

Isotopes

All atoms can be recognized by the number of protons and neutrons they contain in their nuclei. *The number of protons in the nucleus is known as **atomic number (Z)**.* In an atom (atom is a neutral entity), the number of protons equal to number electrons, so the atomic number also means the number of electrons existing outside the nucleus:

$$\begin{aligned}\text{Atomic number (Z)} &= \text{number of protons} \\ &= \text{number of electrons}\end{aligned}$$

Remember, this is true only for an atom because atom is neutral. For example, the atomic number of sodium is 11. This means that sodium atom contains 11 protons inside the nucleus and 11 electrons outside the nucleus.

In addition to atomic number, there is also another quantity known as **mass number (A)**, *which is the sum of protons and neutrons present in the nucleus of an atom:*

$$\begin{aligned}\text{Mass number (A)} &= \text{number of protons} + \text{number of neutrons} \\ &= \text{atomic number} + \text{number of neutrons} \\ &= Z + \text{number of neutrons}\end{aligned}$$

Now we can calculate the number of neutrons using the mass number and atomic number.

Therefore,

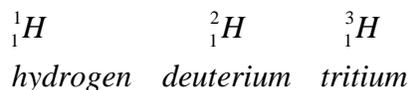
$$\begin{aligned}\text{Number of neutrons} &= (\text{number of protons} + \text{number of neutrons}) \\ &\quad - \text{number of protons} \\ &= A - Z\end{aligned}$$

In almost all the cases, the atoms of the same element are not alike as predicted by the Dalton's atomic theory, but they have different masses. Thus, *atoms that have the same atomic number but different mass numbers are labeled as **isotopes**.* Isotopes can also be defined as *two or more atoms with the same atomic number but with different mass numbers.* The commonly accepted symbol for isotope is



where X is the symbol for an element, and A and Z defined above. Take a look at the following example.

The hydrogen has three isotopes, which are,



They all contain one proton (=1, lower number), and have 0, 1, and 2 neutrons respectively. These isotopes are given different names to identify them; hydrogen contains no neutron, deuterium contains one neutron and tritium contains two neutrons.

Uranium is an important radioactive element that has two common isotopes with mass number 235 and 238 respectively:



The first isotope contains 143 (= 235 – 92) neutrons and the second 146 (=238 -92). The first isotope is used in atomic bombs and nuclear reactors. On the other hand, the second isotope does not have the properties necessary for these applications.

There is another way to identify the isotopes of elements. Only the mass number is used instead of both Z and A. The above two isotopes are identified by uranium-235 and uranium-238 instead of the above symbols. This is because the atomic number is the same as long as it is the same element. In this case it is 92. **If we know the atomic symbol, we know its atomic number, and vice versa.**

Chemical properties of elements are primarily determined by the electrons but not by the neutrons. Therefore, the isotopes of the same element have similar chemical behavior.

Example

Give the number of protons, electrons, and neutrons in each of the following isotopes:



Answer

- (a) The atomic number is 17, so there are 17 protons and 17 electrons. The mass number is 35, so there are 18 (=35-17) neutrons.
- (b) The atomic number is 8, so there are 8 protons and 8 electrons. The mass number 17, so there are 9 (=17-8) neutrons.
- (c) The atomic number is 11, so there are 11 protons and 11 electrons. The mass number 24, so there are 13 (=24-11) neutrons.
- (d) The atomic number is 7, so there are 7 protons and 7 electrons. The mass number 14, so there are 7 (=14-7) neutrons.
- (e) The atomic number is 19, so there are 19 protons and 19 electrons. The mass number 39, so there are 20 (=39-19) neutrons.
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