An atom is the smallest unit of an element that can exist. Every atom is made up of protons, neutrons, and electrons. These particles define a nuclide and its chemical properties and were discovered in the early 20th century and are described by modern atomic theory.

**Nuclide**

Nuclides are specific types of atoms or nuclei. Every nuclide has a chemical element symbol (E) as well as an atomic number (Z), the number of protons in the nucleus, and a mass number (A), the total number of protons and neutrons in the nucleus. The symbol for the element is as shown below:

\[^{A}_{Z}E\]

An example is neon, which has the element symbol Ne, atomic number 10 and mass number 20.

\[^{20}_{10}Ne\]

A nuclide has a measurable amount of energy and lasts for a measurable amount of time. Stable nuclides can exist in the same state indefinitely, but unstable nuclides are radioactive and decay over time. Some unstable nuclides occur in nature, but others are synthesized artificially through nuclear reactions. They emit energy (\(\alpha\), \(\beta\), or \(\gamma\) emissions) until they reach stability.

**Atomic Number**

Every element has a defining atomic number, with the symbol "Z". If an atom is neutrally charged, it has the same number of protons and electrons. If it is charged, there may be more protons than electrons or vice versa, but the atomic number remains the same. In the element symbol, the charge goes on the right side of the element. For instance, O\(^{2-}\) is an oxygen anion. O\(^{2-}\) still has an atomic number of 8, corresponding to the 8 protons, but it has 10 electrons. Every element has a different atomic number, ranging from 1 to over 100. On the periodic table, the elements are arranged in the order of atomic number across a period. The atomic number is usually located above the element symbol. For example, hydrogen has one proton and one electron, so it has an atomic number of 1. Copper has the atomic number of 29 for its 29 protons.

<table>
<thead>
<tr>
<th>Atomic Number</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element's Symbol</td>
<td>B</td>
<td>C</td>
<td>N</td>
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</tbody>
</table>
Atomic Number and Chemical Properties

The atomic number defines an element's chemical properties. The number of electrons in an atom determines bonding and other chemical properties. In a neutral atom, the atomic number, Z, is also the number of electrons. These electrons are found in a cloud surrounding the nucleus, located by probability in electron shells or orbitals. The shell farthest from the nucleus is the valence shell. The electrons in this valence shell are involved in chemical bonding and show the behavior of the atom. The bonding electrons influence the molecular geometry and structure of the atom. They interact with each other and with other atoms in chemical reactions. The atomic number is unique to each atom and defines its characteristics of bonding or behavior or reactivity. Therefore, every atom, with a different atomic number, acts in a different manner.

Mass Number

The mass of an atom is mostly localized to the nucleus. Because an electron has negligible mass relative to that of a proton or a neutron, the mass number is calculated by the sum of the number of protons and neutrons. Each proton and neutron's mass is approximately one atomic mass unit (AMU). The two added together results in the mass number:

\[A=p^+ + n\]

Elements can also have isotopes with the same atomic number, but different numbers of neutrons. There may be a few more or a few less neutrons, and so the mass is increased or decreased. On the periodic table, the mass number is usually located below the element symbol. The mass number listed is the average mass of all of the element's isotopes. Each isotope has a certain percentage abundance found in nature, and these are added and averaged to obtain the average mass number.

For example, \(^{4}\text{He}\) has a mass number of 4. Its atomic number is 2, which is not always included in the notation because He is defined by the atomic number 2.

References

3. IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A.
Problems

1. How many protons, neutrons, and electrons do chlorine atoms have?
2. The mass of gold (Au) is 197, how many neutrons does it have?
3. Carbon has several isotopes. $^{14}$C has how many protons, electrons, and neutrons?
4. What is the atomic number of Li$^+$? How many protons and electrons does Li$^+$ have?
5. What does the mass number on the periodic table represent?

Answers

1. Because chlorine has an atomic number of 17, chlorine has 17 protons, 18, neutrons, and 17 electrons
2. 118 neutrons
3. 6 protons, 8 neutrons, and 6 electrons
4. Z=3, 3 protons, 2 electrons
5. The mass number represents the average mass of all of the isotopes of that particular element.