01
CHEMICAL FOUNDATIONS

A. ELEMENTS, ATOMS, & MOLECULES

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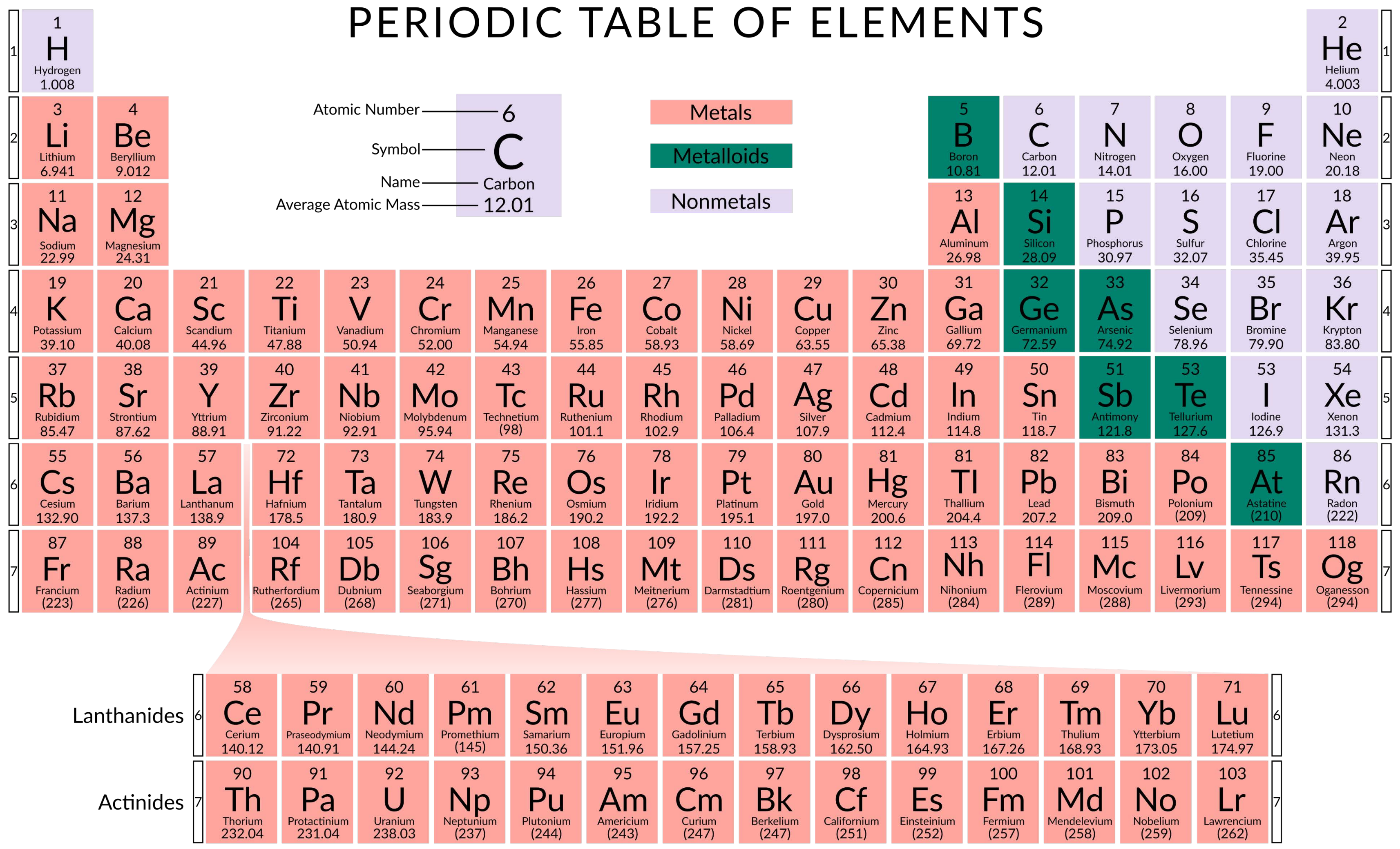
ELEMENTS

Objective: *Understand what elements are*
Know the seven diatomic molecules

All of the matter in the universe can be broken down into a little over one hundred different simpler substances. These fundamental substances are called elements, which cannot be chemically broken down further, and are organized into the periodic table of elements we know today.



Often, the term "element" is used in several different contexts. Perhaps most common is using the term to distinguish between different types of atoms. For instance, water (H_2O) is composed of the two elements: hydrogen (H) and oxygen (O).

More specifically though, we could use the term "elements" to refer to atomic elements, which are single atoms of a particular element. For example, the element argon (Ar) exists as single atoms of Ar.

Or, we could be referring to molecular elements, which are *molecules* (two or more atoms together) comprised of the same element. For example, the elements oxygen and hydrogen typically exist as a diatomic molecules, O_2 and H_2.

There are *seven* elements that exist as diatomic molecules:

H_2, O_2, N_2, Cl_2, Br_2, I_2, and F_2

PERIODIC TABLE OF ELEMENTS

Atomic Number — 6
Symbol — C
Name — Carbon
Average Atomic Mass — 12.01

Metals
Metalloids
Nonmetals

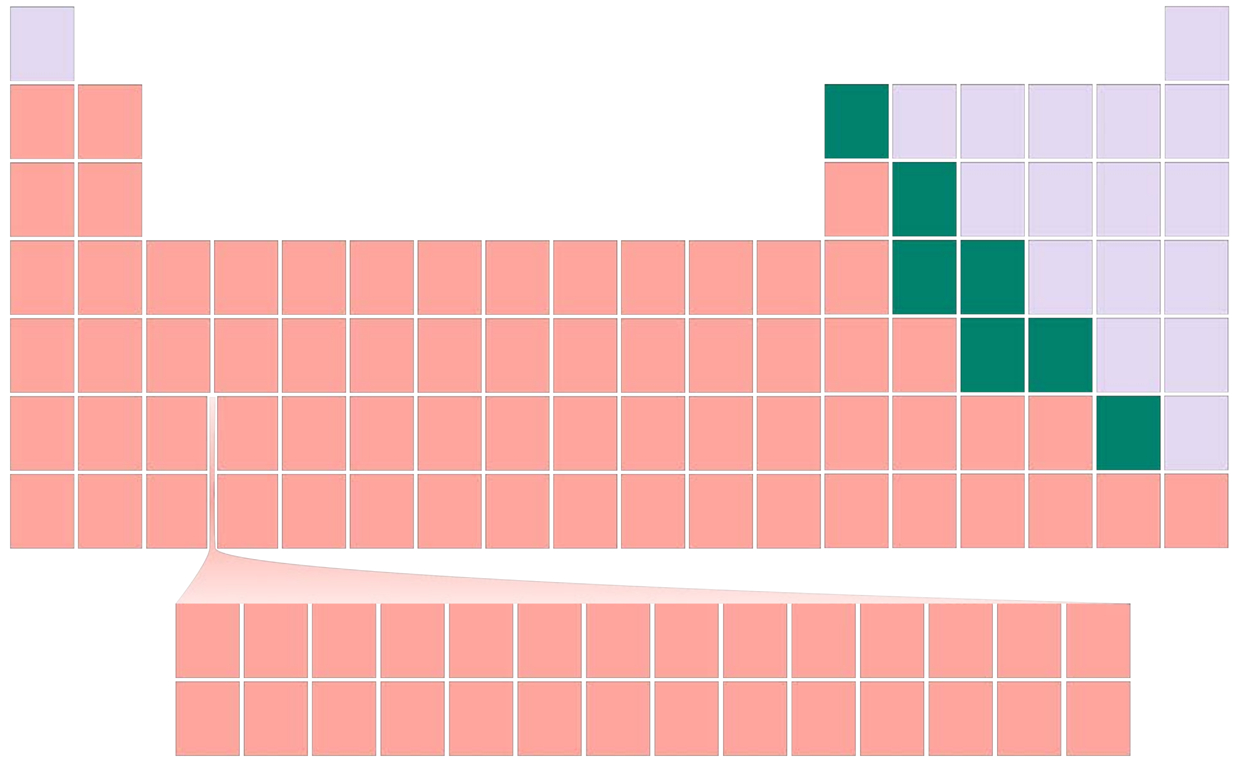
1	1 H Hydrogen 1.008																	2 He Helium 4.003	1
2	3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18	2
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95	3
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.59	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80	4
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	53 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3	5
6	55 Cs Cesium 132.90	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	78 Ir Iridium 192.2	79 Pt Platinum 195.1	80 Au Gold 197.0	81 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)	6
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (265)	105 Db Dubnium (268)	106 Sg Seaborgium (271)	107 Bh Bohrium (270)	108 Hs Hassium (277)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)	113 Nh Nihonium (284)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)	7

Lanthanides	6	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.05	71 Lu Lutetium 174.97	6
Actinides	7	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)	7

THE PERIODIC TABLE OF ELEMENTS

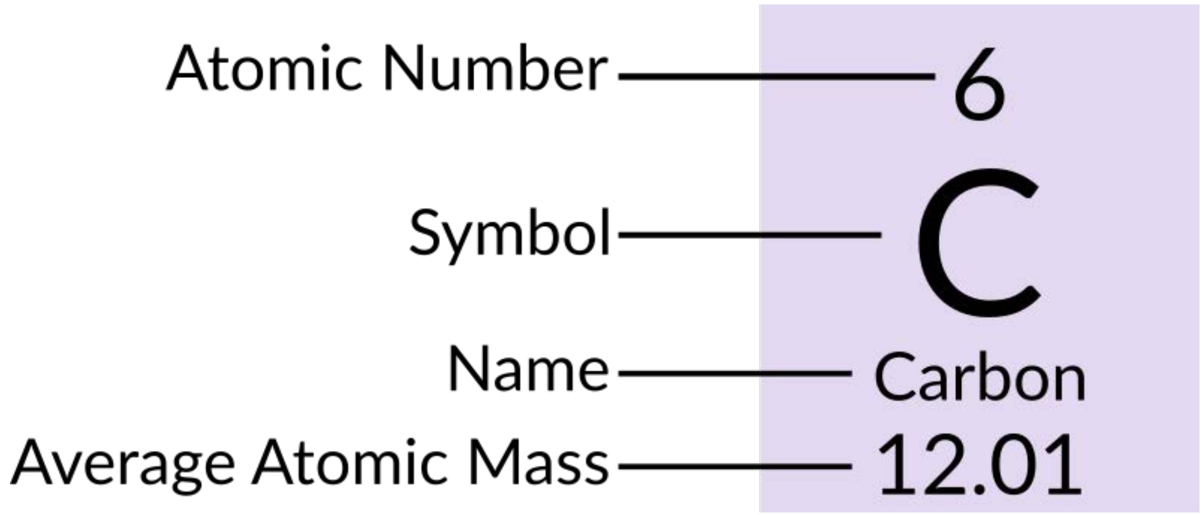
Objective: *Be able to read and interpret data on the periodic table*

As the name suggests, there are actually patterns or periodic trends that arise within specific sets of elements on the periodic table—these will be discussed later.



From a cursory glance, there are *three* main classes of elements: metals (shown in pink on the left), nonmetals (shown in lavender on the right), and metalloids or semimetals (shown in green between metals and nonmetals).

There is a lot of information given on the periodic table. As an example, let us consider the element carbon.



Most apparent is the name and symbol for the element: carbon has the symbol C. Next, the atomic number (Z) tells us how many protons are in the nucleus—the periodic table is actually ordered by *increasing* atomic number. The atomic number also tells us the number of electrons in a *neutral* atom of that element. So, a neutral C atom has 6 protons and 6 electrons. Finally, the average atomic mass is also given.

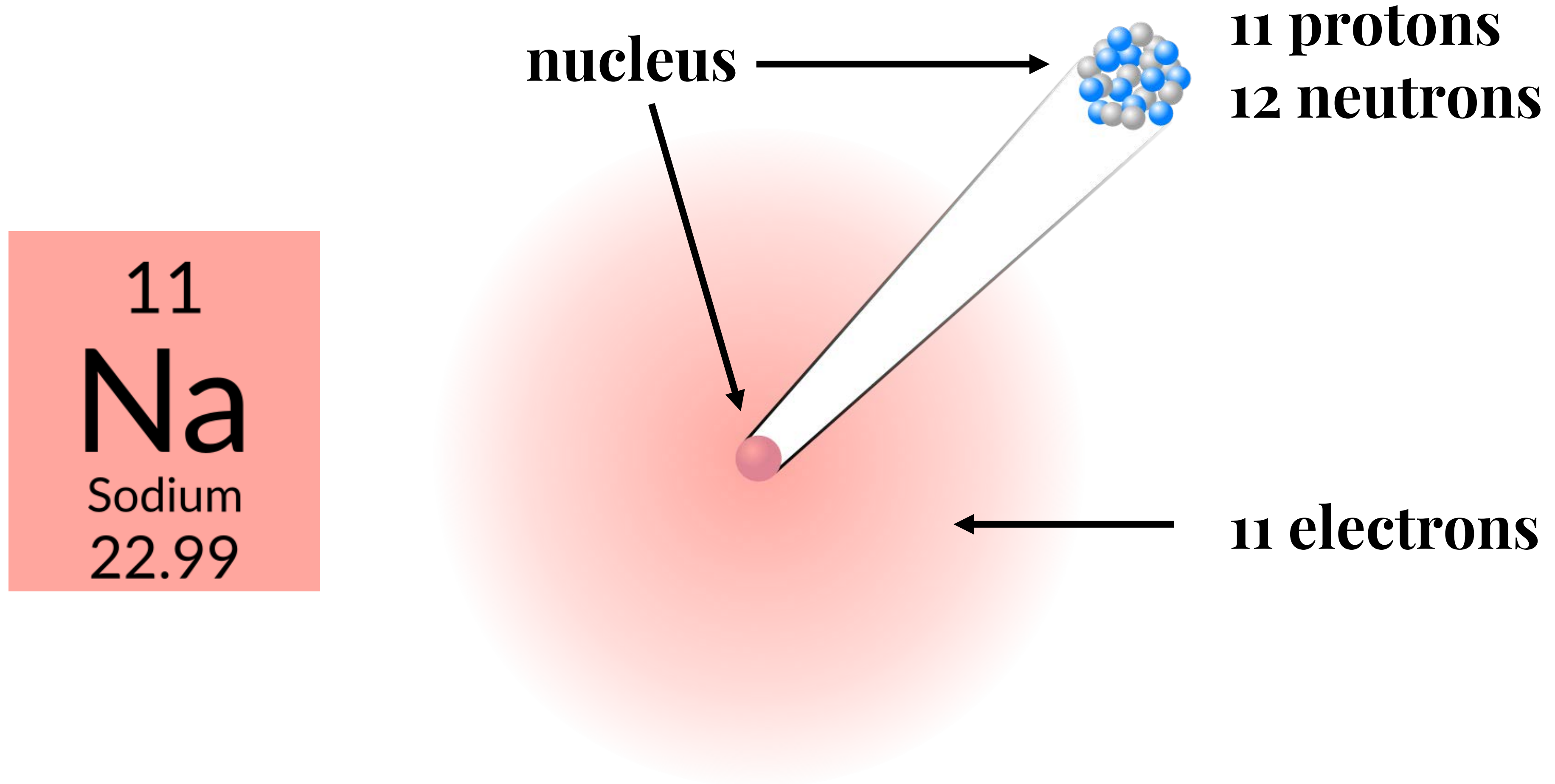
ATOMS

Objective: *Understand the different components of an atom*
Be able to determine the number of protons and neutrons in an atom given the mass number (A)

In some capacity, we can consider the atom as the smallest unit of matter which can still be considered an element. We will go into much greater detail about atomic structure later, but let us first pick apart the most important details.

Every atom contains the same general features. The first is the nucleus, which is a dense center of mass made of positively charged protons and neutral neutrons. The nucleus occupies a tiny fraction of the size of an atom, but contains the greatest percentage of its mass. Beyond the nucleus are the electrons, which are much light and negatively charged particles. For now, we can simply imagine all of the electrons existing as a cloud about the nucleus.

As an example, let us consider an atom of sodium (Na).



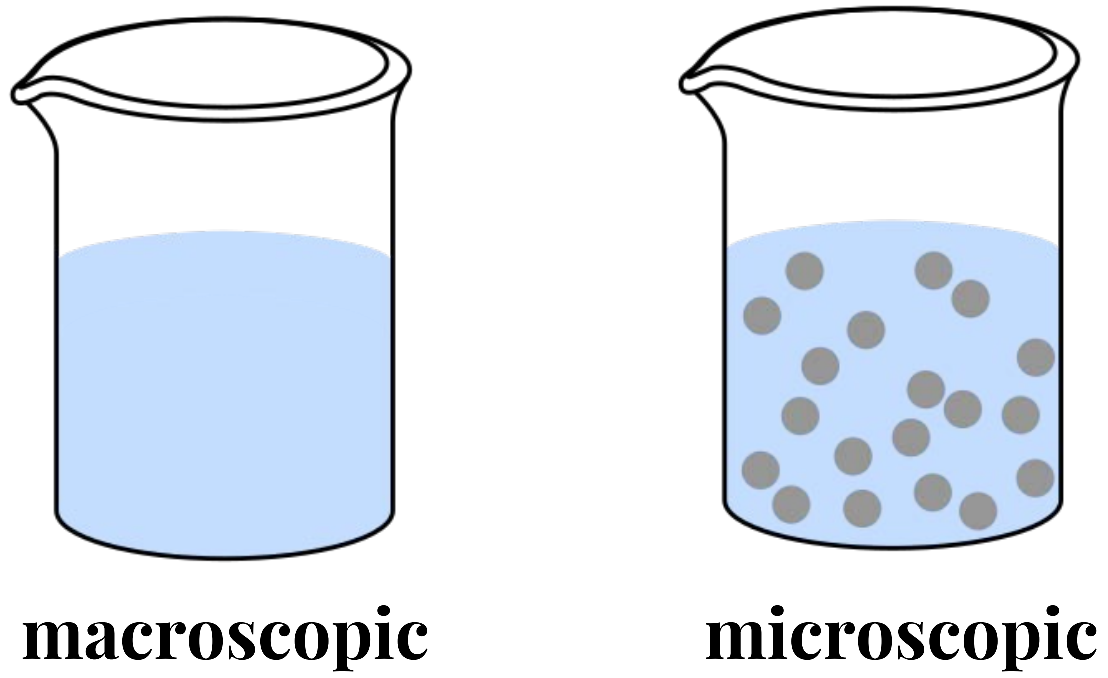
Na has an atomic number (Z) of 11, meaning a *neutral* Na atom contains 11 protons and 11 electrons—note how the charges cancel out. It is the atomic number (the number of protons, Z) that defines the atom as Na. So, if the number of protons is *changed*, the identity of the element changes!

We need the mass number (A), the sum of the number of protons and neutrons, to determine the number of neutrons. Na has a mass number of 23, so it has 12 neutrons.

MOLECULES

Objective: *Understand the differences between different types of particles (atoms, molecules, and compounds)*

Often, understanding chemistry involves being able to describe what is happening at the microscopic level. These microscopic pictures require us to envision *particles*, or the different individual "pieces" of matter.



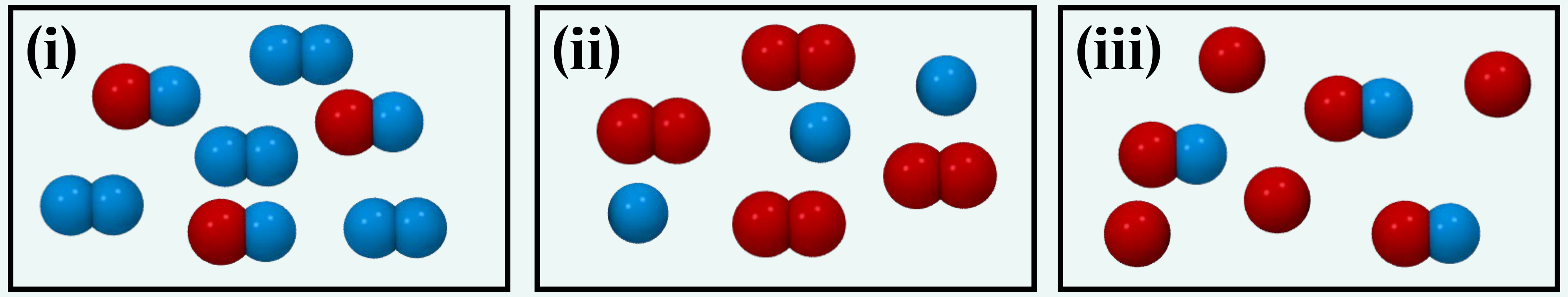
For instance, consider a beaker containing a sugar-water solution. Macroscopically, we observe the beaker as a clear solution (left). *Micro*scopically, we can imagine the solution as molecules of sugar surrounded by liquid water (right).

There are many different types of particles to consider. Probably the easiest particle to distinguish is an atom, which was described previously.

More often though, we need consider molecules, which are two or more atoms joined together that act as a single unit. If the types of elements in a molecule are all the *same*, we refer to them as molecular elements. However, if the atoms in a molecule are *different* elements, we may further classify this as a compound. So, all compounds are molecules.

Concept Question

Which microscopic picture(s) represent(s) a mixture of an element and a compound?



Pictures (i) and (iii) only.