CHAPTER 4

The Periodic Table of Elements

Keywords

- Periodic Table of Elements
- Groups
- Periods
- Noble gases
- Alkali metals
- Halogens
- Metalloids
- Transition elements

What will you learn?

4.1 The Development of the Periodic Table of Elements
4.2 The Arrangement in the Periodic Table of Elements
4.3 Elements in Group 18
4.4 Elements in Group 1
4.5 Elements in Group 17
4.6 Elements in Period 3
4.7 Transition Elements

Bulletin

Is the chlorine content in the swimming pool harmful to the health of users? The answer is no. You need not worry because water treated with chlorine only kills bacteria or dangerous organisms. Users of the swimming pool do not get infected with contagious diseases. In fact, you need not worry about the effects of accidentally swallowing 100 cm^3 of chlorinated water each day during your swimming activity.

The strong smell in the swimming pool results from the reaction of urea (from sweat) with chlorine. This reaction produces a substance called trichloramine (nitrogen trichloride). This substance may be harmful to health. Therefore, before entering the swimming pool, it is advisable for you to clean yourself first so that the urea due to sweat on the surface of the skin is removed.

Did you know that the characteristics of chlorine element can be obtained by studying the position of chlorine in the Periodic Table of Elements? This is because all the elements in the Periodic Table of Elements are arranged systematically, therefore we are able to know the characteristics of chlorine element.

Who invented the Periodic Table of Elements?

How are elements classified in the Periodic Table of Elements?

What are the special characteristics of transition elements?

4.1 The Development of the Periodic Table of Elements

The **Periodic Table of Elements** classifies known chemical elements in a table according to certain characteristics. Many theories were explained by scientists before the modern Periodic Table of Elements was produced. What were those theories? Do you know the scientists involved in the development of the Periodic Table of Elements?

Learning Standard

At the end of the lesson, pupils are able to:
4.1.1 Describe the historical development of the Periodic Table of Elements
4.1.2 Deduce the basic principle of arrangement of elements in the Periodic Table of Elements

Antoine Lavoisier
(1743 – 1794)

Lavoisier classified elements according to certain groups such as gases, non-metals, metals and metal oxides. However, his classification was less accurate because he also classified light, heat and a few compounds into the groups as elements. Besides, there were several elements that were classified into the same group but showed different chemical properties.

Dobereiner found that the atomic mass of strontium atom, Sr was similar to the average mass of calcium atom, Ca and barium atom, Ba. These elements had the same chemical properties. A similar condition occurred with chlorine, Cl, bromine, Br and iodine, I. The group consisting of these three elements was named **triad**. Dobereiner's classification was limited to several elements only. However, his classification showed the relationship between the chemical properties of elements and atomic mass.

Johann W. Dobereiner
(1780 – 1849)

John Newlands
(1837 – 1898)

Newlands arranged elements according to their increasing atomic masses. He arranged seven elements in a row because he found that the chemical and physical properties of the first element recurred at every eighth element. He named the arrangement as the **Law of Octaves**. The Law of Octaves had only been conformed by the first 17 elements. However, the recurrence in properties of the eighth element showed the presence of periodic pattern in the properties of elements.

Lothar Meyer
(1830 – 1895)

Meyer plotted the graph of atomic volume against atomic mass of elements. He found that the elements at equivalent positions on the curve of the graph had similar chemical properties. For example, referring to the alkali metals such as lithium, sodium, potassium and rubidium that were located at the peaks of the curve. Meyer also proved the recurrence in properties of elements similar to Newlands.

Mendeleev arranged the elements according to their increasing atomic masses. Only elements with similar chemical properties were arranged in the same vertical columns. He had left several empty spaces in his periodic table to be filled by elements, yet to be discovered. He was successful in predicting the properties of undiscovered elements based on the properties of elements located above and below an element in the table.

Dmitri Mendeleev
(1834 – 1907)

Henry Moseley
(1887 – 1915)

Moseley studied the frequencies of X-ray released by various elements and eventually found a relationship between the X-ray spectrum and proton numbers. He proposed that each element ought to have its own proton number. Then, he arranged the elements in the Periodic Table of Elements according to their increasing proton numbers. Moseley also left empty spaces in his periodic table like Mendeleev and successfully predicted four elements, namely technetium, Tc, promethium, Pm, hafnium, Hf and rhenium, Re which were discovered later.

Basic Principle of Arrangement of Elements in the Periodic Table of Elements

Elements in the Periodic Table of Elements are arranged in **ascending order of proton numbers**, ranging from 1 to 118. Elements with similar chemical properties are placed in the same vertical columns.

Several new elements which were discovered such as nihonium, Nh, moscovium, Mc, tennessine, Ts and oganesson, Og were added into Period 7 of the Periodic Table of Elements.

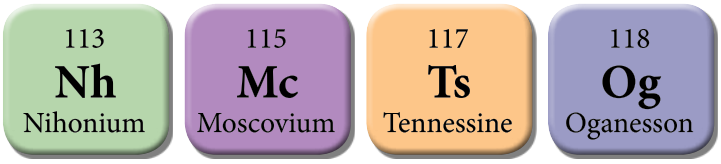


Figure 4.1 *The new elements*

Brain Teaser

From the historical development of the Periodic Table of Elements learned, predict the basic principle in the arrangement of the elements.

HISTORY INTEGRATION

New elements discovered are named after the location or the name of the scientist.

Activity 4.1

Discussing the importance of classifying the elements

21st Century Skills CT

1. Carry out the Think-Pair-Share activity.
2. Scan the QR code on the right on the development of the Periodic Table of Elements and think of the importance of classifying the elements.
3. Discuss with your partner.
4. Share your outcomes in front of the class.

Development of the Periodic Table of Elements

http://bit.ly/35Sgp0A

Test Yourself 4.1

1. Name the scientists that made the following discoveries:
   (a) Classified elements into four groups according to their chemical properties, that is gases, non-metals, metals and metal oxides
   (b) Proposed the Law of Octaves
   (c) Constructed the triad groups consisting of three elements with similar chemical properties
2. In the historical development of the Periodic Table of Elements, Moseley arranged the elements in ascending order of proton numbers. However, before the modern Periodic Table of Elements was used, scientists made their own discoveries. Compare how Dobereiner and Newlands arranged the elements in the Periodic Table of Elements before Moseley.

4.2 The Arrangement in the Periodic Table of Elements

Learning Standard

At the end of the lesson, pupils are able to:
4.2.1 Describe briefly the modern Periodic Table of Elements
4.2.2 Generalise the relationship between the proton number and the position of elements in the Periodic Table of Elements

The modern **Periodic Table of Elements** is a form of systematic classification of elements in ascending order of proton numbers from left to right and from top to bottom. The arrangement of elements is discussed from the aspects of groups, periods, proton number and electron arrangement.

The vertical columns in the Periodic Table of Elements are called **Groups**. There are 18 groups in the Periodic Table of Elements. The number of valence electrons will determine the position of the group of an element. Figure 4.2 shows the position of the group of an element based on the number of valence electrons.

Literacy Tips

You have learned the positions of metals, non-metals and noble gases in the Periodic Table of Elements in Form 1.

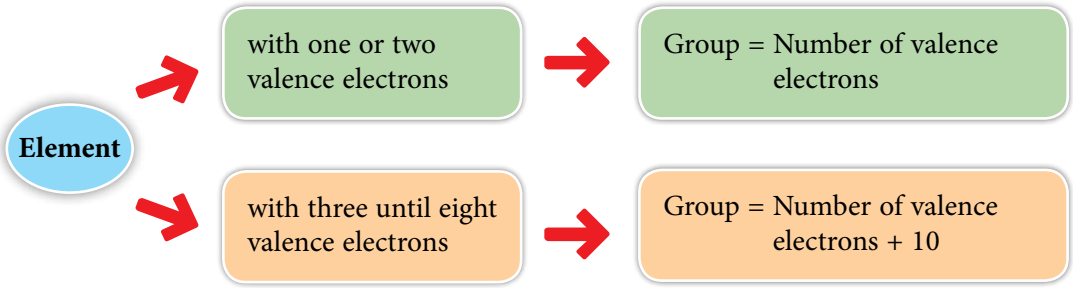


Figure 4.2 *Position of the group of an element*

The horizontal rows in the Periodic Table of Elements are called **Periods**. There are seven periods in the Periodic Table of Elements. The number of shells filled with electrons will determine the position of an element in a period.

Table 4.1 explains the relationship between the proton number and the position of an element in the Periodic Table of Elements based on the aspects of groups and periods.

Table 4.1 *Relationship between the proton number and the position of elements in the Periodic Table of Elements.*

Element	Proton number	Electron arrangement	Valence electron	Group	Number of shells filled with electrons	Period
Lithium, Li	3	2.1	1	1	2	2
Calcium, Ca	20	2.8.8.2	2	2	4	4
Aluminium, Al	13	2.8.3	3	3 + 10 = 13	3	3
Silicon, Si	14	2.8.4	4	4 + 10 = 14	3	3
Nitrogen, N	7	2.5	5	5 + 10 = 15	2	2
Oxygen, O	8	2.6	6	6 + 10 = 16	2	2
Bromine, Br	35	2.8.18.7	7	7 + 10 = 17	4	4
Krypton, Kr	36	2.8.18.8	8	8 + 10 = 18	4	4

Activity 4.2

21st Century Skills CT

Predicting the group and period of an element based on its electron arrangement

1. Carry out the Round Table activity.
2. Choose a representative to speak out the proton number of an element.
3. Group members take turns to note down the electron arrangement, group and period of that element on a piece of paper.
4. Discuss the correct answer.
5. Pin up your outcomes on the class notice board as a reference for other groups.

Test Yourself 4.2

1. Write the symbols for magnesium, copper and fluorine.
2. State the electron arrangement and group, for each of the following elements. Refer the Data Table of Elements on page 276 to get the proton number of each element.
   (a) Potassium, K
   (b) Carbon, C
   (c) Chlorine, Cl
   (d) Argon, Ar
3. Draw the electron arrangements of lithium, Li and carbon, C.

4.3 Elements in Group 18

Learning Standard

At the end of the lesson, pupils are able to:
4.3.1 Relate the inert nature of Group 18 elements to its stability
4.3.2 Generalise the changes in physical properties of elements when going down Group 18
4.3.3 Describe briefly the uses of Group 18 elements in daily life

Group 18 consists of elements of helium, He, neon, Ne, argon, Ar, krypton, Kr, xenon, Xe, radon, Rn and oganesson, Og. Elements in Group 18 are known as noble gases or inert gases. Activity 4.3 shows the relationship between the inert nature and the stability of the electron arrangement in an element.

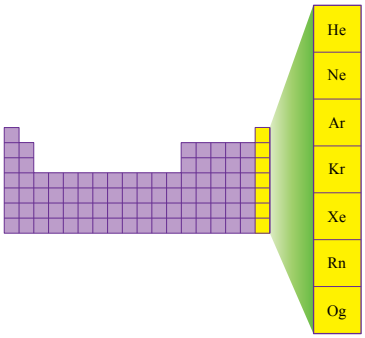


Figure 4.3 Positions of Group 18 elements in the Periodic Table of Elements

More information on inert properties of neon
http://bit.ly/33zc7cm

Activity 4.3

Relating the inert nature with the stability of duplet and octet electron arrangements of Group 18 elements

1. Carry out this activity in groups.

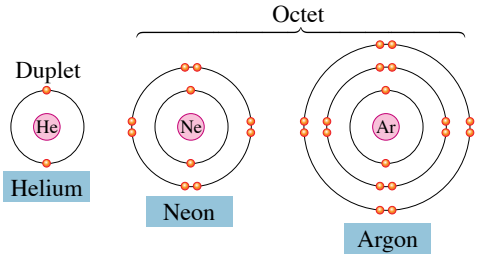


Figure 4.4

2. Based on Figure 4.4, discuss the relationship between the inert nature of Group 18 elements and the stability of electron arrangement in an element.
3. Present your findings in front of the class.

Noble gases are chemically unreactive due to valence shells that are fully filled with electrons. Noble gases have achieved a stable duplet or octet electron arrangement, causing the atoms of noble gases to not donate, accept nor share electrons with the atoms of other elements. The atoms of noble gases exist as monoatoms.

Chemistry Lens

Noble gas is also known as inert gas.

Changes in Physical Properties of Elements When Going Down Group 18

Going down Group 18, the size of atomic radius increases due to the increase in the number of electrons and electron filled shells.

Table 4.2 *Physical properties of Group 18 elements*

Element	Atomic radius (nm)	Melting point (°C)	Boiling point (°C)	Density (g cm^{-3})
Helium, He	0.050	–270	–269	0.00017
Neon, Ne	0.070	–248	–246	0.00080
Argon, Ar	0.094	–189	–186	0.00170
Krypton, Kr	0.109	–156	–152	0.00350
Xenon, Xe	0.130	–122	–108	0.00550
Radon, Rn	–	–71	–62	–

Going down the group, the melting point and boiling point of the elements increase. Increase in the atomic size of elements will increase the attraction force between the atoms. Therefore, the attraction force becomes stronger and more heat energy is required to overcome this force.

Brain Teaser

Try to relate the increase in the density of the elements with the atomic mass and atomic size of each element, when going down the group.

Activity 4.4

21st Century Skills

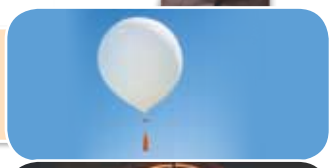
Constructing a model to compare the physical properties and changes in the physical properties of Group 18 elements

1. Carry out the Three Stray One Stay activity.
2. Construct a 2D or 3D model to compare the physical properties of at least two elements in Group 18.
3. Prepare an exhibition corner in class and display the models from each group.
4. Choose a representative to give explanations on the comparison and changes in the physical properties of the selected Group 18 elements. The rest of the members will move around to seek information from other groups on their selected Group 18 elements.

Uses of Group 18 Elements in Daily Life

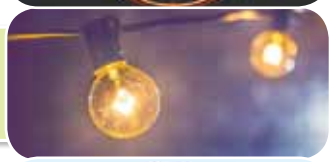
You have identified the list of elements found in Group 18 and studied the changes in the physical properties of the elements as you go down the group. Did you know that Group 18 elements have many uses in our daily life?

Helium
- Used to fill weather balloons
- Used in the oxygen tanks of divers



Neon
- Used in advertising board lights

Argon
- Used to fill in electric bulbs
- Used to provide an inert atmosphere for welding in high temperature



Krypton
- Used in flashlight of cameras
- Used in lasers for eye retina treatment

Xenon
- Used in lighthouse lamps
- Used for anesthesia

Radon
- Used to treat cancer

Figure 4.5 *Uses of Group 18 elements*

Activity 4.5

Summarising the uses of Group 18 elements in daily life

1. Carry out this activity in groups.
2. Watch a video clip on the uses of Group 18 elements in our daily lives by searching the Internet or visiting the link given.
3. Based on the video, discuss with your group members and summarise the uses of Group 18 elements in graphic form.
4. Present your group work in front of the class.

Group 18 elements
http://bit.ly/2Be9EIw

Test Yourself 4.3

1. State the electron arrangement of helium, He.
2. What is the type of electron arrangement of argon atom, Ar?
3. Explain why neon, Ne does not react with other elements.
4. Compare the boiling point of helium and argon. Explain.

4.4 Elements in Group 1

Learning Standard

At the end of the lesson, pupils are able to:

4.4.1 Generalise the changes in physical properties of elements when going down Group 1

4.4.2 Investigate through experiment the chemical properties of Group 1 elements with:
- Water
- Oxygen gas
- Chlorine

4.4.3 Generalise the changes in the reactivity of elements when going down Group 1

4.4.4 Reason out the physical and chemical properties of the other elements in Group 1

Group 1 is made up of lithium, Li, sodium, Na, potassium, K, rubidium, Rb, caesium, Cs and francium, Fr. Group 1 elements are also known as alkali metals.

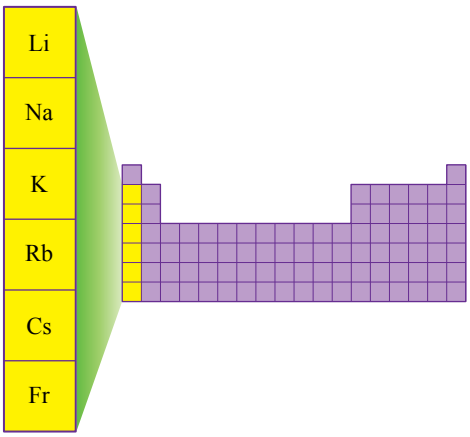


Figure 4.6 *Positions of Group 1 elements in the Periodic Table of Elements*

Photograph 4.1 shows the uses of several Group 1 elements. What other uses of these elements that you know?

Lithium, Li is used in battery production.

Sodium, Na is used in sodium vapour lamps.

Potassium, K is used in fertilisers.

Photograph 4.1 *Uses of Group 1 elements*

Changes in Physical Properties of Elements When Going Down Group 1

Going down Group 1, the atomic radius of elements increases as shown in Table 4.3.

Table 4.3 *Physical properties of several Group 1 elements*

Element	Atomic radius (nm)	Melting point (°C)	Boiling point (°C)
Lithium, Li	0.133	186	1342
Sodium, Na	0.186	98	880
Potassium, K	0.203	64	760

Group 1 elements have low melting point and boiling point if compared to other metals like iron that has a melting point of 1 540 °C and boiling point of 2 760 °C. Why do the melting point and boiling point of elements decrease when going down the group? The increase in the atomic size down the group will weaken the attraction force between the atoms. Therefore, less heat energy is required to overcome the attraction forces between the metal atoms.

Group 1 elements are soft metals, with low density and float on the surface of water. These alkali metals also have a grey shiny surface at room temperature.

Chemical Properties of Group 1 Elements

Group 1 elements have one electron in the valence shell. In a chemical reaction, these atoms donate one electron and form an ion with the +1 charge.

$$M \rightarrow M^+ + e^-$$

What will happen when Group 1 elements react with water, oxygen gas or chlorine gas?

Experiment 4.1

Aim: To study the chemical properties of Group 1 elements.

Problem statement: What are the chemical properties of Group 1 elements, when they react with water, oxygen gas and chlorine gas?

Materials: Lithium, sodium, potassium, distilled water, filter paper, red litmus paper, oxygen and chlorine gas

Apparatus: Forceps, white tile, basin, knife, combustion spoon, gas jar with lid, 10 cm^3 measuring cylinder and Bunsen burner

A Reaction of Group 1 elements with water (Demonstration by the teacher)

Hypothesis: Going down the group, the reactivity of alkali metals with water will increase.

Variables:

(a) Manipulated : Type of alkali metal

(b) Responding : Reactivity of alkali metal with water

(c) Fixed : Size of alkali metal

Safety Precaution

Be careful when putting the alkali metal into the water. Only small quantities should be used.

Procedure:

1. Cut lithium into small pieces using a knife and forceps. Dry a piece of the metal on a filter paper.
2. Put the piece of lithium slowly into a basin filled with water as shown in Figure 4.7.

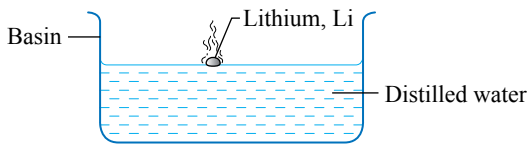


Figure 4.7

3. When the reaction is complete, test the solution with a red litmus paper.
4. Record your observations in Table 4.4.
5. Repeat steps 1 to 4 with sodium and potassium.

B Reaction of Group 1 elements with oxygen gas

Make a hypothesis and state all the variables for part B.

Procedure:

1. Cut lithium into small pieces using a knife and forceps. Dry a piece of the metal on a filter paper.
2. Put the piece of lithium onto a combustion spoon.
3. Heat until it starts to burn and immediately insert the spoon into a gas jar filled with oxygen gas as shown in Figure 4.8.
4. When the reaction is complete, add 10 cm^3 of water into the gas jar and shake.
5. Test the solution using a red litmus paper.
6. Record your observations in Table 4.4.
7. Repeat steps 1 to 6 with sodium and potassium.

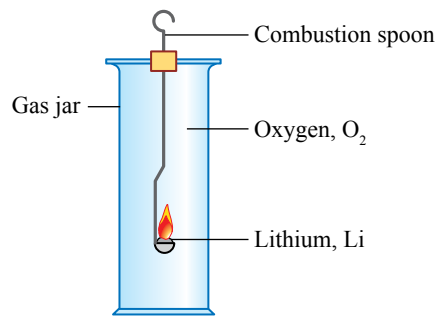


Figure 4.8

C Reaction of Group 1 elements with chlorine gas

Make a hypothesis and state all the variables for part C.

Procedure:

1. Cut lithium into small pieces using a knife and forceps. Dry a piece of the metal on a filter paper.
2. Put the piece of lithium onto a combustion spoon.
3. Heat until it starts to burn and immediately insert the spoon into a gas jar filled with chlorine gas as shown in Figure 4.8.
4. Record your observations in Table 4.4.
5. Repeat steps 1 to 4 with sodium and potassium.

Results:

Table 4.4

Metal	Observation		
	With water	With oxygen gas	With chlorine gas
Lithium			
Sodium			
Potassium			

Conclusion:

Is the hypothesis acceptable? What is the conclusion of this experiment?

Discussion:

1. Write the chemical equation for the reaction of lithium, sodium and potassium with:
   (a) Water
   (b) Oxygen gas
   (c) Chlorine gas
2. Arrange the reactivity of alkali metals lithium, sodium and potassium with water, oxygen gas and chlorine gas in ascending order.

Prepare a complete report after carrying out this experiment.

Reaction of Group 1 Elements with Water, Oxygen Gas and Chlorine Gas

Lithium, sodium and potassium have the same chemical properties but different reactivity.

EduwebTV: Alkali metal
http://bit.ly/31h4LZN

When alkali metals react with water, alkaline hydroxide solution and hydrogen gas is formed. For example, reaction of lithium with water will produce lithium hydroxide and hydrogen gas.

$$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$$

When alkali metals burn in oxygen gas, a white solid that is metal oxide will be formed. For example, reaction of lithium with oxygen gas will produce lithium oxide.

$$4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$$

Solid metal oxide will form an alkaline solution when dissolved in water. For example, reaction of lithium oxide with water will produce lithium hydroxide.

$$Li_2O(s) + H_2O(l) \rightarrow 2LiOH(aq)$$

When alkali metals burn in chlorine gas, a white solid, that is metal chloride will be formed. For example, reaction of sodium with chlorine gas will produce sodium chloride.

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

Changes in Reactivity of Elements Going Down Group 1

Experiment 4.1 shows the reactivity of elements increases when going down Group 1. Why do the changes occur?

The reactivity of alkali metals in Group 1 is due to the tendency of an atom to donate its valence electrons. The number of shells filled with electrons increases when going down Group 1. This causes the increase in atomic size.

The position of valence electrons is placed further away from the nucleus of an atom. When the nuclear attraction force towards the valence electrons weakens, the electrons are more easily donated.

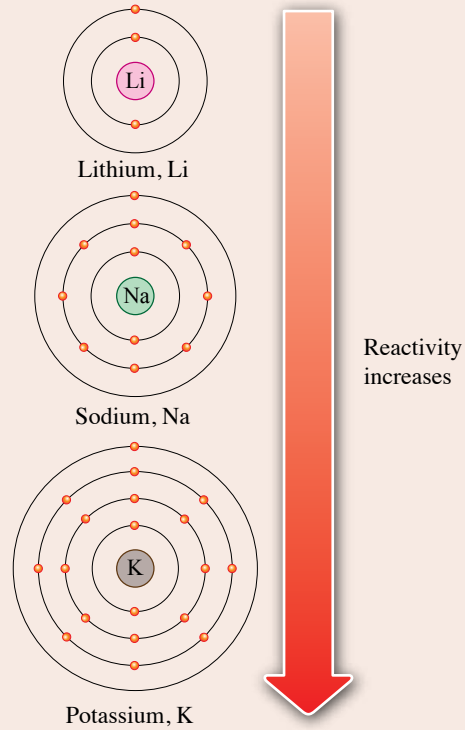


Figure 4.9 *Reactivity of elements increases when going down Group 1*

Physical and Chemical Properties of Other Elements in Group 1

You have studied the properties of lithium, sodium and potassium. How about the properties of other atoms such as rubidium, caesium and francium?

Like other alkali metals, rubidium, caesium and francium elements are soft metals with shiny surfaces and have low melting point and boiling point. Rubidium and caesium are metals that are very reactive and burn easily. Rubidium and caesium are usually combined with other elements. Thus, they are difficult to be isolated chemically. Francium element is an unstable radioactive isotope with a short half-life. All three elements are very reactive with water and oxygen.

Reactions of elements in Group 1 with water

http://bit.ly/2MhYybu

Chemistry & Us

Lithium batteries like those used in smartphones can explode when charged excessively because it accepts current rapidly. So, only original and good quality chargers should be used to charge your devices.

Test Yourself 4.4

1. Give two examples of Group 1 elements.
2. Table 4.5 shows the electron arrangement for elements *X*, *Y* and *Z*.

Table 4.5

Elements	Electron arrangement
X	2.1
Y	2.8.8.1
Z	2.8.18.8.1

(a) Give two differences in physical properties between elements *X*, *Y* and *Z*.

(b) Element *X* reacts with oxygen when heated. Write the chemical equation for this reaction.

(c) Arrange the reactivity of elements *X*, *Y* and *Z* in ascending order. Explain the difference in reactivity.

4.5 Elements in Group 17

Group 17 consists of fluorine, F, chlorine, Cl, bromine, Br, iodine, I, astatine, At and tennessine, Ts. Group 17 elements are known as halogens and exist as diatomic molecules.

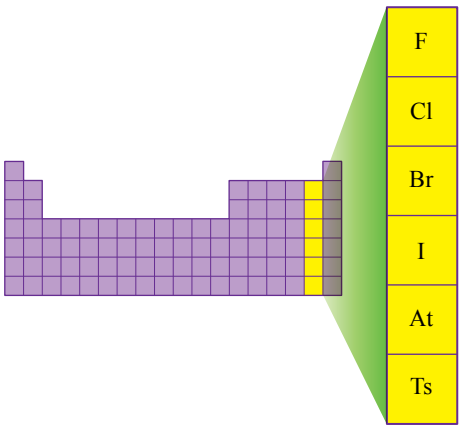


Figure 4.10 *Position of Group 17 elements in the Periodic Table of Elements*

Learning Standard

At the end of the lesson, pupils are able to:

4.5.1 Generalise the changes in the physical properties of elements when going down Group 17

4.5.2 Summarise the chemical properties of Group 17 elements

4.5.3 Generalise the changes in the reactivity of elements when going down Group 17

4.5.4 Reason out the physical and chemical properties of other elements in Group 17

Do you know the uses of Group 17 elements in our daily lives? Photograph 4.2 shows the examples of daily uses for elements chlorine, bromine and iodine.

Chlorine in bleach | Bromine as a substance in fire extinguishers | Iodine as a disinfectant

Photograph 4.2 *Uses of Group 17 elements*

Changes in Physical Properties of Elements When Going Down Group 17

Going down Group 17, the physical state of halogens at room temperature changes from gas to liquid and finally to solid as shown in Table 4.6.

Table 4.6 *Physical properties of several Group 17 elements*

Element	Physical state	Melting point (°C)	Boiling point (°C)	Density (g cm^{-3})
Chlorine, Cl	Gas	–101	–34	0.00300
Bromine, Br	Liquid	–7	59	3.11900
Iodine, I	Solid	114	184	4.95000

Going down the group, the increase in molecular size will cause the attraction force between molecules to become stronger. The melting point and boiling point of halogens will increase because more heat energy is required to overcome the intermolecular forces. The density of elements also increases with the increase in mass when going down the group.

Group 17 elements have different colours. Chlorine gas is greenish yellow, liquid bromine is reddish brown while solid iodine is purplish black.

Chemical Properties of Group 17 Elements

Group 17 elements have seven electrons in the valence shell. In chemical reactions, these atoms receive one electron and form ions with –1 charge.

$$X + e^- \rightarrow X^-$$

What will happen if Group 17 elements react with water, metals or alkalis?

Activity 4.6

Watching the reactions of Group 17 elements

21st Century Skills

1. Carry out the activity in groups.
2. Based on Internet search, watch the video clips on the reactions of Group 17 elements with water, metal and alkali.

Reaction of halogen with water	Reaction of halogen with iron, Fe	Reaction of halogen with sodium hydroxide, NaOH
http://bit.ly/2ILzLdZ	*http://bit.ly/2VJzpcR*	*http://bit.ly/32kGWS4*

3. Based on the videos above, discuss the following questions:
   (a) Write chemical equations for the reactions of chlorine with water, iron and sodium hydroxide.
   (b) Arrange the reactivity of chlorine, bromine and iodine with iron in ascending order.
   (c) Halogens are reactive non-metal elements. Explain.

Reaction of Group 17 Elements with Water, Metal and Alkali

Chlorine, bromine and iodine have the same chemical properties but different reactivity.

When halogens react with water, an acidic solution is formed. For example, the reaction of chlorine with water will produce hydrochloric acid and hypochlorous acid.

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

When halogens react with metal, a metal halide is formed. For example, the reaction of iron with bromine will produce iron(III) bromide.

$$2Fe(s) + 3Br_2(l) \rightarrow 2FeBr_3(s)$$

When halogens react with an alkaline solution, metal halide, metal halate and water will be formed. For example, the reaction of iodine with sodium hydroxide will produce sodium iodide, sodium iodate(I) and water.

$$I_2(s) + 2NaOH(aq) \rightarrow NaI(aq) + NaOI(aq) + H_2O(l)$$

HISTORY INTEGRATION

Antoine Balard discovered hypochlorous acid when he added a dilute suspension of mercury(II) oxide into a flask filled with chlorine gas.

Changes in Reactivity of Elements Down Group 17

Did you know that the reactivity of elements decreases when going down Group 17? Increasing atomic size will cause the valence shell to be further from the nucleus. This will cause the nuclear attraction force towards the electrons to become weaker. Thus, the difficulty in attracting electrons to fill the valence shell will increase.

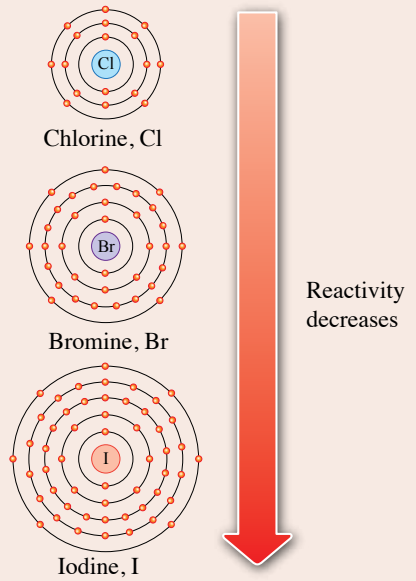


Figure 4.11 *Reactivity of elements decreases when going down Group 17*

Activity 4.7

Watching the safety precautions in handling Group 17 elements

1. Carry out the activity in groups.
2. Watch the video clip on safety precautions on handling Group 17 elements by surfing the Internet.
3. Based on the video, carry out a forum titled 'Safety Precautions in Handling Group 17 Elements'. Discuss the following questions:
   (a) Group 17 elements are dangerous. Explain.
   (b) What are the safety precautions taken when handling halogens like chlorine and bromine in the laboratory?

Example on safety measures in handling halogens

http://bit.ly/33vshDO

CAUTION

Be careful when handling Group 17 elements because they are dangerous.

Physical and Chemical Properties of Other Elements in Group 17

Based on what you have learned, can you predict the physical and chemical properties of fluorine and astatine? Generally, all halogens are soluble in organic solvents and do not conduct heat nor electricity. Fluorine is a light-yellow poisonous gas. This gas which is very reactive and corrosive will cause a strong explosion when combined with hydrogen gas. Astatine is a rare radioactive element because it is not chemically stable.

Test Yourself 4.5

1. State three physical properties of elements down the Group 17.
2. Fluorine is very reactive compared to iodine. The reaction of fluorine with almost all other elements is very vigorous. Why is fluorine more reactive compared to iodine?
3. Give two examples of substances that contain Group 17 elements.
4. Astatine is not used in the science laboratory. Explain.

4.6 Elements in Period 3

Learning Standard

At the end of the lesson, pupils are able to:

4.6.1 Describe the trends in physical properties of elements across Period 3

4.6.2 Conduct an experiment to observe changes in the properties of the oxides of elements across Period 3

4.6.3 Describe briefly the uses of semi-metals

Period 3 consists of elements sodium, Na, magnesium, Mg, aluminium, Al, silicon, Si, phosphorus, P, sulphur, S, chlorine, Cl, and argon, Ar.

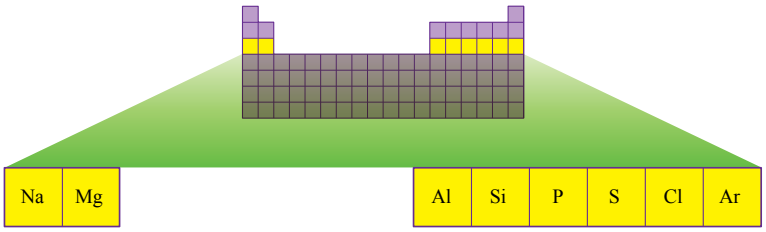


Figure 4.12 *Position of Period 3 elements in the Periodic Table of Elements*

You have learned about the uses of sodium, Na, chlorine, Cl, and argon, Ar. The uses of several other elements in Period 3 are shown in Photograph 4.3.

Photograph 4.3 *Uses of Period 3 elements*

Changes in Physical Properties of Elements Across Period 3

Going across Period 3 from left to right, the atomic size will decrease because the atomic radius decreases.

Table 4.7 *Physical properties of Period 3 elements*

Elements	Sodium, Na	Magnesium, Mg	Aluminium, Al	Silicon, Si	Phosphorus, P	Sulphur, S	Chlorine, Cl	Argon, Ar
Atomic radius (nm)	0.186	0.160	0.143	0.118	0.110	0.104	0.100	0.094
Electronegativity	0.9	1.2	1.5	1.8	2.1	2.5	3.0	–
Physical state	Solid						Gas	

Atomic size decreases

Increase in the number of protons across Period 3 will increase the charge in the atom's nucleus. The electronegativity of elements will increase because the nuclear attraction force towards the electrons increases.

The physical state of Period 3 elements will change from solid to gas from left to right across the period. The same goes to metal elements, semi-metal elements and non-metal elements. Sodium, Na, magnesium, Mg and aluminium, Al are metal elements, silicon, Si is a semi-metal element or metalloid while phosphorus, P, sulphur, S, chlorine, Cl and argon, Ar are non-metal elements.

Changes in Chemical Properties of Oxides of Elements Across Period 3

You have learned the properties of metal elements, semi-metal elements and non-metal elements in Period 3. How about the chemical properties of oxides of elements across Period 3?

Experiment 4.2

Aim: To study the change of chemical properties of oxides of elements across Period 3.

Problem statement: How does the chemical properties of oxides of elements change across Period 3?

Materials: Sodium oxide, Na_2O, magnesium oxide, MgO, aluminium oxide, Al_2O_3 sulphur dioxide gas, SO_2, silicon(IV) oxide, SiO_2, distilled water, 2.0 mol dm^{-3} sodium hydroxide, NaOH and 2.0 mol dm^{-3} nitric acid, HNO_3

Apparatus: Test tube, stopper, test tube holder, 10 cm^3 measuring cylinder, pH meter, Bunsen burner, glass rod and spatula

A Reaction of oxides of Period 3 elements with water

Hypothesis: Across Period 3, oxides of elements will change from basic to acidic.

Variables:

(a) Manipulated : Type of oxide of Period 3 elements
(b) Responding : Change in oxide property
(c) Fixed : Volume of water

Procedure:

1. Pour 10 cm^3 distilled water into a test tube containing half spatula of sodium oxide, Na_2O and shake.
2. Measure the pH value of the solution in the test tube using a pH meter.

3. Record your observations.
4. Repeat steps 1 to 3 using magnesium oxide, MgO, aluminium oxide, Al_2O_3 and sulphur dioxide, SO_2.

Results:

Table 4.8

Oxide	Sodium oxide, Na_2O	Magnesium oxide, MgO	Aluminium oxide, Al_2O_3	Sulphur dioxide, SO_2
With water				
pH value				

B Reaction of oxides of Period 3 elements with sodium hydroxide and nitric acid

Make hypothesis and state all the variables for part B.

Procedure:

1. Fill $\frac{1}{4}$ spatula of magnesium oxide powder, MgO into two different test tubes.
2. Add 5 cm^3 of 2.0 mol dm^{-3} sodium hydroxide solution, NaOH into the first test tube.
3. Add 5 cm^3 of 2.0 mol dm^{-3} nitric acid, HNO_3 into the second test tube.

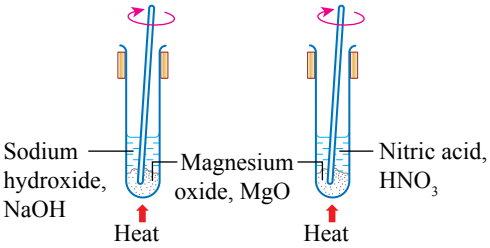


Figure 4.13

4. Heat both test tubes gently and stir using a glass rod as shown in Figure 4.13.
5. Observe the solubility of oxide in both solutions and record your observations.
6. Repeat steps 1 to 5 by using aluminium oxide Al_2O_3 and silicon(IV) oxide, SiO_2.

Results:

Table 4.9

Oxide	Solubility	
	With sodium hydroxide, NaOH	**With nitric acid, HNO_3**
Magnesium oxide, MgO		
Aluminium oxide, Al_2O_3		
Silicon(IV) oxide, SiO_2		

Conclusion:

Is the hypothesis acceptable? What is the conclusion of this experiment?

Discussion:

1. List the basic oxides, amphoteric oxides and acidic oxides.
2. Write the chemical equation for the reaction between basic oxide and nitric acid, HNO_3.
3. Write the chemical equation for the reaction between amphoteric oxide and sodium hydroxide, NaOH.
4. List the elements that have basic oxides and acidic oxides across Period 3.

Prepare a complete report after carrying out this experiment.

Going across Period 3, the properties of oxide change from basic oxide to amphoteric oxide and then to acidic oxide.

Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	Cl_2O_7
Basic oxide		Amphoteric oxide	Acidic oxide			

Figure 4.14 *Properties of oxides of elements across Period 3*

Group 1 and 2 elements form metal oxides that are basic. When dissolved in water, both basic oxides will produce alkaline solutions. Basic oxides also react with acid to form salt and water.

Aluminium forms metal oxide that is amphoteric in property. Aluminium oxide reacts with both acid and alkali to form salt and water.

Elements from Groups 14, 15, 16 and 17 form non-metal oxides that are acidic in property. When dissolved in water, oxides of elements from these groups will produce acidic solutions. Acidic oxides will also react with alkali to form salt and water.

You have learned the change of physical and chemical properties of elements across Period 3. Can you predict the change of properties for elements across Period 2?

Activity 4.8

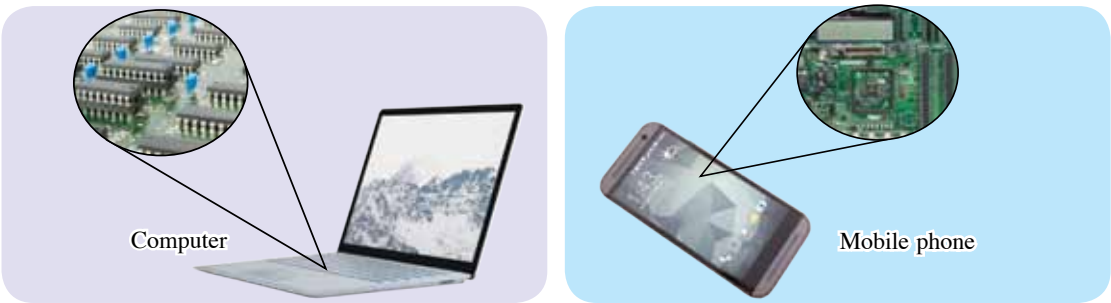
Predicting the change of properties for elements in Period 2

21st Century Skills

1. Carry out the Round Table activity.
2. Based on the change of properties of elements across Period 3, discuss and predict the change of properties for elements across Period 2.
3. Take turns to record the information on a piece of paper.
4. Pin up the outcome of your group discussion on the class bulletin board as a reference to others.

Uses of Semi-Metallic Elements

Semi-metallic elements or metalloid have both the properties of metals and non-metals. These elements are weak conductors of electricity. However, metalloids are good electrical conductors at high temperatures. Based on that property, metalloids like silicon are used as semiconductors in the manufacture of electronic microchips. Photograph 4.4 shows the uses of electronic microchips in the production of computers and mobile phones.



Photograph 4.4 *Electronic microchips used in the making of computers and mobile phones*

Activity 4.9

Discussing the uses of semi-metals in the microelectronic industry

21st Century Skills

1. Carry out the Gallery Walk activity.
2. Collect information from reading materials or suitable websites on the uses of the following semi-metals in the microelectronic industry.

   Silicon, Si

   Germanium, Ge

3. Discuss among your group members and prepare a presentation.
4. Display your group work in the class. Move around in groups to see the work of other groups.
5. Write comments on their work and paste them.

Test Yourself 4.6

1. Why are the elements sodium, Na, magnesium, Mg, aluminium, Al, silicon, Si, phosphorus, P, sulphur, S, chlorine, Cl and argon, Ar in the same period?
2. Silicon exists as a solid at room temperature while non-metals like chlorine exists as a gas. Explain.
3. Figure 4.15 shows several elements in the Periodic Table of Elements.

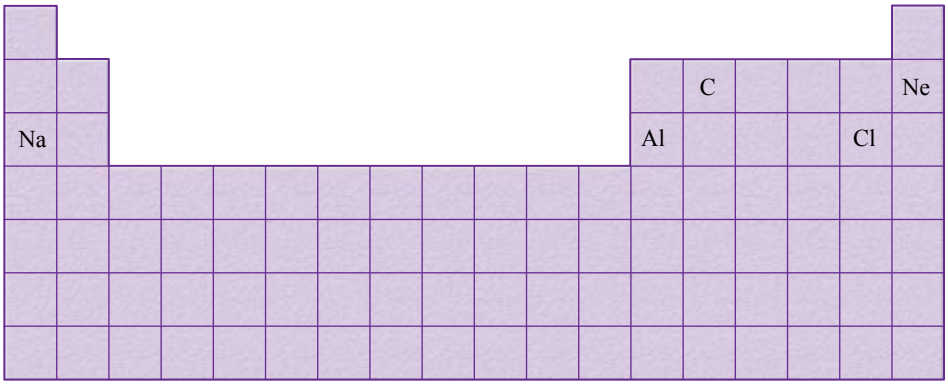


Figure 4.15

(a) When aluminium and chlorine are compared, which element has a smaller atomic size? Explain.

(b) Which element forms an amphoteric oxide?

(c) Arrange all the elements in accending order of atomic size.

4.7 Transition Elements

Learning Standard

At the end of the lesson, pupils are able to:
4.7.1 Determine the position of transition elements in the Periodic Table of Elements
4.7.2 Explain the special characteristics of a few transition elements with examples
4.7.3 List the uses of transition elements in industry

Position of Transition Elements

Transition elements are placed in Group 3 and 12 in the Periodic Table of Elements. Examples of transition elements include chromium, Cr, manganese, Mn, iron, Fe, and copper, Cu. The yellow portion in Figure 4.16 shows the position of transition elements in the Periodic Table of Elements.

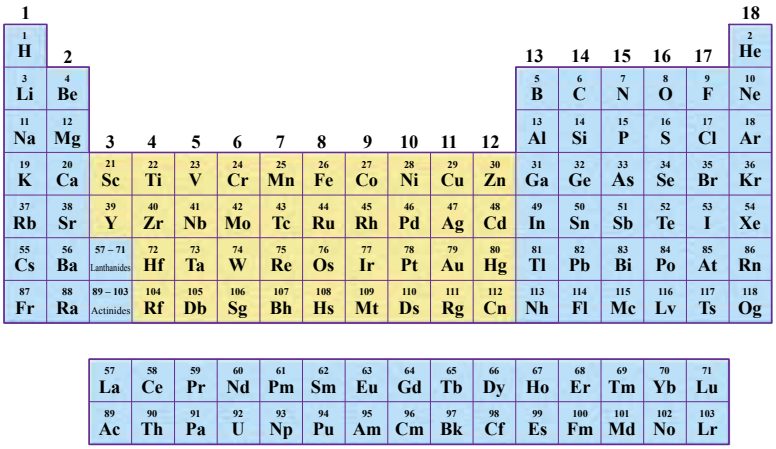


Figure 4.16 *Position of transition elements in the Periodic Table of Elements*

Position of transition elements

http://bit.ly/2B8OlYG

All transition elements are metals with the following properties:

- Solids with shiny surfaces
- Very hard compared to metals in Groups 1 and 2
- Have high densities
- Have high melting points and boiling points

Chemistry Lens

Scandium and zinc are not considered as transition elements because both do not show characteristics of transition elements.

Special Characteristics for Several Transition Elements in the Periodic Table of Elements

Transition elements are metals with high melting point and boiling point, hard, shiny surfaces, malleable and ductile. Transition elements also have special characteristics unknown to other metals. What are the special characteristics possessed by transition elements?

1. Transition elements function as a catalyst to increase the rate of reaction without undergoing chemical change at the end of the reaction. For example, iron filings are used as a catalyst in the Haber Process.

$$N_2(g) + 3H_2(g) \underset{450 - 550\ ^{\circ}C,\ Fe}{\overset{200 - 300\ atm}{\rightleftharpoons}} 2NH_3(g)$$

2 Transition elements form coloured ions or compounds.

Photograph 4.5 *Coloured compounds of transition elements*

Table 4.10

Transition element ions	Colour of solution
Chromium(III) ion, $Cr^{3+}(aq)$ Dichromate(VI) ion, $Cr_2O_7^{2-}(aq)$	Green Orange
Manganese(II) ion, $Mn^{2+}(aq)$ Manganate(VII) ion, $MnO_4^-(aq)$	Pink Purple
Iron(II) ion, $Fe^{2+}(aq)$ Iron(III) ion, $Fe^{3+}(aq)$	Green Brown
Copper(II) ion, $Cu^{2+}(aq)$	Blue

EduwebTV: Transition elements

http://bit.ly/2BcvM5Z

Activity 4.10

Observing the colour of the transition element compounds

1. Observe the colour of the following transition element compounds:
   (a) Chromium(III) chloride, $CrCl_3$
   (b) Potassium dichromate(VI), $K_2Cr_2O_7$
   (c) Manganese(II) chloride, $MnCl_2$
   (d) Manganese(IV) oxide, MnO_2
   (e) Potassium manganate(VII), $KMnO_4$
   (f) Iron(II) sulphate, $FeSO_4$
   (g) Iron(III) chloride, $FeCl_3$
   (h) Copper(I) oxide, Cu_2O
   (i) Copper(II) oxide, CuO
2. Present your findings in the form of a suitable mind map to share with your friends.

3 Transition elements have more than one oxidation number.

Table 4.11

Transition element	Oxidation number	Compound
Chromium, Cr	+3 +6	Chromium(III) chloride, $CrCl_3$ Potassium dichromate(VI), $K_2Cr_2O_7$
Mangan, Mn	+2 +4 +7	Manganese(II) chloride, $MnCl_2$ Manganese(IV) oxide, MnO_2 Potassium manganate(VII), $KMnO_4$
Iron, Fe	+2 +3	Iron(II) sulphate, $FeSO_4$ Iron(III) chloride, $FeCl_3$
Copper, Cu	+1 +2	Copper(I) oxide, Cu_2O Copper(II) oxide, CuO

4 Transition elements can form complex ions.

Table 4.12

Ion of transition element	Formula
Tetraaminecopper(II) ion	$[Cu(NH_3)_4]^{2+}$
Hexacyanoferrate(III) ion	$[Fe(CN)_6]^{3-}$
Hexacyanoferrate(II) ion	$[Fe(CN)_6]^{4-}$
Hexaaquaferrate(II) ion	$[Fe(H_2O)_6]^{2+}$

Activity 4.11

21st Century Skills CT

Conducting the learning activity based on the problems related to the special characteristics of transition elements

1. Carry out the activity in groups.
2. Read and understand the following passage:

   Scientists found a special characteristic of certain transition elements that can 'remember' their form. For example, an alloy called Nitinol is a mixture of nickel and titanium that can return to its original form after the alloy is bent. This alloy is used in making spectacle frames and treating broken bones.

3. Gather information on problems that can be solved using transition elements and their special characteristics.
4. Justify the use of transition elements and relate them to their special characteristics.
5. Prepare a multimedia presentation based on your findings.
6. Present your group work in front of the class.

Uses of Transition Elements in Industry

One of the special characteristics of transition elements is their use as a catalyst in industries. Do you know which transition elements are involved in that function? Figure 4.17 shows the examples of transition elements that function as a catalyst in industries.

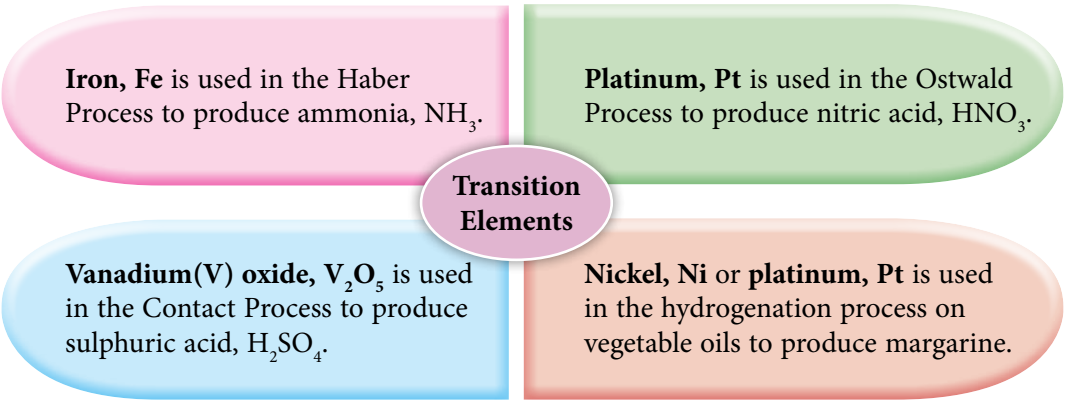


Figure 4.17 Transition elements as catalysts in industries

Apart from catalyst, other uses of transition elements are shown in Photograph 4.6.

Manganese is used to make stained glass windows

Iron is used to build bridges

Titanium is used to make paints

Photograph 4.6 *Uses of transition elements*

Activity 4.12

Making a scrap book/ brochure/ pamphlet/ poster to show the uses of several transition elements in various industries

1. Carry out this activity in groups.
2. Gather information from various reading materials and search relevant websites for the use of several transition elements in various industries.
3. Discuss with your group members and present your findings in a scrap book/ brochure/ pamphlet/ poster.
4. Exhibit the scrap book/ brochure/ pamphlet/ poster in the laboratory or class.

Test Yourself 4.7

1. Table 4.13 shows three transition elements that exist in gems.

Table 4.13

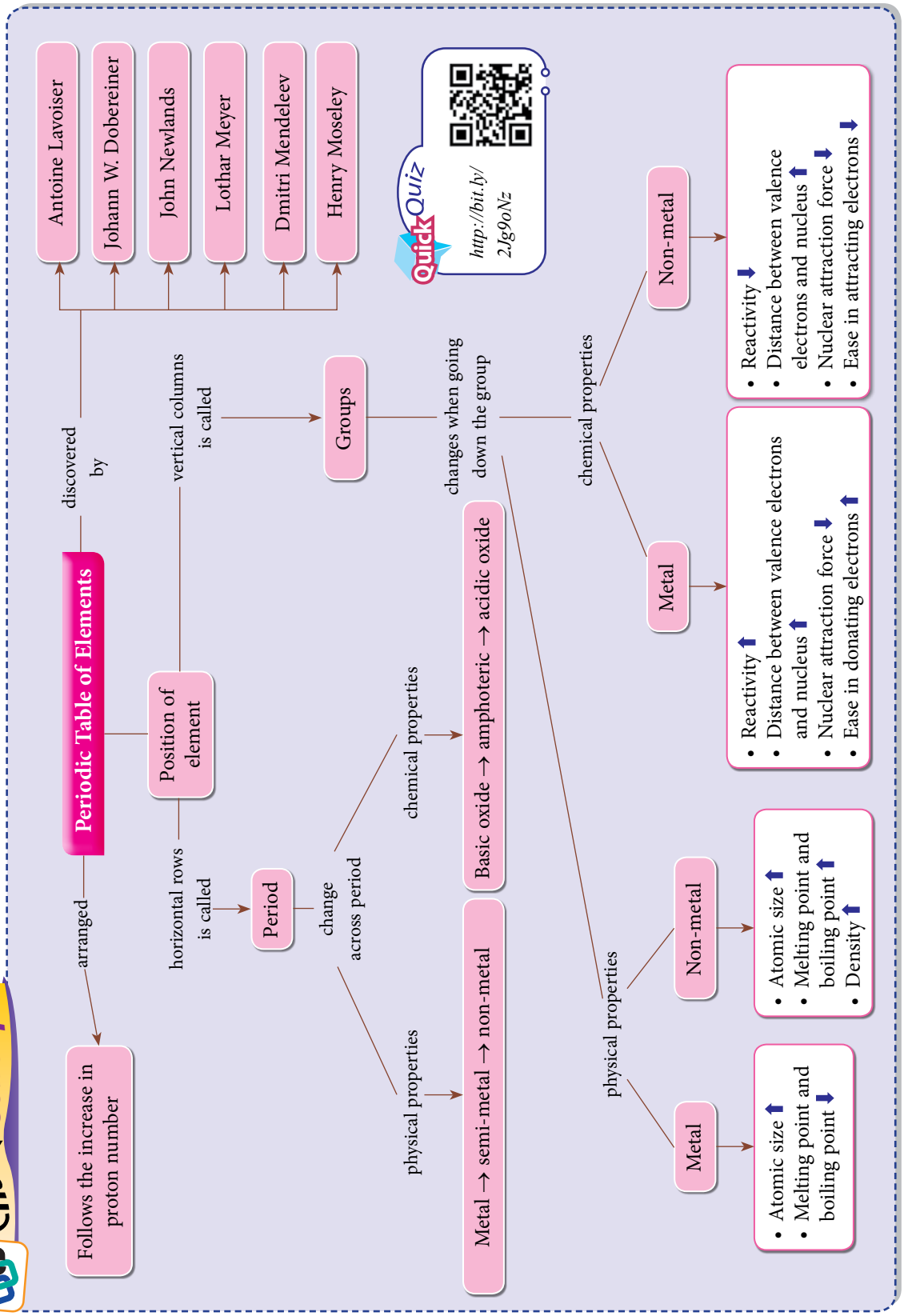
Gem	Transition element
Ruby	Chromium
Sapphire	Iron, titanium
Amethyst	Manganese

(a) What are the special characteristics of the transition elements shown in Table 4.13?

(b) Apart from the characteristics given in 1(a), what are the other characteristics found in transition elements?

2. Give examples of several transition elements used in industry.

Chain Concept



SELF Reflection

1. What new knowledge have you learned in **The Periodic Table of Elements**?
2. Which is the most interesting subtopic in **The Periodic Table of Elements**? Why?
3. Give a few examples of elements in **The Periodic Table of Elements** that you use in your daily life.
4. Rate your performance in **The Periodic Table of Elements** on a scale of 1 to 10; 1 being the lowest and 10 the highest. Why would you rate yourself at that level?
5. What else would you like to know about **The Periodic Table of Elements?**

http://bit.ly/31kIQk8

Achievement Test 4

1. How did Moseley arrange the elements in the Periodic Table of Elements?

2. Figure 1 shows the chemical symbol for element *X*.
   (a) Which group does element *X* belong to in the Periodic Table of Elements?
   (b) Which period does element *X* belong to in the Periodic Table of Elements?

$^{35}_{17}X$

Figure 1

3. A restaurant owner uses colourful electric lights to attract his customers. What is the substance suitable for making such lights?

4. State the physical and chemical properties of the element with electron arrangement 2.8.8.1.

5. State the element in Period 3 that forms an amphoteric oxide.

6. Figure 2 shows several elements in the Periodic Table of Elements that are represented by alphabets *X* and *Y*.

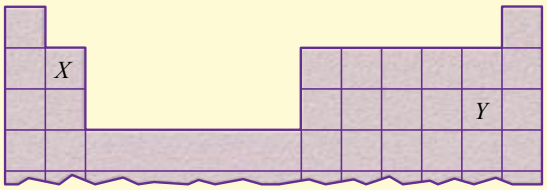


Figure 2

   (a) Write the electron arrangement for atom *X* and atom *Y*.
   (b) Explain two differences in chemical properties between element *X* and element *Y*.
   (c) Why does the reactivity of elements in the same group as *X*, increase when going down the group, but the reactivity of elements in the same group as *Y* decreases?

7. Chlorine, Cl_2 reacts with sodium, Na to form a compound. Write the chemical equation for the reaction.

8. Figure 3 shows the electron arrangement for the element *G*.
   (a) Which group does element *G* belong to in the Periodic Table of Elements?
   (b) Which period does element *G* belong to in the Periodic Table of Elements?
   (c) State a physical property of element *G*.

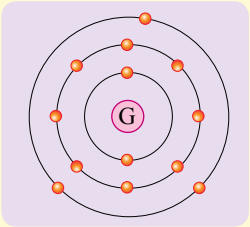


Figure 3

9. Na Mg Al Si P S Cl Ar
   (a) State which element is a metal, metalloid or non-metal from the list of elements given above.
   (b) Explain the change in atomic radius across the Period from left to right.
   (c) Which element is a noble gas?
   (d) Write the chemical equation when a metal reacts with water.

10. Give the colour of the following transition element ions:
   (a) Iron(II) ion
   (b) Iron(III) ion

Enrichment Corner

1. Photograph 1 shows a few microchips. Silicon element is widely used in the manufacture industries of microchips.

Photograph 1 *Microchips*

What is the property of silicon that enables this element to be used in the manufacture of microchips instead of a metal like lithium? Explain.

Check Answers

https://bit.ly/2pHzJ04