

## Elements, Atoms and Ions Notes

### • The History of Atomic Theory

Circa. 400-5 BC. Greek philosopher Democritus proposes the idea of matter being made up of small, indivisible particles (*atomos*).

Late 18<sup>th</sup> Century. Lavoisier proposes the Law of conservation of mass and Proust proposes the Law of constant composition.

Early 19<sup>th</sup> Century. Using the previously unconnected ideas above, John Dalton formulates his Atomic Theory.

### • Dalton's Atomic Theory states the following.

1. Elements are made from tiny particles called atoms.
2. All atoms of a given element are identical. (See Isotopes below).
3. The atoms of a given element are different to those of any other element.
4. Atoms of different elements combine to form compounds. A given compound always has the same relative numbers and types of atoms. (Law of constant composition).

• Atoms cannot be created or destroyed in a chemical reaction they are simply rearranged to form new compounds. (Law of conservation of mass).

### • Structure of the Atom and The Periodic Table

A number of experiments were being carried out in the 19<sup>th</sup> and 20<sup>th</sup> centuries that began to identify the sub-atomic particles, which make up the atom. A summary of those experiments is given below.

Scientist	Experiment	Knowledge gained	Relating to
Crookes	Cathode Ray Tube	Negative particles of some kind exist	Electron
J. J. Thompson	Cathode Ray Deflection	Mass/charge ratio of the electron determined	Electron
Millikan	Oil Drop Experiment	Charge on the electron	Electron
Rutherford, Marsden and Geiger	Gold Foil Experiment	Nucleus present in atom	The nucleus of an atom and the proton

In the first part of the 20<sup>th</sup> Century, following **Chadwick's discovery of the neutron**, **Bohr proposed the idea that the atom was made up of the nucleus containing protons and neutrons that was being orbited by electrons in specific, allowed orbits.** This particle model of the electron and atom was expanded a few years after Bohr's original ideas to incorporate the wave nature of the electrons.

PARTICLE	CHARGE	MASS	POSITION in atom
PROTON	+1	1u	Nucleus
NEUTRON	0	1u	Nucleus
ELECTRON	-1	$\frac{1}{1836}u$ (i.e. very small)	Outside

*Note:* (u) denotes atomic mass units (amu). When comparing the masses of protons and neutrons, neutrons are slightly more massive; protons having a mass of 1.007276 amu's and neutrons, 1.008665 amu's.

The atomic numbers (in the table below printed above the symbol and sometimes referred to as Z) and mass numbers (in the table below printed below the symbol and sometimes referred to as A) that appear on the periodic table have specific meanings.

Atomic number = the number of protons in the nucleus of one atom of the element (**Z**)

Since all atoms are neutral it also tells us the number of electrons surrounding the nucleus. (Note: When atoms lose or gain electrons they become charged and form ions).

Mass number = the number of protons + the number of neutrons in one atom of the element (**A**)

## Isotopes

Atoms with the same number of protons and electrons, but different numbers of neutrons are called **isotopes**. This leads to the modification of Dalton's Atomic Theory point 2, to read: All Atoms of the same element contain the same number of protons and electrons but may have different numbers of neutrons. In other words all atoms of an element are NOT identical as they may contain a different number of neutrons.

Since it is the electrons in atoms that affect the chemical properties of a substance isotopes of the same element have the same chemical properties.

Atoms that have the same number of protons but differ in number of neutrons are isotopes. Any atom that has a difference in electrons and protons is an ion (it is charged). Remember that electrons are *negative* so if an atom has **more** electrons than protons, it will be negatively charged. If it has less electrons than protons, it will be positively charged. The most important aspect of this information is to see that the number of electrons tells us the charge (+ or - or neutral), the number of neutrons identifies the isotope and the number of protons identifies the element.

Generic Isotopic Symbol:



**A = Mass Number    Z = Atomic Number    X = Atomic Symbol**

**Mass Number = # protons + # neutrons**

**Atomic Number = # protons = the identity of the element**

**Atomic Symbol = chemical symbol of the element**

**Example #1:** An specific atom of nitrogen was found to have 7 protons (if it didn't, it wouldn't be nitrogen), 9 neutrons and 7 electrons. This information tells us that this is an isotope and the mass number which is the sum of the protons and the neutrons is  $7 + 9 = 16$ . In that the number of protons equals the number of electrons then this is a neutral atom and not an

ion. The isotopic symbol therefore would be:  ${}_{7}^{16}\text{N}$

**Example #2:** An atom was found to have 16 protons, 19 neutrons and 16 electrons. Write the isotopic symbol: 16 protons means that the atom has the atomic number of 16 which is the element sulfur. The mass number (A) is equal to the #protons + #neutrons =  $16 + 19 = 35$ . The number of protons equal the number of electrons so this is a neutral

atom, not an ion. The isotopic symbol therefore is:  ${}_{16}^{35}\text{S}$

How can you find the number of neutrons in an isotope? Remember that the mass number (A) is the sum of the protons plus neutrons in an isotope but the atomic number (Z) is only the number of protons. So, if you subtract the Z number (at the bottom) from the A number (at the top) you can determine the number of neutrons.

**Example#3:** Given the following isotopic symbol, determine the number of neutrons:  ${}_{17}^{37}\text{Cl}$      $\frac{37 = \text{protons} + \text{neutrons}}{-17 = \text{protons}} = 20$  neutrons  
This isotope has 17 protons, has no charge so it has 17 electrons and  $37 - 17 = 20$  neutrons.

**Example#4:** Write the isotopic symbol for an atom with 15 protons, 19 neutrons and 18 electrons.  ${}_{15}^{34}\text{P}^{3-}$

Note that this is a charged ion because it has 3 more electrons (negatively charged) than protons. The mass number is the sum of the protons plus the neutrons ( $15 + 19 = 34$ ) and since it has 15 protons then the identity of the element is known by the atomic number 15 which is phosphorus.

### Task

1. Which of the following four statements describe isotopes? (There may be more than one correct answer).

- i) Atoms of an element having different numbers of electrons
- ii) Atoms of an element having different numbers of neutrons
- iii)  ${}_{19}^{40}\text{K}$  and  ${}_{18}^{40}\text{Ar}$
- iv)  ${}_{38}^{90}\text{Sr}$  and  ${}_{38}^{92}\text{Sr}$

2. Determine the number of protons, electrons and neutrons in,

