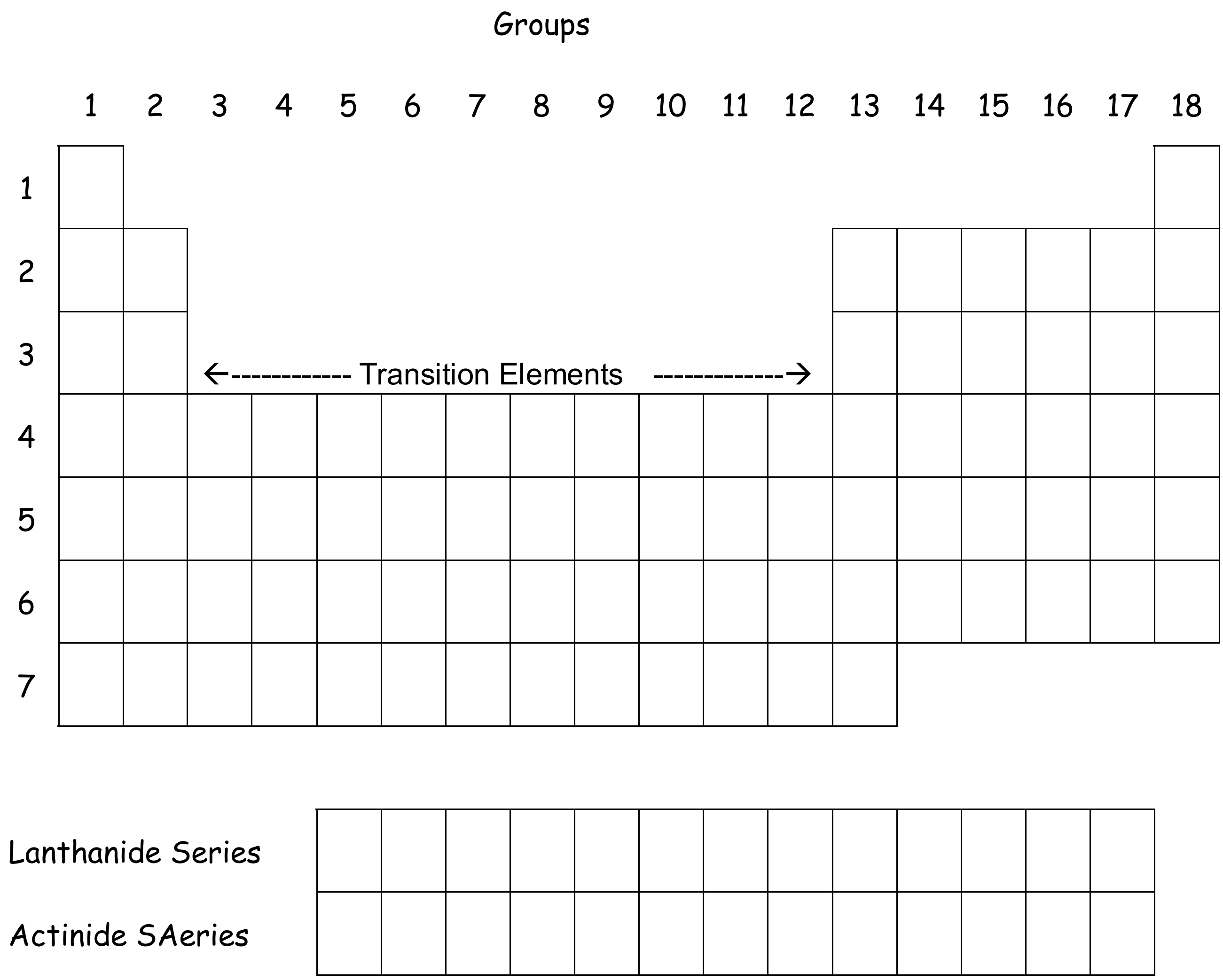
CHAPTER 4: PERIODIC TABLE OF ELEMENTS

1.	**Antoine Lavoisier (1743 – 1794)** - In 1789, Antoine Lavoisier became the first scientist to classify substances, including light and heat, into metals and non-metals. - His classification, however, was unsuccessful because light, heat and a few other compounds were also considered as elements.
2.	**Johann Dobereiner (1780 – 1849)** - In 1829, Dobereiner divided the elements into groups of three elements with similar chemical properties, known as Dobereiner's triads. - The atomic mass of the middle element was approximately the average atomic mass of the other two elements in each triad. - This classification led chemists to realize that there was a relationship between the chemical properties and the atomic mass of each element.
3.	**John Newlands (1837 – 1898)** - From 1864 to 1865, Newlands arranged the known elements in order of increasing atomic mass. Elements with similar properties recurred at every eighth element. This was known as the Law of Octaves. - His contribution was a failure because the Law of Octaves was obeyed by the first 17 elements only. - However, John Newlands was the first chemist to show the existence of a periodic pattern for the properties of elements.
4.	**Lothar Meyer (1830 – 1895)** - In 1870, Meyer plotted a graph of the atomic volume against the atomic mass for all the known elements - He realized that elements with similar chemical properties occupied equivalent positions on the curve. - He was successful in showing that the properties of the elements formed a periodic pattern against their atomic masses.
5.	**Dmitri Mendeleev (1834 – 1907)** - In 1869, Mendeleev arranged the elements in order of increasing atomic mass and grouped them according to similar chemical properties. - He left gaps in the table to be filled by undiscovered elements. - He was able to predict the properties of undiscovered elements
6.	**Henry J.G. Moseley (1887 – 1915)** - In 1914, Moseley studied the X-ray spectrum of elements. - From the experiment, he concluded that proton number should be the basis for the periodic change of chemical properties instead of the atomic mass. - He arranged the elements in order of increasing proton number in the Periodic Table. Thus, he confirmed the work of Mendeleev.

7.	**Modern Periodic Table**
	- Elements in the Periodic Table are arranged in an increasing order of proton number, ranging from 1 to 113. - Elements with similar chemical properties are placed in the same vertical column - ***Each vertical column of elements*** is called a ***group***. - The vertical columns are known as Group 1 to Group 18. - The *<u>number of valance electrons</u>* in an atom decides the position of the group of an element in the Periodic Table. - ***Each of these horizontal rows of elements*** is called ***period***. - The horizontal rows are known as Period 1 to Period 7. - The *<u>number of shells occupied with electrons</u>* in the atom decides the position of the period of an element in the Periodic Table.

Periodic Table



8. **Group 18 elements**

- **Helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Ra).**
- The elements are known as **noble gases**.
- Noble gases are **monoatomic**.

Physical properties:

- Noble gases have very small atomic sizes.
- The atomic size increasing as the number of occupied shells in the atom increases from helium to radon.
- They are colorless gases at room temperature and pressure.
- Noble gases have low melting and boiling points.
- The melting point and boiling point of element increase when going down Group 18.
- Since the atomic size of each element increases down the group, the forces of attraction between the atoms of each element become the stronger. Thus, more heat energy is required to overcome the stronger forces of attraction during melting or boiling.
- They also have low densities.

Element	Proton Number	Electron Arrangement	Atomic radius size	Melting / Boiling point	Density
He	2	2 (***duplet*** electron arrangement)	**Increase** down the group because the number of shells occupied with electron increase	**Increase** down the group because the forces of attraction become stronger	**Increase** down the group because the relative atomic mass of element inccreased
Ne	10	2.8 (***octet*** electron arrangement)			
Ar	18	2.8.8			
Kr	36				
Xe	54				

Chemical properties:

- All noble gases are **inert** which means chemically unreactive.
- Helium has two electrons. This is called a duplet electron arrangement.
- Other noble gases have eight valence electrons, which are called the octet electron arrangement.
- These electron arrangements are very **stable** because the outermost occupied shells are full. That is why noble gases exist as monoatomic gases and are chemically unreactive..

Use of Group 18 elements

Noble gas	Use / Application
Helium	- helium gas is used to fill airship, weather balloons and hot air balloons - Liquid helium is used to cool metals into superconductors. - Helium is mixed with oxygen and used by divers
Neon	- Neon gas is used in advertising lights and television tubes. - Neon is used in landing lights for planes at airstrips
Argon	- Argon gas is used to provide an inert atmosphere for welding at high temperature - Argon is used to fill an electric bulb to prevent the filament of the bulb from burning
Krypton	- Krypton gas is used in lasers to repair the retina of the eye - It also used to fill photographic flash lamps.
Xenon	- Xenon gas s used for making electron tubes and stroboscopic lamps. - Xenon also used in bubble chambers in atomic energy reactors. - Xenon is used as anaesthetic in the medical field
Radon	- Radon is used in the treatment of cancer.

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9. **Group 1 Elements**

- Lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs), and francium (Fr).
- Group 1 elements are also known as alkali metals.

Physical properties:

- Group 1 elements are soft metals with low densities and low melting points.
- They have silvery and shiny surfaces.
- They are also good conductors of heat and electricity.
- When going down the group, the hardness, melting point and boiling point decrease.
- When going down the group, the atomic sizes increase.

Element	Proton Number	Electron Arrangement	Atomic Radius Size	Boiling & Melting Point	Density
Li			**Increase** when going gown the group because the number of shells occupied with electron increase	**Decrease** when going down the group because the metallic bonding between atoms becomes weaker	**Increase** when going down the group because the increase in atomic mass is bigger than the increase in volume
Na					
K					
Rb					
Cs					
Fr					

Chemical properties:

- Group 1 elements have similar chemical properties.
- Alkali metals have one electron in their outermost occupied shells.
- Each of them react by donating one electron from its outermost occupied shell to form an ion with a charge of +1, thus achieving the stable electron arrangement of the atom of noble gas.
- Alkali metals react vigorously with water to produce alkaline metal hydroxide solutions and hydrogen gas, H_2.

  Example: $2Li(s) + 2H_2O(l) \rightarrow 2LiOH + H_2$
- Alkali metals burn in oxygen gas, O_2 rapidly to produce white solid metal oxides.

  Example: $4Li(s) + O_2(g) \rightarrow 2LiO(s)$
- Alkali metals burn in halogen (Cl_2, Br_2) gas to form white solid metal halides.

  Example: $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$
- The reactivity of Group 1 elements increase down the group.
- ***When going down the group***, the atomic size increase, the single valence electron in the outermost occupied shell becomes further away from the nucleus.
- The attraction between nucleus and the valence electron becomes weaker.
- Therefore, it is easier for the atom to donate the single valence electron to achieve the stable electron arrangement for the atom of noble gas.

Safety precautions in handling Group 1 elements:

- All alkali metals are extremely reactive.
- Alkali metals must be stored in paraffin oil in bottles.
- Do not hold alkali metals with your bare hands.
- Use forceps to take them and remember to wear safety goggles and gloves.
- When conducting experiment, make sure that only a small piece of alkali metals is used.

EXPERIMENT 4.1

Aim:

To investigate the chemical properties of lithium, sodium and potassium

Problem Statement:

How does the reactivity of Group 1 elements change when they react with water and oxygen gas, O_2?

A) The reaction of alkali metals with water

Hypothesis:

When going down Group 1, alkali metals become more reactive in their reactions with water.

Materials:

Small pieces of lithium, sodium and potassium, filter paper, distilled water, red litmus paper and three gas jars filled with oxygen gas, O_2.

Apparatus:

Water troughs, small knife, forceps, gas jars, gas jar spoon and gas jar covers.

Variables:

Manipulated variable : Different types of alkali metals

Responding variable : Reactivity of metals

Fixed variables : Water, size of metals

Operational definition:

An alkali metal that reacts more vigorously with water is a more reactive metal.

Procedure:

1. Cut a small piece of lithium using a knife and forceps.
2. Dry the oil on the surface of the lithium with filter paper.
3. Place the lithium slowly onto the water surface in a trough.
4. When the reaction stops, test the solution produced with red litmus paper.
5. Demonstration by teacher: Your teacher will repeat steps 1 to 4 using sodium and potassium to replace lithium one by one.
6. Record your observations in a table.

Procedure:

Diagram

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Diagram

B) The reaction of alkali metals with oxygen gas, O_2.

Hypothesis:
When going down Group 1, alkali metals become more reactive in their reactions with oxygen gas, O_2.

Materials:

Apparatus:

Variables:
Manipulated variable : …………………………………………..
Responding variable : …………………………………………..
Fixed variables : …………………………………………..

Procedure:

1. Cut a small piece of lithium using a knife and forceps.
2. Dry the oil on the surface of the lithium with filter paper.
3. Put the lithium in a gas jar spoon.
4. Heat the lithium strongly until it burns.
5. Transfer the gas jar spoon quickly into a gas jar filled with oxygen gas, O_2.
6. Observe what happens.
7. When the reaction stops, pour 10 cm^3 of water into the gas jar. Shake the gas jar. Test the solution formed with red litmus paper.
8. Demonstration by teacher: Your teacher will repeat the steps 1 to 7 using sodium and potassium to replace lithium one by one.
9. Record your observations in a table.

Procedure:

Diagram

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Data and Observation:

Section	Observation		
	Lithium	Sodium	Potassium
A			
B			

Interpreting data:

1. Based on your result, arrange the alkali metals in ascending order of reactivity.
2. Do all the alkali metals show similar chemical properties? Suggest a reason for your answer.
3. Name the substance formed which caused the red litmus paper to change colour in both Section A and B.

Answer:
1.

2.

3.

Discussion:

1. Why are the experiments involving sodium and potassium demonstrated by your teacher and not carried out by the students?
2. Write the chemical equations for the reactions of lithium, sodium and potassium with
    a) Water
    b) Oxygen gas, O_2
3. Write the chemical equations for the reactions between the products from the combustion of each alkali metal with water.

Answer:
1.

2. a) i
ii
iii

b) i
ii
iii

3.

Conclusion:
Can each of the hypotheses be accepted?

Answer:

10. **Group 17 Elements**

- Fluorine (Fl), chlorine (Cl), bromine (Br), iodine (I) and astatine (At)
- Group 17 elements also known as halogens.
- They are poisonous.

Physical properties:

- Halogens have low melting and boiling because their molecules are attracted to each other by weak forces.
- When going down the group, the physical state of halogens at room temperature changes from gas to liquid, then to solid.
- When going down the group, the molecular sizes is increase, the melting and boiling points also increase.

<table>
<tr><th>Halogen</th><th>Proton Number</th><th>Electron Arrangement</th><th>Physical Sate</th><th>Atomic Radius</th><th>Melting & Boiling point</th><th>Density</th></tr>
<tr><td>F_2</td><td></td><td></td><td>Yellowish green gas</td><td rowspan="4">Increase because the number of shells occupied with electron increase</td><td rowspan="4">Increase because molecular size increase so the Van der Waals' forces of attraction between molecules become stronger</td><td rowspan="4">Increase because the increase in atomic mass is bigger than the increase in volume</td></tr>
<tr><td>Cl_2</td><td></td><td></td><td>Yellowish green gas</td></tr>
<tr><td>Br_2</td><td></td><td></td><td>Reddish Brown liquid</td></tr>
<tr><td>I_2</td><td></td><td></td><td>Purplish black solid</td></tr>
</table>

Chemical properties:

- All halogens have ***seven valence electrons***.
- When halogens take part in chemical reactions, their atoms always ***gain one electron*** to achieve a stable ***octet electron arrangemen***t.
- They ***exhibit similar chemical properties***.
- When going down Group 17, the atomic size of halogens increases.
- The outermost occupied shell of each halogen atom becomes further from the nucleus.
- Therefore, the strength to attract one electron into the outermost occupied shell by the nucleus becomes weaker.
- This cause the ***reactivity to decrease down the group***.

Chemical Properties of Gorup 17

Halogens + water ⟶ two acids

$Cl_2(aq) + H_2O(l) \rightleftharpoons HCl(aq) + HOCl(aq)$

Chlorine, water ⟶ Hydrochloric acid, Hypochlorus acid

Halogens + Iron ⟶ Iron (III) halides

$2Fe(s) + 3X_2(g) \rightleftharpoons 2FeX_3(s)$

Iron, halogen gas ⟶ iron (III) halides

Halogens + Sodium hydroxide ⟶ Sodium halide + Sodium halite + water

$X_2 + 2NaOH(aq) \rightleftharpoons NaX(aq) + NaOX(aq) + H_2O(l)$

Halogen gas, Sodium hydroxide ⟶ Sodium halide, Sodium halite, water

Safety precautions in handling Group 17 elements:

- Fluorine is a very dangerously reactive substance whereas astatine is radioactive.
- Fluorine gas, chlorine gas, bromine vapour and iodine vapour are poisonous.
- We must handle them in a fume chamber.
- We must also wear safety goggles and gloves when handling these halogens.

Experiment 4.2

Aim:

To investigate the chemical properties of Group 17 elements

Problem Statement:

How do halogens react with water, iron and sodium hydroxide, NaOH solution?

A) Reactions of halogens with water

Hypothesis:

1. Halogens form acidic solutions when they react with water.
2. Halogens show bleaching properties when they react with water.

Variables:

Manipulated variable :

Responding variable :

Fixed variable :

Material:

Chlorine gas, Cl_2, liquid bromine, Br_2, solid Iodine, I_2, blue litmus paper, water, iron wool, soda lime, 2 mol dm^{-3} sodium hydroxide, NaOH solution.

Apparatus:

Test tubes, dropper, test tube holders, stoppers, combustion tubes, delivery tubes, Bunsen burner, retort stand and clamp

Operational definition:

1. When blue litmus paper turns red, the solution formed shows acidic property.
2. When blue litmus paper turns white, the solution formed shows bleaching property.

Procedure:

I Chlorine with water

1. Pass the chlorine gas, Cl_2 into 5 cm^3 of distilled water in a test tube.
2. Put a piece of blue litmus paper into the solution formed.
3. Observe any changes in colour.
4. Record your observation in a table.

Diagram

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II Bromine with water

1. 1. Put two drops liquid bromine, Br_2 into 5 cm^3 of distilled water in a test tube.
2. Put a piece of blue litmus paper into the solution formed.
3. Observe any changes in colour.
4. Record your observation in a table.

Diagram

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III Iodine with water

1. Put a small piece of solid iodine, I_2 into 5 cm^3 of distilled water in a test tube.
2. Close the test tube with a stopper and shake vigorously until no further changes occur.
3. Put a piece of blue litmus paper into the solution formed.
4. Observe any changes in colour.
5. Record your observation in a table.

Diagram

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B) Reaction of halogens with iron

Hypothesis:
Halogens form iron (III) halides when they react with iron.

Variable:
Manipulated variable : ……………………………………….
Responding variable : ……………………………………….
Fixed variable : ……………………………………….

Operational definition:
The appearance of a brown solid shows the formation of iron (III) halides.

Procedure:
I Chlorine with iron

1. Set up the apparatus.
2. Heat the iron wool in the combustion tube strongly.
3. When the iron wool becomes red hot, pass the chlorine gas, Cl_2 over the hot iron wool.
4. Observe any changes. Record your observation in a table.

Diagram

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II Bromine with iron

1. Set up the apparatus.
2. Heat the iron wool in the combustion tube strongly.
3. When the iron wool becomes red hot, warm the liquid bromine, Br_2 in the test tube to vapourise it.
4. Pass the bromine gass, Br_2 over the hot iron wool until no further changes occur.
5. Record your observation in a table.

Diagram

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III Iodine with iron

1. Set up the apparatus.
2. Heat the iron wool in the combustion tube strongly.
3. When the iron wool becomes red hot, heat the iodine, I_2 crystal in the test tube to sublime it.
4. Pass the iodine vapour over the hot iron wool until no further changes occur.
5. Record your observation in a table.

Diagram

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C) reactions of halogens with sodium hydroxide, NaOH solution

Hypothesis:

Variable:

Procedure:

I Chlorine with sodium hydroxide, NaOH solution

1. Pass chlorine gas, Cl_2 into 2 cm^3 of sodium hydroxide, NaOH solution in a test tube.
2. Close the test tube with a stopper and shake the solution formed.
3. Observe any changes in colour. Reocrd your observation in a table.

Diagram

1	
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II Bromine with sodium hydroxide, NaOH solution

1. Add teo drops of liquid bromine, Br_2 to 2 cm^3 of sodium hydroxide, NaOH solution in a test tube.
2. Close the test tube with a stopper and shake the solution formed.
3. Observe any changes in colour.
4. Reocrd your observation in a table.

Diagram

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III Iodine with sodium hydroxide, NaOH solution

1. Add a small piece of iodine, I_2 to 2 cm^3 of sodium hydroxide, NaOH solution in a test tube.
2. Close the test tube with a stopper and shake the solution formed.
3. Observe any changes in colour.
4. Reocrd your observation in a table.

Diagram

1	
2	
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4	

Data and observation:

Halogen / Reactant	Observation		
	Chlorine	**Bromine**	**Iodine**
Water			
Iron wool			
Sodium hydroxide, NaOH solution			

Interpreting data:

1. What inference can you make based on the observation for each Section A, B and C regarding the chemical properties of chlorine, bromine and iodine? Explain your answer.

Answer:

Discussion:

1. In Section A,
    a) state the properties exhibited by each halogen when they react with water.
    b) Name the products formed when chlorine, bromine and iodine react with water.
    c) Write the chemical equations of chlorine, bromine and iodine with water.
2. What is the function of soda lime in Section B?
3. Why must the iron wool be heated first before the halogens are passed over it in Section B?
4. a) Name the products for the reactions between chlorine, bromine and iodine with iron.
   b) Write the chemical equations for the reaction in 4(a)
5. a) Name the products when chlorine, bromine and iodine react with sodium hydroxide NaOH solution.
   b) Write the chemical equations for the reactions in 5(a).
6. Describe the changes in reactivity of Group 17 elements when going down the group. Explain your answer.

Answer:

11. **Elements in a Period (Period 3)**

- Element across a period in the Periodic Table exhibit a periodic change in properties.

Element of Period 3	Na	Mg	Al	Si	P	S	Cl	Ar
Proton number	11	12	13	14	15	16	17	18
Electron arrangement	2.8.1	2.8.2	2.8.3	2.8.4	2.8.5	2.8.6	2.8.7	2.8.8
Atomic radius (pm)	186	160	143	118	110	104	100	94
Physical state at room temperature	Solid	Solid	Solid	Solid	Solid	Solid	Gas	Gas
Electronegativity	0.9	1.2	1.5	1.8	2.1	2.5	3.0	-

Across Period 3

- The proton number increases by one unit from one element to the next element.
- All the atoms of the elements have three shells occupied with electrons
- The number of valence electrons in each atom increases from 1 to 8.
- All the elements exist as solid except chlorine and argon which are gases.
- The atomic radius of elements decrease. This is due to the increasing nuclei attraction on the valence electrons.
- The electronegativity of elements increase. This is also due to the increasing nuclei attraction on the valence electrons and the decrease in atomic size.
- Electronegativity of an elements refers to the measurement if the strength of an atom in its molecule to attract electrons towards its nucleus.

Uses of semi-metals in Industry

- Silicon and germanium are used as semiconductors.
- Semiconductors are used to make diodes and transistors. They are widely used in the making of microchips for the manufacture of computers, mobile phones, televisions, video recorders, calculators, radio and other microelectronic equipment.

12. **Transition Elements**

- Transition elements are elements from Group 3 to Group 12 in the Periodic Table.
- All the transition elements are metals, which are usually solids with shiny surfaces.
- They are ductile, malleable and have high tensile strength.
- They also have high melting and boiling points as well as high densities.
- They are good conductors of heat and electricity.
- Transition elements show different oxidation number in their compounds.
- Example: $Fe + Cl_2 \rightarrow FeCl_2$ / $2Fe + 3Cl_2 \rightarrow 2FeCl_3$.
- Transition elements form colored ions or compounds.
- Example: $FeCl_2$ crystal is green; $FeCl_3$ crystal is brown.
- Transition elements and their compounds are useful catalyst.
- Example: NH_3 : Haber process, Pt: Ostwald process, Ni: Halogenation, V_2O_5: Contact process