Post Graduate Course in Reflective Teaching with ICT

S03 Interactive Science Teaching

Teacher Coursebook (Atomic Structure)

This coursebook belongs to:

Name: ....

Class: ....

Section: ....

CLIx subject team
Anish Mokashi
Anup Saxena
Arpita Pandey
Deepak Verma
Dinesh Kumar Verma
Honey Singh
Judith Perry
Priyanka Saxena
Sayali Chougale
Umesh K Chouhan
V. V. Binoy

Academic mentor
Arvind Sardana
Bhas Bapat
Prof. Bholeshwar Dube
Himanshu Srivastva
Prof. Kishore Panwar
Rajesh Khindri
Vivek Mehta

Academic support
Amitabh Mukharjee
Anu Gupta
Dr. Ramani Atkuri
Saurav Shome
Dr. Sumit Roy

Production Management
Pallavi Seth

Editors
C. N. Subramaniam
Madhav Kelkar
Praveen Allamsetti
Rashmi Paliwal
Late Rex D. Rozario
Suresh Kosaraju
Sushil Joshi
Tultul Biswas

Translators
Chitti Sreeram
Madhav Kelkar
Lokesh Malti Prakash
Satyamadhvi Nanduri
Shivani Bajaj

Video development support
Deepak Verma
Khizar Mohammad Khan
Kumar Mohit
Pallav Thudgar
Tariq Khan

Software development
Brandon Hanks
Varun Jain

Software Support
Shahid Ahmad

Illustrations
Ankita Thakur
Heera Dhurvay
Khizar Mohammad Khan
Tariq Khan

Design
Ankita Thakur
Gauri Wandalkar
Ishita Biswas
Kanak Shashi

Voice over
Dinesh Kumar Verma
Gaurav Yadav
Honey Singh
Pallavi Seth
Priyanka Saxena
Subeer Kangsabanik
Vandana Pandey

Special Thanks

Arvind Gupta (for straw flute video), Dominic Mazzoni and Roger Dannenberg (for Audacity Software), Eklavya Bal Vigyanik Team (for textbooks).

We would like to sincerely acknowledge all the resources that we have referred to for the development of our modules.

A Note for Teachers

'All things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another'

If all the scientific knowledge were destroyed in some catastrophe, then Feynman reckoned we could pass greatest amount of scientific knowledge with the fewest of words in the above statement regarding the atomic theory.

Atomic theory is key to understanding the diverse nature of different matter around us. The differences in elements stem from the differences in their atoms. The structure of atoms of the elements determines how the elements and their compounds behave chemically. Understanding how matters behave is important and useful for investigation across various disciplines of science.

The key questions and focus areas of modules are:

- What can be considered as pure substances?
- Why don't we get large number of element in the free state?
- Why some of the elements like the inert gases can exist in the free state?
- Why do elements combine to form compounds?

Table of Contents

Student Module: Atomic Structure

Section 1: Basic Module Information

Prior Knowledge

1. Name and symbols of some common chemical elements such as Hydrogen, Oxygen
2. Name and symbols of some common chemical compounds such as Sodium Chloride
3. Chemical Change

Structure of the Module

Lesson 1: Why Chemistry
- Why Chemistry
- Periodic table
- What is an element?
- The language of chemistry I
- The language of chemistry II

Lesson 2: Need of the Atom
- Need for an Atom I
- Need for an Atom II

Lesson 3: Atom and Atom Factory
- Atom
- Atom factory
- Atom factory again!
- Review atom
- Electrons & Chemical reactivity of an element

Lesson 4: The Rule of 8
- The rule of 8
- Na & Ne - Cl & Ar
- H & He - O & Ne

Lesson 5: Molecule Factory
- Molecule factory
- Some more molecules
- Molecule Review

Student Feedback Survey
Credits

Expected Timeline

Preparation Time: 2 weeks
Teachers should spend 2 hours on the digital tools (Video analysis player and Run Kitty Run game) to get familiar with them. They would further require two hours of self-study and preparation for classroom instructions.

Implementation: 3 weeks
1. Lesson 1 - Two 40 Minutes Period or 1 Block Teaching Period
2. Lesson 2 - Two 40 Minutes Period or 1 Block Teaching Period
3. Lesson 3 (includes digital activity) - One 40 Minutes Period and 1 hour-long Block Teaching Period for simulation
4. Lesson 4 - 1 Block Teaching Period

5. Lesson 5 (includes digital activity) - 1 Block Teaching Period for simulation and One 40 Minute Periods for Teaching and Assessment
6. Feedback - One 40 Minute long Period for Feedback and Remediation

Assignment: 1 Week

Requirements

Please make sure of the following:

1. Assign a notebook (which we call as journal) for yourself. Assign one page for each of the days for note taking. You can record your reflections, experiences or learning in this notebook.
2. You should have access to a computer that has a browser and internet connection.

Section 2: Pedagogic Approach

Pedagogical Pillars

This module is designed by keeping the three pedagogic pillars in mind.

Collaboration: In scientific endeavour, collaboration is uniquely important. Peer review and replication of studies are standard practice in scientific research. The scientific community is dependent on one another for generation of valid scientific knowledge. Hence, it is important to provide opportunity for collaboration while learning science.

The students do the digital simulations in pairs or groups. A student would have to explain their decisions to their peers. This would serve two purposes. The peers would be able to identify the gaps in their understanding and correct it at the same time. It is recommended that the teachers should encourage discussion among students.

Learning from mistakes: Mistakes and misunderstanding are important sources of learning. We all have intuitive explanations for the phenomena around us e.g., many people in ancient Greece and India believed matter is made up of earth, water, fire etc. Examining our mistakes and misunderstandings opens the door to critical understanding of the scientific concepts.

The digital activities give students a chance to learn from their mistakes. In the 'Atom Factory' activity students can play with the constituents of the atoms, learn from their mistakes and check the correct configuration of the elements. In the same activity the game gives students two attempts for each question. Students get a chance to examine their answers, and ponder why the answer was incorrect. They are able to check the answer if they do not get the answer the second time.

Authentic learning: The module begins with some examples of application of chemistry in day-to-day life. Chemistry is not something which scientists do in a laboratory. It is all around us. In this module students examine the notion of pure substances. Clean air or water appear to be pure but scientifically these cannot be regarded as pure substances. It was difficult to discover elements that are pure substances since most of the elements are not found in their pure forms. This also raises the question why elements do not exist in their pure forms. Understanding the structure of atoms of different elements and their effect on chemical properties of the elements helps us understand the formation of different substances around us. Moreover, this makes us appreciate the fact that all substances in the universe from stars to trees share common building blocks.

Role of Models

Models hold great significance in the world of science. From the double helix model of DNA to the Bohr's model of atom, models have expanded our understanding of the natural phenomena. Building models, deducing their prediction, comparing the prediction to observations, comparing different models and revising them are important aspects of theory construction and testing in science. At the same time observational data can also be organized in the form of models.

While learning science, models can help students build critical understanding of the concepts. Students should be exposed to different types of representations such as 3-dimensional concrete models and 2-dimensional simulations. This exposure could help students to distinguish between a system and its representation and create complex mental models. The science lessons could provide opportunity to students explicitly create mental representations and engage with thought experiments.

This module focuses on critical understanding of Bohr's atomic model and uses it to explain the behavior of substances in chemical reaction. The module makes it clear that the model is a close approximation of the atomic structure. Quantum physics has further refined our understanding of the atoms and the subatomic particles. However, Bohr's model can be considered as a good stepping stone to exploring more complex ideas regarding the atomic theory. In science, models and theories evolve continuously and different models can co-exist. Not all models may be perfect or complete. We choose the model which serves us the best in the given condition e.g. For subatomic particles we use quantum mechanics, for macroscopic objects we use classical mechanics while for extremely massive objects general relativity is used.

Section 3: Notes for Implementing Student Module

Lesson 1: Why Chemistry
Learning Objectives: Students will be able to:

1. Understand the questions chemistry pursues and appreciate the use of chemistry in various fields of science
2. Recognize the chemical symbols of some of the common elements and explain how they have been named.
3. Define what is an element and describe why elements are considered pure substances

What are pure substances? We can separate out mixtures using different methods till the substances appear pure to our eyes e.g. water collected by condensation. But can these substances be considered pure substances. Scientists have devised methods which can further divide the substances till we are left with substances that we call elements. Scientists have discovered a total of 118 elements till date. 94 of these elements occur naturally on earth while 24 have been synthesized in the labs. The elements are organized in a table in a systematic manner. This table is known as the periodic table. The elements are represented by the two letters - the first letter of the symbol is same as the first letter of element's name (or its latin name) and the second letter is any other letter from the element's name (or its latin name). These representations or codes are known as chemical symbols.

Lesson 2: Need of the Atom
Learning Objectives: Students will be able to

1. Recognize that most of the pure elements readily react to form compounds.
2. Identify the differences in chemical properties of noble gases and other elements.
3. Differentiate between elements and compounds
4. Differentiate between atoms and molecules

The lesson starts with a video of a piece of sodium metal being cut. The change of the cut cross-section is shiny at the beginning but soon loses its shine. On examination scientists have found that Sodium reacts with Oxygen in the atmosphere to produce Sodium Oxide. Similarly most of the other elements readily undergo chemical change and form compounds. These compounds are usually more stable than pure elements. During formation of compounds, two or more atoms of different elements combine and form a molecule. E.g. Two Hydrogen and one Oxygen atom combine to produce a water molecule. One Sodium and One Chlorine atom combine to produce a sodium chloride molecule. Molecules need not be formed by atoms of different elements. The atoms of many gaseous elements (that exist in gaseous stage under standard temperature and pressure) cannot exist in free state -two or more atoms of the same element combine to form molecules e.g. Hydrogen molecule, Oxygen molecule.

However, even though the elements in the last (18^{th}) column exist as gases under standard temperature and pressure, they do not form molecules. These gases are also non-reactive in nature under normal condition and do not form compounds with other elements. These elements can exist in free state and are known as noble elements.

This makes us wonder -
Why most atoms cannot exist independently *(without reacting with atoms of the same or different elements)* like the atoms of the noble gases?

To answer this question we need to examine the differences in the structure of the atoms of noble gases and other elements.

Lesson 3: Atom and Atom Factory
Learning Objectives: Students will be able to

1. Understand the structure of atom according to Bohr's atomic model
2. Recognize the basic properties and of electrons, protons and neutrons
3. Differentiate between atomic number and atomic mass
4. Appreciate that Bohr's atomic model is an approximation of the structure of atom and that behaviour of particles inside atom is more complex

5. Identify that electron orbitals can contain a specific number of electrons

Students should be given a basic overview of the Bohr's atomic model. This includes the knowledge of the properties of the three particles, namely, electrons, neutrons and protons. Electrons are negatively charged particles and have negligible mass compared to protons and neutrons. Protons are positively charged whereas neutrons do not possess any charge. Most of the mass of the atoms are concentrated at the center where the protons and the neutrons reside. This is known as the nucleus of the atom. The electrons revolve around the nucleus in specified paths known as orbits. This model is an approximation of the structure of atom.

Atomic Number - The number of protons in the nucleus of the atoms of a element is known as the atomic number of the element. In the neutral state the number of protons and electrons in the atoms remain the same and hence they do not have a net charge. Atoms can be ionized (have a net charge) by losing or gaining electrons. Hence, the number of electrons in the atoms of an element are not always constant. Similarly, the number of neutrons in the nucleus can also differ in different isotopes of the same element. Hence, elements are identified by their atomic number. In the periodic table the elements are organized in the increasing order of their atomic number.

Atomic Mass Number - The sum of the number of protons and neutrons in the atoms of an element is known as the atomic mass number of the element. Atomic mass number of the same element can be different for different isotopes. E.g. ^{12}C and ^{13}C isotopes of carbon have atomic mass 12 and 13 respectively.

The symbol of an element is accompanied by a subscript and a superscript. One such example is given below. Magnesium has atomic number 12. It has three isotopes of atomic mass number 24, 25 and 26 respectively.

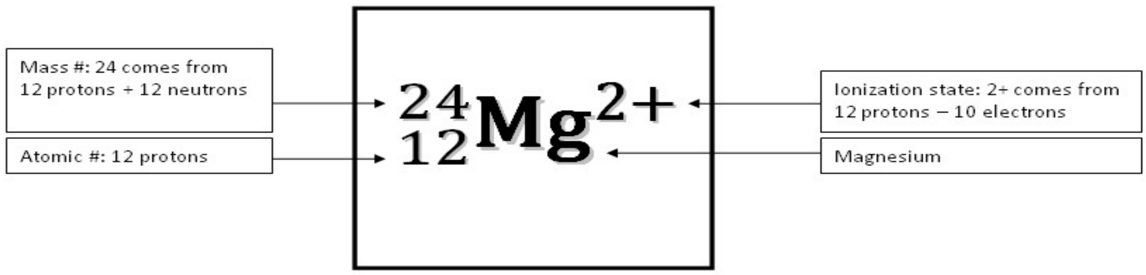

Figure 1: Convention of writing Mass number and Atomic Number of an element (Credit: By Uopchem25123 [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], from Wikimedia Commons)

In the Figure 1 the subscript on the left represents the atomic number which is 12 i.e. Magnesium atom has 12 protons. The superscript on the left of the symbol represents the mass number. This symbol represents the ^{24}Mg isotope i.e. this Magnesium atom has 24-12 =12 neutrons. The superscript on the top right corner represents the net charge the atom carries. If nothing is written there the atom has zero net charge. In this case the +2 represents the net double positive charge this Magnesium atom carries. So, the atom has 10 electrons in total.

Formation of ions would be explored later in lesson 3 and 4 but students must be familiar with the different components of the chemical symbol that they are going to explore in the digital activity.

Digital Activity: Atom Factory

Learning Objectives: In this activity students will be able to:

1. Build atoms till atomic number 10.
2. Identify the contribution of neutrons, protons and electrons to the atomic number, atomic mass number and the net charge of the atoms.
3. Identify alternative representations of electrons in the form or electron cloud.

The ‘Atom Factory’ activity has three components i.e. ‘Build an Atom’, ‘Symbols’ and ‘Game’. The first time, students will spend only 10 minutes on the App. Teachers will do the debriefing. Then students will make atoms one after another.

The students should first go through ‘Build an Atom’ and ‘Symbols’ only. They should make the atoms of different elements one by one in the increasing order of their atomic number. Both the activities are similar. In ‘Symbols’ component students can explicitly check different components of the chemical symbol for the atoms they are making.

Digital Activity: Atom Factory Again!
Learning Objectives: Students will be able to
1. Identify the order of filling of the electron orbitals.
2. Identify the maximum number of electrons that the first and the second orbitals can take.

Students explore the ‘Build an Atom’ component again. In this activity they focus on the electrons only. They can be asked to check if the second orbital can be filled without filling the first orbital. They can be asked to check the maximum number of electrons that can be placed in the first and the second orbitals.

The students can then be asked to explore the ‘Game’ in which they get a chance to practice the knowledge they have acquired.

Students can then answer the questions under the ‘Review what you have learned’ section.

Lesson 4: The Rule of 8
Learning Objectives: Students will be able to
1. Compare the distribution of electrons in the noble gases with the distribution of elements in other elements.
2. Describe how ionic bond helps Sodium and Chlorine attain stability in Sodium Chloride molecule.
3. Describe how covalent bond helps Hydrogen and Oxygen attain stability in the water molecule.

The lesson starts with examination of atomic structure of noble gases. The outermost orbitals of the atoms of noble gases are full which renders them chemically inert under normal temperature and pressure. Atoms of other elements try to attain this stable electronic configuration by combining with other atoms of same or different elements. The module details how formation of both ionic and covalent bonds helps elements attain stable electronic configuration.

Lesson 5: Molecule factory
Learning Objectives: Students will be able to
1. Describe formation of different molecules such as Nitrogen (N_2), Water (H_2O), Hydrogen Peroxide (H_2O_2) and Ammonia (NH_3).

Digital Activity: Molecule Factory

Learning Objectives: In this activity students will be able to
1. Build some common molecules such as H_2, O_2, H_2O. N_2, CO_2.
2. Build molecules such as O_3, C_2H_4, N_2O, CH_3Cl.

Students practice building molecules in the ‘Molecule Factory’ activity. Students get to visualize how atom bonds, number of atoms in a particular atom and their arrangement.

After the digital lesson the teacher should continue classroom lecture in which she recaps formation of covalent bonds and explain electronic configuration of molecule such as Nitrogen (N_2). The students can be asked to figure out the formation of one or two molecules by themselves.

Students then go to the lab answer the questions under ‘Molecule Review’ section and fill the ‘Student Feedback Survey’.