ATOMIC THEORY

The smallest component of an element that uniquely defines the identity of that element is called an atom . Individual atoms are extremely small. It would take about fifty million atoms in a row to make a line that is 1 cm long. The period at the end of a printed sentence has several million atoms in it.

The concept that atoms play a fundamental role in chemistry is formalized by the modern atomic theory , first proposed by John Dalton, an English scientist, in 1803. It consists of three parts:

1. All matter is made up of atoms. Atoms cannot be divided, created or destroyed
2. All atoms of the same element are identical. Different elements have different types of atoms
3. Chemical reactions occur when atoms are rearranged. Compounds are formed from atoms of the constituent elements.

These concepts form the basis of chemistry.

Although the word **atom** comes from a Greek word that means indivisible, we understand now that atoms themselves are composed of smaller parts called **subatomic particles** . The first part to be discovered was the electron , a tiny subatomic particle with a negative charge. It is often represented as e^-, with the right superscript showing the negative charge. Later, two larger particles were discovered. The proton is a larger (but still tiny) subatomic particle with a positive charge, represented as p^+. The neutron is a subatomic particle with about the same mass as a proton but no charge. It is represented as either n or n^0. We now know that all atoms of all elements are composed of electrons, protons, and (with one exception) neutrons. Table 3.1 summarizes the properties of these three subatomic particles.

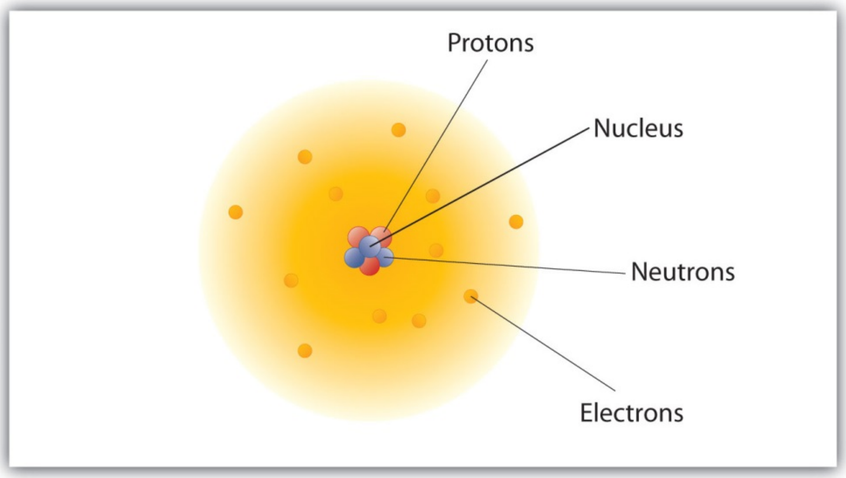
Table 3.1. Properties of the Three Subatomic Particles

Name	Symbol	Mass (approx.; kg)	Charge

Name	Symbol	Mass (approx.; kg)	Charge
Proton	p^+	1.6×10^{-27}	1+
Neutron	n, n^0	1.6×10^{-27}	none
Electron	e^-	9.1×10^{-31}	1-

Later in 1910, experiments by Ernest Rutherford in England pointed to a nuclear model of the atom. The relatively massive protons and neutrons are collected in the center of the atom, in a very small region called the nucleus of the atom (plural **nuclei**). The electrons are rotating in shells orbiting the nucleus. (See Figure 3.1. The Structure of the Atom .)

Figure 3.1. The Structure of the Atom



Atoms have protons and neutrons in the center, making the nucleus positively charged, while the negatively charged electrons orbit the nucleus.

The modern atomic theory states that atoms of one element are the same, while atoms of different elements are different. What makes atoms of different elements different? The fundamental characteristic that all atoms of the same element share is the **number of protons** . All atoms of hydrogen have one and only one proton in the nucleus; all atoms of iron have 26 protons in the nucleus. This number of protons is so important to the identity of an atom that it is called the atomic number of the element. Thus, hydrogen has an atomic number of 1, while iron has an atomic number of 26. Each element has its own characteristic atomic number.

However, atoms of the same element can have different numbers of neutrons. Atoms of the same element (i.e., atoms with the same number of protons) with different numbers of neutrons are called isotopes . Most naturally occurring elements exist as isotopes. For example, most hydrogen atoms have a single proton in their nucleus. However, a small number (about one in a million) of hydrogen atoms have a proton and a neutron in their nuclei. This particular isotope of hydrogen is called deuterium. A very rare form of hydrogen has one proton and two neutrons in the nucleus; this isotope of hydrogen is called tritium. The sum of the number of protons and neutrons in the nucleus is called the mass number of the isotope.

In a neutral atom the number of electrons equals the number of protons, so the overall charge of an atom is zero.

When referring to an atom, we simply use the element's name: the term **sodium** refers to the element as well as an atom of sodium. But it can be unwieldy to use the name of elements all the time. Instead, chemistry defines a symbol for each element. The atomic symbol is a one- or two-letter abbreviation of the name of the element. By convention, the first letter of an element's symbol is always capitalized, while the second letter (if present) is lowercase. Thus, the symbol for hydrogen is H, the symbol for sodium is Na, and the symbol for nickel is Ni. Most symbols come from the English name of the element, although some symbols come from an element's Latin name. (The symbol for Sodium, Na, comes from its Latin name, **Natrium** .) Table 3.2.lists some common elements and their symbols. You should memorize the symbols in Table 3.2. Names and Symbols of Common Elements , as this is how we will be representing elements throughout chemistry.

Table 3.2. Names and Symbols of Common Elements

Element Name	Symbol		Element Name	Symbol
Aluminum	Al		Mercury	Hg
Argon	Ar		Molybdenum	Mo
Arsenic	As		Neon	Ne
Barium	Ba		Nickel	Ni
Beryllium	Be		Nitrogen	N
Bismuth	Bi		Oxygen	O
Boron	B		Palladium	Pd
Bromine	Br		Phosphorus	P
Calcium	Ca		Platinum	Pt
Carbon	C		Potassium	K
Chlorine	Cl		Radium	Ra
Chromium	Cr		Radon	Rn
Cobalt	Co		Rubidium	Rb
Copper	Cu		Scandium	Sc
Fluorine	F		Selenium	Se
Gallium	Ga		Silicon	Si

Element Name	Symbol		Element Name	Symbol
Germanium	Ge		Silver	Ag
Gold	Au		Sodium	Na
Helium	He		Strontium	Sr
Hydrogen	H		Sulfur	S
Iodine	I		Tantalum	Ta
Iridium	Ir		Tin	Sn
Iron	Fe		Titanium	Ti
Krypton	Kr		Tungsten	W
Lead	Pb		Uranium	U
Lithium	Li		Xenon	Xe
Magnesium	Mg		Zinc	Zn
Manganese	Mn		Zirconium	Zr

The elements are grouped together in a special chart called the Periodic Table . A simple Periodic Table is shown in Figure 3.2 , while a more extensive one is presented in Chapter 17, *Appendix: Periodic Table of the Elements* . The elements on the periodic table are listed in order of ascending atomic number. The periodic table has a special shape that will become important to us when we consider the organization of electrons in atoms (see

Figure 3.2. A Simple Periodic Table

1 H 1.00794																1 H 1.00794	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.581538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6534	29 Cu 63.545	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.504	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 196.56655	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.94.79	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.56655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.58038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		118 (293)

58 Ce 140.116	59 Pr 140.50765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967
90 Th 232.0381	91 Pa 231.035888	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

There is an easy way to represent isotopes using the atomic symbols. We use the construction

where X is the symbol of the element, **A** is the mass number, and **Z** is the atomic number. Thus, for the isotope of carbon that has 6 protons and 6 neutrons, the symbol is

where C is the symbol for the element, 6 represents the atomic number, and 12 represents the mass number.

It is also common to state the mass number after the name of an element to indicate a particular isotope. **Carbon-12** represents an isotope of carbon with 6 protons and 6 neutrons, while **uranium-238** is an isotope of uranium that has 146 neutrons.

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