INCREASING ACCESS TO SECONDARY SCHOOL LEVEL EDUCATION THROUGH THE PRODUCTION OF QUALITY LEARNING MATERIALS

JUNIOR SECONDARY LEVEL

CHEMISTRY

Module 4: Periodic Classification of the Elements

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JUNIOR SECONDARY LEVEL SCIENCE - CHEMISTRY

MODULE 1- Introduction to Chemistry

MODULE 2 – Matter and Change of State

Unit 1 – Matter and Change of State

Unit 2 – Building Blocks of Matter

MODULE 3 – Heat, Energy, Air and Combustion

Unit 1 – Heat, Energy, Air and Combustion

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MODULE 4 – Periodic Classification of the Elements

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MODULE 4 – UNIT 1

PERIODIC CLASSIFICATION OF THE ELEMENTS

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MODULE 4

UNIT 1

PERIODIC CLASSIFICATION OF THE ELEMENTS

INTRODUCTION

In Module 2, we came across atoms, elements and compounds. With the discovery of many elements in the 19th century, attempts were made to compare the newly discovered elements with those already known.

Various scientists suggested ways of doing so by grouping them according to some common features and behaviour. This gave rise to a table known as the Periodic Table nowadays.

Module 2 of the Physics components also addresses issues raised here. You can study both together.

In this Unit we are going to consider elements in relation to their positions in the Periodic Table. We are also going to have a closer look at the structure of atoms.

OBJECTIVES

After completing the module, you'll be able to:

- state the chemical symbol of the first twenty elements
- write symbols for the first twenty elements
- explain the meaning of the periodic table
- describe the trends in physical properties down group 1
- describe the trends in chemical properties down group 2

- describe an atom
- describe the arrangement of sub-atomic particles
- explain the meaning of electronic configuration
- state the properties of each sub-atomic particles
- write the electronic configuration of the first twenty elements
- draw an electron diagram of an atom of the first twenty elements

1.0 CHEMICAL SYMBOLS

We normally use a symbol as a shorthand method to represent one atom of an element. The symbols in use nowadays are internationally recognised. For a number of elements, their symbols are represented by the first letter of their names. Since there are only 26 letters in the alphabet and more than 100 elements, it is not possible for us to attribute one letter to each element. The symbols of most elements consist of two letters. The first letter is always a capital letter and the second a small letter. The symbols of certain elements have been derived from their Latin names.

Note: **You can also refer to Physics - Module 2, 2.4.**

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 1

Complete the blanks below:

(i) A symbol is an abbreviation used to represent……..

……

(ii) The symbols are standard and are recognised ……

……

You will find the answer at the end of the Module.

1.1 SYMBOLS OF ELEMENTS

The Swedish Chemist Jöns Berzelius pioneered a system to derive symbols for the elements. This is still currently used. A symbol should be the first letter of the element's name e.g. *O for Oxygen.*

- First letter and another letter e.g. *He for Helium.*
- First letter and another letter in the Latin name e.g. *Pb from Plumbum*, Latin name for Lead.

The Pictorial Periodic Table

I	II	IIIb	IVb	Vb	VIb	VIIb	VIIIb			Ib	IIb	III	IV	V	VI	VII	0
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq		Uuh		Uuo

Lanthanides *	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Actinides **	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 2

The symbol for Hydrogen is H; that of Helium is He.

Complete the table below by writing down the symbol attributed to each element.

Element	Symbol
Hydrogen	H
Helium	He
Carbon	
Magnesium	
Argon	
Calcium	
Silicon	
Boron	

	Aluminium	
	Phosphorus	
	Potassium	
	Oxygen	
	Beryllium	
	Nitrogen	
		li
		F
	Neon	
		Ci
	Sodium	
		S

You will find the answer at the end of the Module.

Some elements have names ending in IUM. They are generally metals. There are exceptions of course e.g. *Helium and Selenium are non-metals*.

Elements ending in INE or ON are non-metals. But again iron ends in ON. It is a metal though.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 3

Here is a list of symbols for a few elements (other than those considered so far). Write the name of the corresponding element.

Name of Element	Symbol
	Ag
	Au
	Hg
	Br
	I
	U
	Sn
	Pb
	Zn
	Cu

You will find the answer at the end of the Module.

1.2 PERIODIC TABLE

The Periodic Table is a way of classifying and arranging elements. The elements are arranged in a definite pattern. The Periodic Table is divided into:

1. groups
2. periods.

1.2.1 GROUP

A group is a vertical column of elements. There are eight groups in the Periodic Table. Elements in the same group (of the P.T) have similar chemical properties

1.2.2 PERIOD

A period is a horizontal row of elements. Period 1 contains only two elements: hydrogen and helium. Periods 2 and 3 each contains eight elements.

The 'Periodic Table' in blank form is

I	II	III	IV	V	VI	VII	VIII

Note: Please refer to Physics - Module 2, 2.5.7.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 4

(a) What is the Periodic Table?

……

……

……

(b) What do the Roman numerals represent?

……

……

(c) Now insert the first 20 elements in the blank spaces to show their positions in the Periodic Table.

You will find the answer at the end of the Module.

Elements found in the same group (of the Periodic Table) have similar chemical properties. Remember the group means the same vertical column.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 5

Give an example of an element with similar chemical properties:

(a) Sodium resembles ……

(b) Chlorine resembles ……..

(c) Magnesium resembles ……..

(d) Argon resembles ……..

You will find the answer at the end of the Module.

1.2.3 GROUP I

Group I elements are also known as alkali metals. They are relatively soft metals and can easily be cut with a blade. Alkali metals are good conductors for electricity. Compared to other metals, they have a low density. Lithium is the lightest alkali metal. Moving down the group, there is a gradual change in melting point .The metals also become more reactive down the group.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 6

(a) Lithium is in group I of the Periodic Table.

Its co-members are …….. ,…….. .

(b) Delete the words, which are incorrect in each.

As we go from lithium to potassium.

(i) The atoms become larger/smaller.

(ii) Melting points increase/decrease.

(iii) Reactivity increases/decreases.

You will find the answer at the end of the Module.

1.2.4 GROUP II

The members of group II elements are all metals .As in group I, they show trends in chemical properties. On moving down the group, the reactivity of the metals increases.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 7

(*a*) *The first member of group II of the Periodic Table is Beryllium.*

(i) The second member is ……..

(ii) The third member is ……..

(b) As we go down the list of elements in group II we note that

(i) chemical reactivity ……

(ii) atoms of the element become ……..

You will find the answer at the end of the Module.

1.2.5 Group VII

In group VII the elements are the **halogens.** They are non-metals. The members are: fluorine, chlorine, bromine and iodine.

Reactivity decreases down the group of halogens. These non-metals have affinity for metals. They react together e.g. sodium and chlorine form sodium chloride.

We can now proceed with the following investigation.

INVESTIGATION 1: Showing reactivity down a group

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Test tubes in a rack • Samples of magnesium, calcium • Dilute hydrochloric acid **Method**: *Place 2 test tubes side by side in a test tube rack.* *Pour about 5 cm^3 of dilute hydrochloric acid in each.* *Label them as X and Y.* *Drop a piece of magnesium ribbon in X and a few granules of calcium in Y.* *Record your observations* …… …… …… …… …… …… *What can you conclude?* …… …… …… ……

I am sure that you noted bubbles of gas (hydrogen) in both X and Y. In Y bubbles occur more rapidly than in X.

I am sure that you are able to draw the right conclusion. Calcium is more reactive than magnesium.

On moving down the group, the compounds of group II elements become more stable towards heat. They must be heated for a longer time and at a higher temperature for decomposition to take place.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 8

Consider the two compounds, magnesium carbonate and calcium carbonate

(a) Which one is expected to be more stable towards heat?

……..

(b) …… is more easily decomposed by heat than ……

You will find the answer at the end of the Module.

1.3 ATOMS - COMPONENTS

As we have seen earlier, atoms are the building blocks of all substances. All atoms contain three fundamental particles:

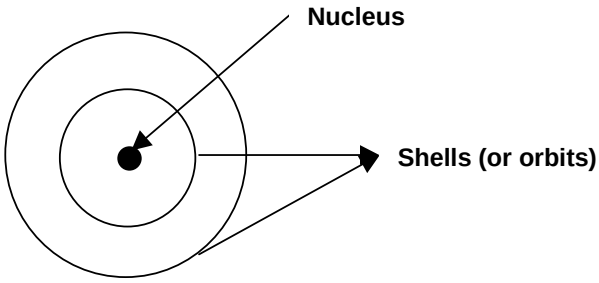
(i) protons
(ii) electrons
(iii) neutrons.

This doesn't mean to say that all atoms are similar in nature. For example, an iron atom is different from a zinc atom. This is because they have different numbers of protons, neutrons and electrons.

Protons are positively charged whereas electrons are negatively charged. Neutrons do not carry any charge.

A proton has the same mass as a neutron .An electron is about 2000 times lighter than a proton or neutron.

We can represent an atom as follows:



Note: Please refer to Physics - Module 2, 2.5 and 2.51.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 9

(a) *Define an atom*

……

……

……

(b) *The atom generally consists of 3 types of sub-atomic particles.*
What are they?

(i) ……

(ii) ……

(iii) ……

You will find the answer at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 10

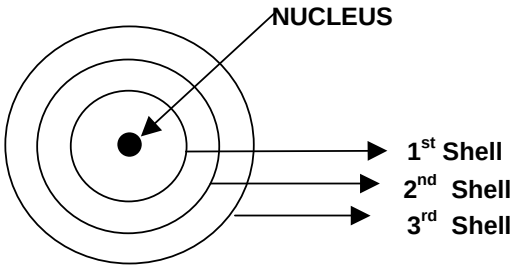
Complete the table below about the 3 types of sub-atomic particles.

	Name of Sub-atomic particle	***Relative mass (on atomic mass scale)***	***Charge (if any)***
1.	*Proton*		
2.	*Neutron*		
3.	*Electron*		

You will find the answer at the end of the Module.

1.4 ATOMIC STRUCTURE

An atom consists of a dense tiny core called the nucleus .It is found at the centre of the atom. The nucleus contains protons and neutrons tightly packed together. The electrons are found in electron shells outside the nucleus. They move around the nucleus in orbits at high speeds. An atom can be visualised as a miniature solar system with the nucleus at the centre. An atom contains the same number of electrons and protons. The overall charge of any atom is zero.



✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 11

(*a*) *Write 'True' or 'False' for each of the statements about the nucleus of an atom.*

(i) *It is located centrally in the atom.* ----------

(ii) *It contains protons and electrons.* ----------

(iii) *It contains protons and neutrons.* ----------

(iv) *It is massive.* ----------

(v) *It carries no charge.* ----------

(vi) *It is negatively charged.* ----------

(vii) *It is surrounded by shell(s) of electrons.* ----------

(b) *Write 'True' or 'False' for statements concerning the shells in an atom.*

(i) *They occur around the nucleus.*----------

(ii) *They contain only electrons.* ----------

(iii) *They contain the same number of electrons as the number of protons in the nucleus.*----------

(iv) *The shell nearest to the nucleus is the last shell.* ----------

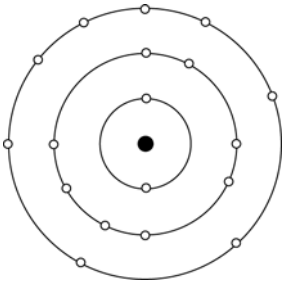
(v) *The outermost shell is furthest from the nucleus.* ----------

(vi) *All atoms of the same element have the same number of shells.* ----------

You will find the answer at the end of the Module.

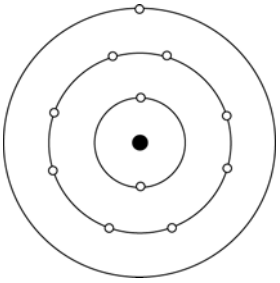
1.5 ELECTRONIC CONFIGURATION

Electron shells are found at different distances from the nucleus. They are numbered 1,2.3…. outwards from the nucleus. The first electron shell is found closest to the nucleus. It can hold a maximum of two electrons. The second shell can accommodate a maximum of eight electrons. The third shell can have up to eighteen electrons. The electron shell found furthest from the nucleus is called the outermost shell. Electrons in the outermost shell are known as valency electrons.



An atom of Argon

The electronic configuration of an atom shows the arrangement of electrons in the different shells. Sodium has an electronic configuration of 2,8,1. This means that an atom of sodium contains two electrons in the first shell, eight electrons in the second shell and one electron in the third shell. This third shell is the valency shell.



An atom of Sodium

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 12

Complete the blanks below.

(a) In an atom the first shell cannot contain more than ---------- electrons.

(b) The second shell in an atom cannot hold more than ---------- electrons.

(c) In an atom of carbon there are ---------- electrons in the first shell and -------- electrons in the second shell.

(d) We describe the electronic configuration of the carbon atom as ---------.

You will find the answer at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 13

In the space below draw a diagram to show the distribution of electrons in a carbon atom.

You will find the answer at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 14

For the first 20 elements in the Periodic Table, indicate the distribution of electrons in an atom of each. Fill in the table below.

ELECTRONS IN				
Element (Symbol)	**1st shell**	**2nd shell**	**3rd shell**	**4th shell**
H				
He				
Li				
Be				
B				
C				
N				
O				
F				
Ne				
Na				
Mg				
Al				
Si				
P				
S				
Cl				
Ar				
K				
Ca				

You will find the answer at the end of the Module.

POINTS TO REMEMBER

- Elements have symbols. Each of these usually consists of 2 letters or a single letter.
- Elements are arranged in a systematic manner in the Periodic Table.
- Reactivity increases down Group I elements.
- There is a decrease in reactivity down group VII elements.
- Atoms of noble gases have complete shells of electrons.
- The atom consists of a central nucleus surrounded by shells (of electrons)
- The atom contains protons, neutrons and electrons.

MODULE 4 – UNIT 2

BONDING

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MODULE 4

UNIT 2

BONDING

INTRODUCTION

We are now familiar with the structure and electronic configuration of the atom. We also know that elements are made up of atoms.

Atoms of different elements combine together to become more stable or we can simply say they bond together.

This Unit will help you to understand how bonding occurs by using knowledge acquired so far on the structure and electronic configuration of the atom.

OBJECTIVES

After completing this module, you'll be able to:

- distinguish between ionic, metallic and covalent bonding
- relate bonding to the position of elements in the Periodic Table
- describe covalent bonding as the sharing of electrons
- describe ionic bonding as a transfer of electrons
- describe metallic bonding as an attraction between positive nuclei and a sea of electrons.

2.0 ACHIEVING STABILITY IN ATOMS

Atoms of different elements combine with each other to achieve the electronic configuration of the nearest noble gas. The noble gases are as you know unreactive. In other words, noble gases are stable as their outermost shells are full of electrons. Stability can be achieved by losing, gaining or sharing electrons.

2.1 IONS

An ion is formed when an atom loses or gains electrons. There are two types of ions:

(i) anions

(ii) cations

Anions are negatively charged. They are usually formed by non-metals gaining electrons. An anion contains more electrons than protons. Here are two examples.

Atoms		**Anions**
CL	----------	CL
2,8,7		2,8,8 (same as argon)
O	----------	O^{2-}
2,6		2,8(same as neon)

When an atom loses electrons, it becomes a cation. Cations are positively charged. They contain more protons than electrons. Here are some examples.

Atoms		**Cations**
Na	----------	Na^{+}
2,8,1		2,8
Ca	----------	Ca^{2+}
2,8,8,2		2,8,8
Al	----------	Al^{3+}
2,8,3		2,8

We shall now turn to the types of bonding namely:

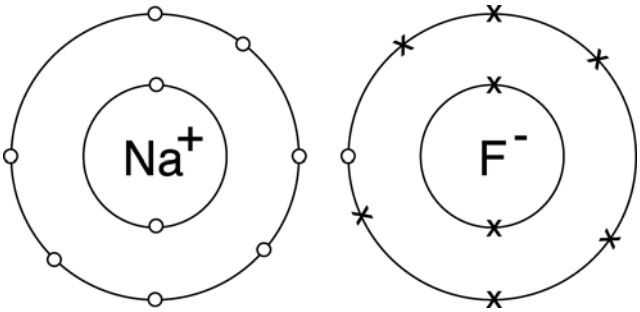
(i) Ionic

(ii) Metallic

(iii) covalent

2.2 IONIC BONDING

Ionic bonds are formed between metals and non-metals. The atom of the metal loses electrons and becomes a cation. The electrons lost by the metal are taken up by the non-metal and an anion is formed. The cation and the anion achieve the electronic arrangement of a noble gas. The cation and the anion attract each other as they are oppositely charged. The force of attraction between the cations and the anions is the ionic bond.



✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 1

Explain ionic bonding between calcium and oxygen.

……..

……

……..

……

You will find the answer at the end of the Module.

2.3 METALLIC BONDING

As the name indicates, metallic bonding occurs in metals.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 2

In which of the following does metallic bonding occur?

(i) water

(ii) aluminium

(iii) calcium

(iv) iron

(v) sulphur

You will find the answer at the end of the Module.

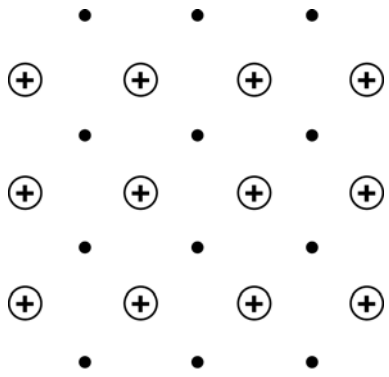
2.3.1 METALLIC BONDING – FORMATION

In metals, the outermost electrons are 'loosely' held in the atom. In fact they 'escape' from the atom, leaving the latter positively charged when sufficient energy is provided. In a metal there are vast numbers of positive ions which are 'drowned' in a 'sea' or 'ocean' of electrons. Bonding occurs between the

positive ions and negative ‘sea’/’ocean’ of electrons as a result of attraction between unlike charges.

The following diagram illustrates bonding in metals.

Metallic Bonding

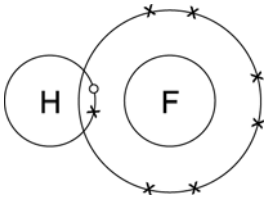


⊕ **Positively charged nucleus**

• **Negatively charged electron**

2.4 COVALENT BONDING

Covalent bonds are usually formed between non-metals. They are formed by the sharing of electrons. Each atom contributes an equal number of electrons for sharing. After sharing, the atoms have the same electronic structure as a noble gas.



Covalent bonding

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 3

(*a*) *Explain covalent bonding between 2 atoms of hydrogen to form a molecule of hydrogen.*

……..

(b) Explain covalent bonding between 2 atoms of oxygen to form a molecule of oxygen.

……

……

(c) Account for covalent bonding between an atom of oxygen and two atoms of hydrogen (in a molecule of water).

……

……..

You will find the answer at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 4

A molecule of ammonia contains one atom of nitrogen bonded covalently to 3 atoms of hydrogen. Using a suitable sketch, show the bonds in a molecule of ammonia.

You will find the answer at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 5

(*a*) *Give 1 instance of a hydrogen atom forming an ionic bond with another element.*

Answer ……..

(b) Explain the formation of the ionic bond in this case.

……

……

……

You will find the answer at the end of the Module.

The type of bonding formed between atoms is related to the positions of the elements in the Periodic Table. Metals are usually found at the beginning of a period (Groups I, II and III) whereas non-metals are found at the end (Groups IV-O).

The noble gases helium, neon and argon do not combine with other elements to form compounds. They have stable electronic arrangements and have no tendency to lose, gain or share electrons.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 6

What is the tendency shown by atoms of

(i) Group VIII (or group O) elements?

……
……
……

(*ii) Metals of groups I and II of the Periodic Table*

……
……
……

(iii) Non metals (excluding noble gases)

……
……
……

You will find the answer at the end of the Module.

2.5 IONIC & COVALENT COMPOUNDS

A Comparison

Ionic	Covalent
• Consists of ions. • Solids at room temperature. • High melting point. • High boiling point. • Do not conduct electricity in the solid state. • Good conductor in molten state or when dissolved in water. • Usually soluble in water. • Insoluble in organic solvents.	• Consists of molecules. • Usually gases, volatile liquids or solids that melt easily. • Non-conductors of electricity. • Usually insoluble in water. • Soluble in organic solvents.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 7

Classify each of the following characteristics as applicable to Ionic or Covalent substances.

1. *Solids under room conditions.----------*
2. *High melting point.----------*
3. *Usually gas or liquid. ----------*
4. *Conducts an electric current when molten or when dissolved in water. --------- (during the process of conducting the electric current there is chemical decomposition).*

You will find the answer at the end of the Module.

POINTS TO REMEMBER

- Ionic bonding involves transfer of electrons from metal to non-metal.
- Bonding in metals is due to positive ions of the metals attached to the sea of electrons around them.
- Covalent bonding is due to the sharing of electron pairs between atoms.
- Ionic compounds are high melting solids.
- Covalent substances are gases or liquids with low boiling points.

ANSWERS TO ACTIVITIES

UNIT 1

Activity 1

(i) an atom of an element

(ii) internationally (or universally)

Activity 2

NO	SYMBOL
1	H
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
19	K
20	Ca

Activity 3

NAME	SYMBOL
SILVER	Ag
GOLD	Au
MERCURY	Hg
BROMINE	Br
IODINE	I
URANIUM	U
TIN	Sn
LEAD	Pb
ZINC	Zn
COPPER	Cu

Activity 4

(a) It is a tabular arrangement of elements. It has vertical sets of elements (in Groups) and horizontal rows of elements (in Periods)

(b) The Roman numerals represent the GROUP NUMBERS.

(c)

I	II	III	IV	V	VI	VII	VIII
H							He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	P	S	Cl	Ar
K	Ca						

Activity 5

(a) ------Potassium (b) ------Fluorine (c) ------Calcium (d)------Neon

Activity 6

(a) sodium, potassium

(b) (i) Delete smaller (ii) Delete increase (iii) Delete decreases

Activity 7

(a) (i) Magnesium (ii) Calcium

(b) (i) increases (ii) larger

Activity 8

(a) Calcium carbonate

(b) Magnesium carbonate ---------- calcium carbonate

Activity 9

(a) It is the smallest particle of an element which is representative of the element.

(b) (i) Protons (ii) neutrons (iii) electrons

Activity 10

	NAME	MASS	Charge (if any)
1	Proton	1	+1
2	Neutron	1	Nil
3	Electron	negligible	-1

Activity 11

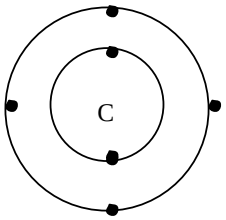
(a) (i) True (ii) False (iii) True
(iv) True (v) False (vi) True
(vii) True

(b) (i) True (ii) True (iii) True
(iv) False (v) True (vi) True

Activity 12

(a) 2 (b) 8 (c) 2 (1^{st} shell), 4 (2^{nd} shell) (d) 2,4

Activity 13



Activity 14

Symbol	1st shell	2nd shell	3rd shell	4th shell
H	1			
He	2			
Li	2	1		
Be	2	2		
B	2	3		
C	2	4		
N	2	5		
O	2	6		
F	2	7		
Ne	2	8		
Na	2	8	1	
Mg	2	8	2	
Al	2	8	3	
Si	2	8	4	
P	2	8	5	
S	2	8	6	
Q	2	8	7	
Ar	2	8	8	
K	2	8	8	1
Ca	2	8	8	2

ANSWERS TO ACTIVITIES

UNIT 2

Activity 1

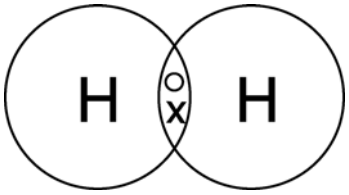
The calcium atom transfers two electrons to the oxygen atom. As a result, calcium forms its cation and oxygen forms its anion. These are attracted to each other as they are oppositely charged. A link is established.

Activity 2

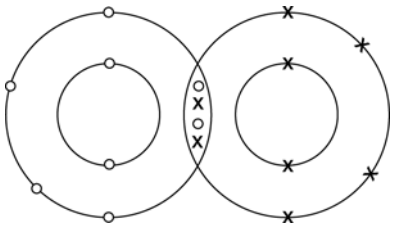
(i) Aluminium (ii) Iron (iii) Calcium

Activity 3

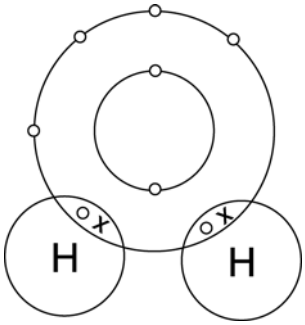
(a) There is sharing of two electrons as shown below.



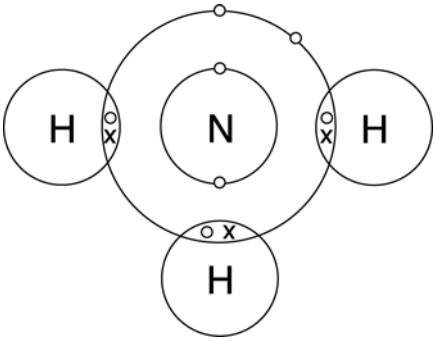
(b) Two pairs of electrons are shared between 2 oxygen atoms.



(c) There is sharing of 2 pairs of electrons as shown below.



Activity 4



Activity 5

(a) Hydrogen combining with sodium

(b) The sodium atom transfers its outermost electron to the hydrogen atom. A sodium cation is formed, together with a hydrogen anion. As they are oppositely charged, they attract and get bonded.

Activity 6

(i) They do NOT tend to lose electrons, to gain electrons, or to share electrons.

(ii) They tend to lose the outermost electron(s) to form positively charged ions.

(iii) They tend to gain electrons from metals and to share electrons with non-metals (except the noble gases)

Activity 7

1. Ionic 2. Ionic 3. Covalent 4. Ionic