7. Atomic Theory, Periodic Classification and Properties of Elements

Exercise Questions

1. Question

Which type of radiation was used in Rutherford's experiment?

A. α

B. β

C. γ

D. X-rays

Answer

The experiment is popularly known as Rutherford's gold foil experiment or Rutherford's alpha ray scattering experiment. A thin gold foil was bombarded using α-particles (positive helium cation). This experiment later led to the discovery of nucleus, and modified the model of an atom.

2. Question

The smallest particle of matter is:

A. Molecule

B. Atom

C. Element

D. Compound

Answer

Atom is considered the smallest indivisible building block of matter in Dalton's Atomic theory. Atoms bond together to form a molecule. An element is formed by atoms of the same kind. A compound is formed by elements combining in a definite proportion. The smallest particle out of the given options is atom.

3. Question

First periodic classification of element was given by:

A. Doberiener

B. Mosley

C. Newland

D. Mendeleev

Answer

Elements were classified for the first time by Johann Wolfgang Döbereiner in 1829. He formed groups of 3 elements called 'Triads' in which the mass of the middle element is approximately equal to the average of masses of the first and the third element. He also stated that the properties of the middle element were intermediate between the other two elements.

4. Question

Modern periodic table is based on which property of the elements:

A. Atomic structure

B. Atomic mass

C. Atomic number

D. valency

Answer

The modern periodic table is introduced by Henry Mosley in 1913. He suggested that the chemical and physical properties of the elements are periodic functions of their atomic number.

5. Question

The number of period and groups in modern periodic table are:

A. 7 & 18

B. 9 & 18

C. 7 & 20

D. 9 & 20

Answer

The modern periodic table consists of 118 elements which are organised into 7 periods and 18 groups.

6. Question

In periodic table, atomic size on moving top to bottom in a group will:

A. decrease

B. remain constant

C. irregularly change

D. increase

Answer

As we go down a group, the atomic number of the element increases. Also, the number of shells increases and the effective nuclear charge decreases. This results in the increase of atomic radius down the group.

7. Question

Vander Waals radius is _____ in comparison to covalent radius:

A. Smaller

B. Larger

C. Same

D. None of above

Answer

Covalent radius (r_c) is the half of the distance between the two nuclei of the atoms bonded by the covalent bond. (see figure below)

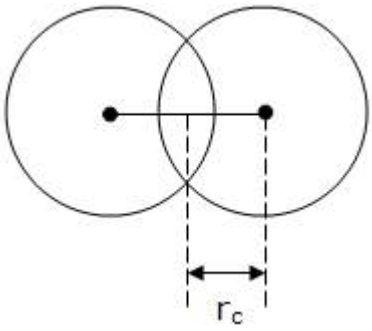


Figure 1: Covalent radius

In the solid state, the half of the distance measured between two non-bonding atoms of a homonuclear diatomic molecule is called van der Waals radius (r_v).

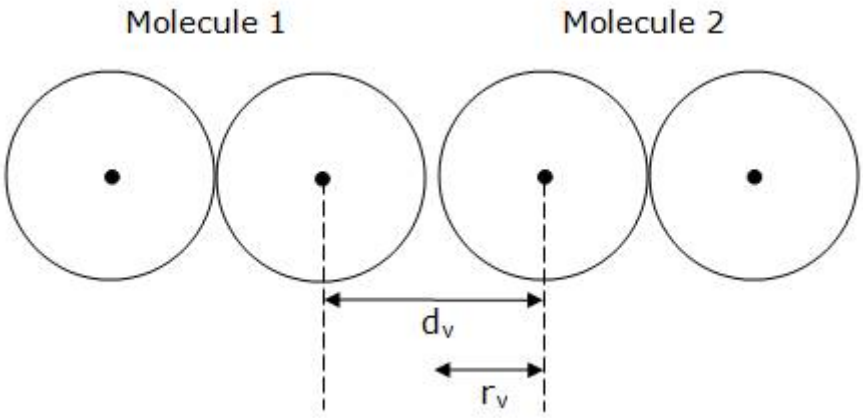


Figure 2: Van der Waals radius

Clearly, van der Waals radius is larger than the covalent radius.

8. Question

The number of elements in a small group is:

A. 2

B. 8

C. 18

D. 32

Answer

This small group is a shell. An electron shell contains a fixed number of electrons. Example,

First shell can contain 2 electrons, second shell can contain 8 electrons and so on.

9. Question

Energy given to remove an electron from a neutral atom is called:

A. Electron gain enthalpy

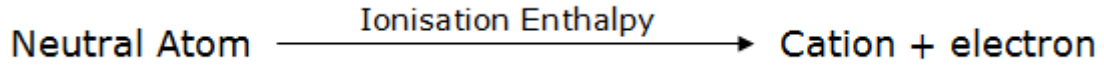
B. Electronegativity

C. Ionisation enthalpy

D. Excitation energy

Answer

Ionisation enthalpy can be defined as the energy required to remove the most loosely bounded electron from a neutral atom in its ground state. It can be expressed by the following expression.



10. Question

Element which has most electronegativity is:

A. H

B. Na

C. Ca

D. F

Answer

Electronegativity is the relative tendency of an element to attract the covalently shared electrons towards it. Fluorine has 7 electrons in its valence shell, and needs one more electron to attain noble gas configuration (Octet rule). Also, fluorine has a small atomic radius and a large effective nuclear charge, and therefore has the maximum electronegativity.

11. Question

Which group elements have the most metallic character?

A. 1

B. 2

C. 5

D. 6

Answer

Elements with lower ionisation enthalpy are said to have more electropositive character (metallic character). Metallic character is defined by the tendency of losing electron(s), to form cations.

Group 1 elements (Alkali metals) have one electron in their valence shell. To attain noble gas configuration, they readily lose the one valence electron. Therefore, they have the lowest ionisation enthalpy and hence the highest electropositive character.

Other metals have multiple electrons in valence shell, and removal of the valence electrons in those cases is energetically not favourable (ie, it requires high energy to remove electrons from such atoms).

As you might know, the metallic character increases down a group, and decreases across a period.

12. Question

State the names of Thomson's atomic model.

Answer

Thomson's atomic model is known as "Plum Pudding Model". This model assumes atom to be a positively charged sphere where the negatively charged electrons are embedded in it. Electrons are similar to the plums present in the pudding. The total positive charge present in the atom is equal to the total negative charge, making atom electrically neutral.

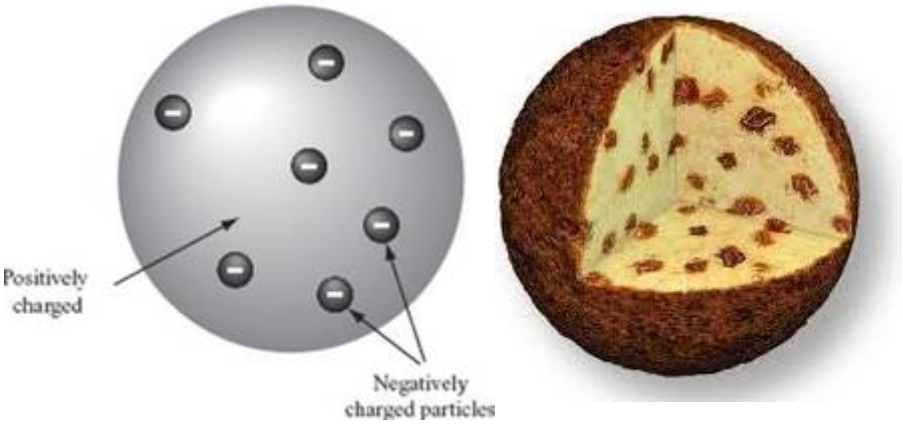


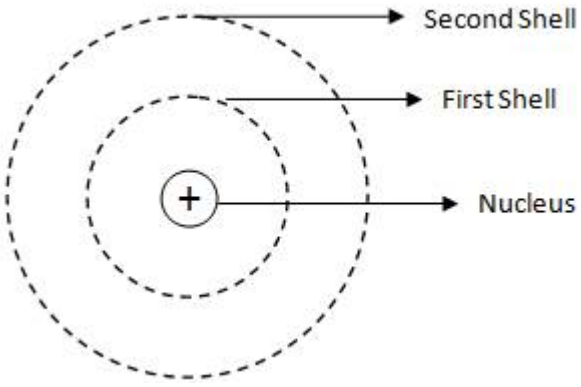
Figure 3: Plum Pudding Model and the real plum pudding

13. Question

What is called Bohr's orbits?

Answer

Bohr's orbits are hypothetical circular paths in which electrons revolve around the nucleus. These paths have definite energy and definite radius and are sometimes called shells or stationary energy levels. The revolution of electrons around nucleus is similar to the revolution of planets around the sun in the solar system. Electrons do not lose or gain energy when it revolves in an orbit.



Note that, not all circular paths around nucleus are possible. The electrons can only revolve in circular orbits in which the angular momentum of the electron is an integral multiple of $h/2\pi$.

14. Question

What is modern periodic law?

Answer

Modern periodic law was defined by Henry Mosley who introduced the modern periodic table. Modern periodic law says that "The chemical and physical properties of the elements are periodic function of their atomic number." In other words, similar properties of the elements repeat periodically when arranged in increasing order of atomic number.

15. Question

Write Mendeleev's periodic law.

Answer

Mendeleev's periodic law says that "The chemical and physical properties of the elements are periodic function of their atomic masses."

16. Question

Based on which property Mendeleev classified elements in periodic table?

Answer

Mendeleev classified the elements in periodic table in the increasing order of atomic masses. Therefore Mendeleev's periodic table is based on the property atomic mass.

17. Question

What name is given to elements of group 18?

Answer

Group 18 elements are called Noble gases or Group zero elements. They are very stable on their own and their outer shell is completely filled.

18. Question

What is the another name of d-block and f-block elements?

Answer

The d-block elements are known as transition elements, and the f-block elements are known as inner transition elements.

19. Question

State the position of metals, non-metals and metalloids in modern periodic table.

Answer

In the modern periodic table, metals are present in the left hand side of the periodic table. As you move towards the right, there is a transition from metals to semimetals (or metalloids). Metalloids are found in the p-block. The right hand side of the periodic table contains non-metals.

Elements of groups 1 and 2 possess high metallic character. Elements of groups 3-12 exhibit a gradual change in the metallic character. Elements like Boron, Silicon, Arsenic, etc form metalloids. Moving further towards the right, non-metals (Oxygen, Fluorine, Chlorine etc) are found.

20. Question

Explain the periodicity of electron gain enthalpy in a group.

Answer

Electron gain enthalpy is the total enthalpy released when an electron is added to the outermost shell of an isolated gaseous atom.

As one goes down a group, the atomic size increases, which means the distance between the nucleus and the outermost electron also increases. At the same time, there is no significant change in the effective nuclear charge down the group. Hence, the ability of nucleus to hold the new incoming electron effectively, also decreases.

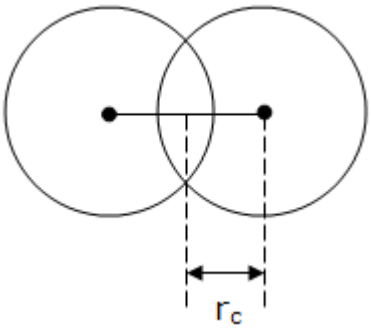
As a result, the value of electron gain enthalpy generally decreases down the group.

21. Question

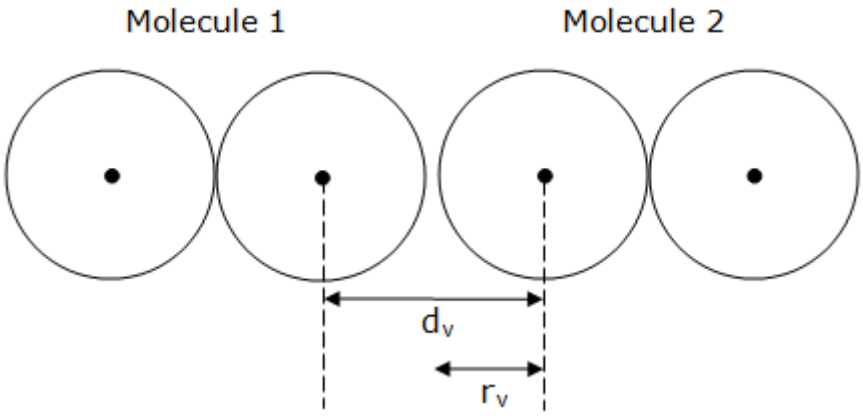
What do you mean by Vander Waal's radii and covalent radii?

Answer

Covalent radius (denoted by r_c) is defined as half of the distance between the two nuclei of the atoms bonded by the covalent bond.



Van der Waal's radius (denoted by r_v) is defined for atoms present in solid state. It is equal to half the distance measured between two non-bonding atoms of a homonuclear diatomic molecule.



Notice that the distance measured is between atoms of molecules which are not bonded to each other (see figure above).

22. Question

Cation is smaller than neutral atom and anion is larger than neutral atom. Why?

Answer

Suppose there are 'N' number of electrons present in a neutral atom. The N electrons are held together by the nucleus.

Cation is the ion obtained by the removal of electron from a neutral atom. When an electron is removed, then there exists N-1 electrons. As a result there will be an increase in effective nuclear charge over the remaining electrons, and hence the size of cation is smaller than the size of neutral atom.

Anion is the ion obtained by adding an electron to the neutral atom. When the electron is added, then there will be N+1 electrons. Here, the effective nuclear charge is decreased over the electrons. Therefore, the size of anion is larger than that of the neutral atom.

23. Question

What is meant by effective nuclear charge? How it changes along a period and a group?

Answer

Effective nuclear charge (Z_{eff}) can be defined as the net positive charge which is experienced by the electrons in the outermost (valence) shell.

Along a period, the effective nuclear charge increases from left to right (from metals to non-metals). Moving from top to bottom of a group, the effective nuclear charge of the element decreases.

24. Question

What periodicity is observed is about valency when we move left to right along a period?

Answer

Valency is the combining capacity of an element. When we move from left to right along a period, we can see that the valency increases by 1 to 4 and then decreases. If the elements react with oxygen, then the valency changes from 1 to 7. When it comes to the f block elements, they exhibit variable valency.

25. Question

Write Dalton's atomic theory.

Answer

Dalton's atomic theory was introduced in 1808. The main postulates are:

1. Each substance is made of very small particles called atoms.

2. Atoms are indivisible particles. In other words, atoms are the fundamental building blocks of matter.

3. The atoms of same element are same in mass, size and chemical properties.

4. The atoms of different elements differ in mass, size and chemical properties.

5. Atoms of different elements combine with each other in definite proportions to form compounds. This is also called Law of definite proportions.

6. In chemical reactions, atoms can reshuffle to form new molecules, but they cannot be created or destroyed in a reaction.

26. Question

Enumerate the properties and drawbacks of Mendeleev's periodic table.

Answer

Mendeleev was the first person to organize the discovered elements in a systematic way.

Properties:

1. He arranged the elements in the increasing order of atomic mass. He observed that when doing so, the properties of elements repeated in regular intervals. Based on this, he made the Periodic Law: "The chemical and physical properties of the elements are periodic function of their atomic masses."

2. The elements are arranged in horizontal rows called periods and vertical columns called groups. Each group contained 2 subgroups A and B. Each period was subdivided into series.

3. He left some gaps in periodic table, predicting the existence of certain elements like Gallium, Germanium and he also predicted their properties,

which turned out to be true.

4. When noble gases were discovered, Mendeleev was able to put them in a new group, without affecting the existing periodic table.

Drawbacks:

1. Elements were not strictly arranged in the increasing order of atomic mass.

2. Certain elements with different properties were under the same group, and certain elements with same properties were under different groups.

3. Hydrogen did not have a fixed position in the periodic table.

4. The isotopes of the elements were given the same place in the table even though they had different atomic masses.

27. Question

Which type of periodicity is exhibited by periodic table following properties of element:

(i) Atomic radii

(ii) Ionisation enthalpy

(iii) Electronegativity

Answer

(i) As we go down a group, the number of shells increases and hence the atomic radii increases. Along a period, the number of shells remain the same, but the effective nuclear charge increases from left to right. This means that there is an increased force of attraction between nucleus and the electrons causing the atomic radii to decrease along a period.

(ii) Ionisation enthalpy is the energy required to remove an electron from an isolated gaseous atom. Ionisation enthalpy decreases down the group because the increased atomic radii down the group cause a decrease in the effective nuclear charge. There will be less force of attraction between nucleus and outermost electron, from which electron can be removed by supplying a small amount of energy.

When going from left to right, the atomic radii decreases and the effective nuclear charge increases. The electron removal process would be more difficult, and it requires more amount of energy. Hence ionization enthalpy increases from left to right in a period.

(iii) Electronegativity is the relative tendency of an element to attract the bonded shared electrons towards it.

Going from top to bottom in a group, the atomic radii increases and the effective nuclear charge decreases. Due to this reason, the elements would

give up the electrons more easily. Thus electronegativity decreases down the group.

Going from left to right, there is an increase in effective nuclear charge and decrease in atomic radii. The increased force of attraction of nucleus would attract the shared electrons to itself. Thus electronegativity increases from left to right in a period.

28. Question

Explain the classification of element by modern periodic table.

Answer

Modern periodic table is introduced by Henry Mosley in 1913. It is a modified version of Mendeleev's Periodic Table. In this classification of elements, he arranged the elements in the increasing order of atomic number, based on the modern periodic law: The chemical and physical properties of the elements are periodic function of their atomic number.

Modern periodic table represents the electronic configuration of the elements. Elements are arranged in vertical columns called groups. and horizontal rows called periods. Elements under the same group have similar properties, whereas period represents the main energy level or shell. There are 7 periods and 18 groups in the new periodic table.

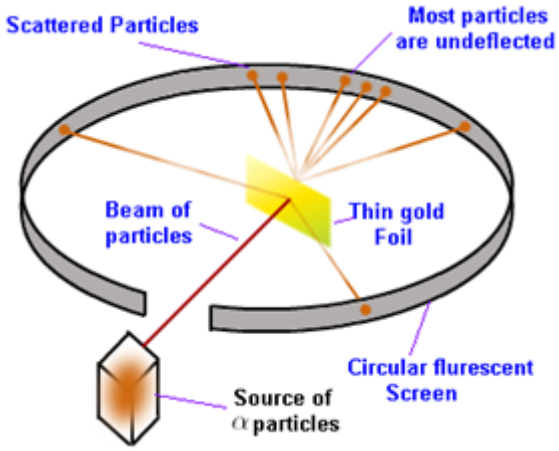
Based on the electronic configuration, the elements are divided into 4 blocks: s, p, d, and f block. The metals are arranged in the left hand side, and the non metals in the right hand side. There is a transition from metals to non-metals if one moves along a period.

29. Question

Explain Rutherford's gold foil experiment. Also mention observation and drawn conclusion from this experiment.

Answer

Rutherford's gold foil experiment led to the discovery of nucleus. The experiment setup can be illustrated as:



α (alpha) particles (helium nucleus cation) of very high energy were bombarded on gold foils of thickness of 100 nm. A circular screen surrounded the thin gold foil, and is coated with a fluorescent material from inside (ZnS). The beam of energetic alpha particles hit the thin gold foil and the scattered beams hit the screen producing a flash on it. This would help in knowing the path of the scattered alpha rays.

Observations:

● Most of the alpha rays passed through the gold foil without any deflection.

● A few alpha particles (say 1 out of 2000) deviated from the original path creating a small angle with the original path.

● A very few alpha particles (say 1 in 20,000 particles) bounced back and returned to its own path. This means that the scattering angle is roughly 180°.

Based on the above observations, Rutherford concluded that,

● Most part of the atom is hollow and chargeless as there were no deflections of alpha rays in most of the cases.

● There exists a region at the centre of the atom where the positive charge is concentrated. The alpha rays which approached near to it were scattered at small angles. The rays which directly hit this region bounced back and retraced the path. This region was later named as nucleus.

● The volume of positive charge region in atom is very less than that of the atom.

This experiment discarded Thomson's atomic model and made way to Rutherford's atomic model.