role in developing scientific theories and principles. We discuss three famous thought experiments in this textbook.

1.1 THE DISCOVERY OF ATOM

In 500 BCE, a Greek philosopher, Leucippus was the first to think about atom so he is known as the father of atomic philosophy. In 430 BCE, another Greek philosopher named Democritus, a student of Leucippus, was the first who thought that matter is made of uniform and indivisible particles called "atomos" (a Greek word meaning uncuttable). This is the first thought experiment about atom in the visible history.

Leucippus

Democritus further thought that atoms also existed for feelings and human soul. He held the shape and size of atoms responsible for properties of matter. He thought that sour taste of substances is due to needle shaped atom while the white colour of matter is due to smooth shaped atoms.

Democritus

The word atom is combination of two Greek words "a" which means not and "tomos" which means to cut.

Before Democritus thought experiment, there were two Greek philosophies about changes in matter, one was that change in matter is just illusion whereas the other was that change in matter is a reality. Democritus argued that changes in matter were due to combination and separation of indivisible particle in matter.

Experimental Background of Atomic Chemistry

In 1808, an English chemist, John Dalton was the first who converted the Democritus thought experiment about atom into scientific theory called Dalton's atomic theory. He wrote a book named a new system of chemical philosophy and presented an experimental picture of the formation of compounds from elements. Later on, two other chemists, Gay-Lussac and Amedeo Avogadro supported Dalton's atomic theory and thus the experimental foundation of atomic chemistry was laid down. In this way, the thought experiment of Democritus was converted to real experiment and the atomic philosophy to atomic chemistry.

1.2 The Maxwell's Demon Experiment

In 1867, a Scottish scientist, James Clerk Maxwell devised a thought experiment on gases. He imagined two containers, say container A and container B, filled with same gases at the same temperature. The two containers shared a small frictionless molecular-sized window in the partitioning wall.

There was a little demon (invisible spirit) on the window who was smart enough to guard the window and detect speed of gas molecules in the two containers.

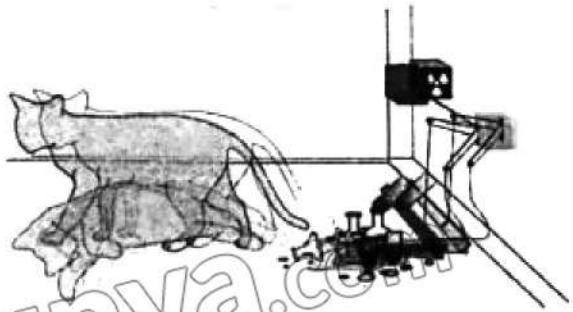
The demon would selectively allow fast-moving molecules to shift from container A to container B and slow-moving molecules from container B to container A. In this way, all high kinetic energy gas molecules will fill container B and low kinetic energy molecules will stay in container A. Theoretically, this will create temperature difference between the two containers, the container A will get hotter while container B colder without the expense of energy. However, this cannot happen without the cost of energy and is against the second law of thermodynamics.

Solution to Maxwell's Demon

The Maxwell's demon thought experiment was a clear violation of second law of thermodynamics which says that heat flows naturally from hotter body to colder body which results in increased entropy of the system. The problem with Maxwell's demon was that the demon was ideally considered to be requiring no energy for the action of opening and closing the window. In fact, the demon's action was not possible without the use of energy hence increase in entropy.

If the demon is considered to be using energy for opening and closing the window, then energy will be used and entropy of the system increased which follows the second law of thermodynamics. In this way, the Maxwell's demon experiment plays role in considering all factors while studying the behaviour of physical systems in physical chemistry.

1.3 THE SCHRODINGER'S CAT EXPERIMENT



Erwin Schrodinger (1887-1961) was an Austrian scientist. He explained his cat experiment picture in a discussion with Einstein while addressing the problems in quantum mechanics. This is why one can safely assume that his cat experiment played an essential role in the development of quantum mechanics.

He imagined to keep a cat enclosed in an opaque box having poison, Geiger counter and a radioactive material. He added that an outside observer would say that the cat is in two states,

both alive and dead at the same time. The actual reason behind these two states of cat is that the radioactive material is also in two states, it decays and does not decay at the same time.

When the box is not opened, the system is in superposition of two states, one is the decayed material-dead cat and the other is undecayed material-alive cat.

He thought that when the radioactive material decayed, the Geiger counter received radiations emitted from that material and pushed the hammer of the container having poison. As a result, the container opened and poison came out which killed the cat.

If the radioactive material did not decay, then the cat would remain alive. It means that one cannot say from outside the box whether the radioactive material decays or not, and the cat is alive or dead until the box is opened or the material and cat interact with the real world.

The cat is in two states, both alive and dead at the same time. Similarly, the radioactive material is in two states, it emits and does not emit radiations at the same time.

The Schrodinger's paradoxical thought experiment can be related with his equation that laid the foundation of quantum mechanics hence quantum chemistry. The equation gives the idea that atoms and sub-atomic particles exist in two states (particle and wave) simultaneously. The two states become one state when they are observed and measured.

1.4 IMAM AL-GHAZALI - HISTORICAL BACKGROUND

Abu Hamid Al-Ghazali was a Muslim theologian and mystic. He was born in 1058 AD in Iran and died in 1111 AD. After completing his education, he moved to Iraq where his teaching and debating received unanimous approval and he got the name of Imam of Iraq. Then he turned away from his worldly status and rank and started seeing things in life with different perspective. He left Baghdad and went Damascus for a short time, then Jerusalem. From there he wrote a famous book "The Revival of Religious Science". He started working on disciplining his soul and improving his nature.

He is considered one of the most influential philosophers of the world and the most prominent Islamic philosopher. His famous work "Tahafut al-Falsafa" (the incoherence of the philosophers) is considered a breakthrough in the history of philosophical thinking of that time. He challenged the philosophical thought of Neoplatonic thinkers, who believed that perfection can be attained in this world, with logic and reason.

1.4.1 Al-Ghazali's Burning Cotton Experiment

Al-Ghazali put forward an idea of necessary causality which says that link between cause and effect is necessary and always true. As an example, Al-Ghazali argued that when a piece of cotton is placed near a burning flame, the cotton will burn. He further added that if another similar cotton piece is brought very close to a similar burning flame, the cotton will burn again.

He thought that the burning flame was the cause to burn cotton piece so there is casual link between burning flame and piece of cotton. He concluded a burning flame necessarily burns the nearby piece of cotton so this theory is called necessary causation.

The necessary causation means one thing is necessarily the cause of another thing. For example, clouds are the cause of rain fall. We can never witness rainfall without clouds.

1.4.2 Al Ghazali's Departure from Necessary Causation

Al-Ghazali performed an experiment in which he brought a cotton piece close to a burning flame. After sometime, the piece of cotton burnt. To him, that meant that the burning flame was the cause of burning cotton.

Do You Know?
Pulling trigger of a gun may cause any event to happen, as the idea of necessary causation is invalid.

He gave another example of a person who couldn't open his eyes. One day, miraculously, the person became able to open his eyelids and see the beauty of world, but he thought the opening of eyelids to be the cause of seeing things around him.

Al-Ghazali, at some stage in his life, departed from his previous point of view. He imagined that what we observe around is the continuation of events, not a kind of direct causation. He said that sticking to the theory of necessary causation would reject the concept of God's will. He put forward the logic that all things have a nature and act in habitual way because nature follows some specific principles. He further added that God created the universe (nature) and He can suspend the habitual succession of events according to His wish.

Interesting Information
God shows miracles by suspending the causal link and habitual course of events.

He argued that the blind man couldn't understand that those were the rays of light striking his eyes and made him able to see around. Actually, the blind man confused the succession of events with causation.

David Hume, another philosopher, supported the Al-Ghazali's approach of continuation of events. He added that there is no natural glue (causal link) that can hold the events around us together, rather they occur one after the another.

1.4.3 Al-Ghazali's Thought Experiment- A Challenge to Inductive Reasoning

Al-Ghazali's thought experiment has the following inductive reasoning.

1. The flame burns a piece of cotton.
2. The piece of cotton burns when kept near the flame.
3. The burning flame is the cause of burning piece of cotton.

The burning cotton experiment of Al-Ghazali proved a challenge to inductive reasoning. He concluded that when a cotton piece is kept near burning flame, it must always burn. This conclusion questions the inductive argument and tells us that repeated observation cannot be always true. He had missed some important factors in data collection, like moisture, chemical

reactions, flow of air and composition of cotton piece etc. This thought experiment hurt our dependence on inductive reasoning and underscores the importance of deductive reasoning.

1.5 REASONING

According to Garrett, "reasoning is a stepwise thinking with a purpose and goal in mind". It means that reasoning is a specialized thinking that enables a person to mentally understand the link between cause and effect of an event. This is also reasoning that makes somebody able to solve a problem in systematic way on the basis of past experiences and present observation. There are two types of reasoning.

1.5.1 Inductive Reasoning.

In inductive reasoning, generalized conclusions are taken from specific observation. In general, we may encounter difficulties while deriving a set of conditions or situation from a specific statement so inductive logic may involve some uncertainty. In order to reduce that ambiguity, we may go beyond the given information and we must work with impartial mind.

Concept Assessment Exercise 1.1

Make inductive reasoning on the reactivity of halogens in periodic table.

1.5.2 Deductive Reasoning.

The deductive reasoning is a research approach that involves testing of hypothesis. It uses general statement to make specific conclusions. Deductive reasoning is also called top-down logic. It tells us that if the given general statement is true then the specific conclusion coming out of it must be true. The following examples, with reference to chemistry, will make deductive reasoning clear.

a. Stability of Chlorine Element

Chlorine is an element that belongs to halogen group (Group VII). We can apply deductive reasoning on it in the following way.

1. The elements that obey octet rule can exist freely.
2. The chlorine element (Cl_2) follows octet rule.
3. The chlorine element (Cl_2) has independent existence.

b. Balancing Chemical Equations

Consider a chemical reaction in which hydrogen gas reacts with oxygen gas to form water.

The deductive reasoning tool for making a balanced chemical equation under the law of conservation of mass can be broken as follows.

Science Titbit
Inductive reasoning tells us the possibility of a conclusion while deductive reasoning refers the outcome of general statement.

1. A balanced chemical equation follows the law of conservation of mass.
2. The following chemical equation is balanced.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

3. The given chemical equation obeys the law of conservation of mass.

c. Chemical Properties of elements

We can relate deductive reasoning process with chemical properties of elements in the following way.

1. All elements belonging to same group have similar chemical properties.
2. Sodium and potassium lie in the same group (group I).
3. Sodium and potassium have similar chemical properties.

Concept Assessment Exercise 1.2

Apply deductive reasoning on the trends in atomic radius along a period in periodic table.

Key Points

- A thought experiment is done in the laboratory of mind, not in your college chemistry laboratory.
- Leucippus (500 BCE) , the Greek philosopher, was the father of the theory of atomism because he originated it.
- Democritus (430 BCE) was the student of Leucippus. He was the first to think that matter is made of small indivisible particles called atoms.
- James Clerk Maxwell presented his thought experiment in 1867 and believed that heat transfers from hot body to cold body without increase in entropy.
- Entropy is the disorder of a system.
- Erwin Schrodinger thought to have a cat in a box may be live and dead at the same time. This thought experiment played a role in the evolution of quantum mechanics.
- Al-Ghazali gave the idea of necessary causation by saying that a piece of cotton kept close to a burning flame must burn. The flame is necessary cause of burning piece of cotton. Later on, he thought that God's will can reject the theory of necessary causation because all natural forces are under control of God.
- Divid Hume supported the concept of continuation of events, not necessary causation. He thought that there is no causal relationship between cause and event, rather one event is followed by another one.
- Inductive reasoning goes from specific conclusion to general statement.
- Deductive reasoning concludes result from general statement. It is also called top-down approach to research.

References for Further Information

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- Al-Ghazali experiment - Prof Riker (Ghazali on necessary causation)
- Al-Ghazali on science, Routledge (Page 939)
- Translation of Al-Ghazali treatises- Concerning Divine Wisdom in the Creation of Man

- The Britanica
- Schrodinger's thought experiment - the magazine "Discover"
- Reasoning -ScienceDirect.com by Kirsty Williamson (Research Method for Student-2nd Edition).

Exercise

1. Choose the correct answer

i. The word atom comes from Greek language which means

A. beautiful B. indivisible

C. smooth D. sharp

ii. Leucippus is known to be the mentor of Democritus and the father of atomic philosophy. Who was the first to use the word atom?

A. Leucippus B. James Clerk Maxwell

C. Democritus D. Erwin Schrodinger

iii. Who put forward the atomic theory?

A. Dalton B. J C Maxwell

C. Al Ghazali D. E Schrodinger

iv. Who observed the movement of molecules from one container to the other in Maxwell's thought experiment?

A. Maxwell B. the demon

C. Maxwell's students D. Maxwell's mentor

v. The Maxwell's demon experiment violates which of the following law?

A. law of conservation of mass

B. the Boyle's law

C. first law of thermodynamics

D. second law of thermodynamics

vi. The Schrodinger's thought experiment is believed to have contributed to evolving the well-known field of physics called

A. plasma physics B. particle physics

C. statistical mechanics D. quantum mechanics

vii. What were the findings for an outside observer in Schrodinger's cat thought experiment?

A. the cat was dead B. the cat was alive

C. the cat was both alive and dead simultaneously

D. the cat was neither alive nor dead

viii. The famous book of Al-Ghazali, "Tahafut-al-Falsafa" challenged the philosophical thought of Neoplatonic thinkers which believed that

A. perfection and happiness are achievable in this world

B. no happiness and perfection exist in this world

C. there is life hereafter

D. man is mortal

ix. Al-Ghazali thought experiment was based on burning

A. paper B. cotton C. wood D. coal

x. What is correct statement about Al-Ghazali's approach?

I. he thought that every event must have a cause

II. he thought that there is succession of events, not causation

III. he thought that God can suspend the habitual continuation of events

A. I & II only B. II & III only C. III only D. I,II &III

2. Give short answer.

i. What was an atom to Democritus?
ii. How did Democritus connect atoms to feelings and properties of matter?
iii. What was the link of life of the cat with radioactive material?
iv. How can we relate Schrodinger's cat experiment with quantum mechanics?
v. Define theory of necessary causation. How did Al-Ghazali prove it?
vi. Define inductive and deductive reasoning.

3. Explain thought experiment of J C Maxwell.

4. Explain the experimental background of atomic theory.

5. Describe what conclusions were drawn by Schrodinger from his thought experiment.

6. How did Al-Ghazali conclude from a piece of burning cotton? Also relate his conclusions with his concept of God involvement in all natural laws.

7. Explain that Al-Ghazali's thought experiment was a challenge to inductive reasoning.

8. Take some examples from chemistry and apply them on inductive and deductive reasoning separately.