

15.6: Atomic Mass and Atomic Number

Learning Outcomes

- Define atomic and mass numbers.
- Determine the number of protons, neutrons, and electrons in an atom.
- Identify the charge and relative mass of subatomic particles.
- Label the location of subatomic particles in the atom.
- Determine the mass of an atom based on its subatomic particles.
- Write A/Z and symbol-mass format for an atom.

Atoms are the fundamental building blocks of all matter and are composed of protons, neutrons, and electrons. Because atoms are electrically neutral, the number of positively charged protons must be equal to the number of negatively charged electrons. Since neutrons do not affect the charge, the number of neutrons is not dependent on the number of protons and will vary even among atoms of the same element.

Atomic Number

The **atomic number (represented by the letter Z)** of an element is the number of protons in the nucleus of each atom of that element. An atom can be classified as a particular element based solely on its atomic number. For example, any atom with an atomic number of 8 (its nucleus contains 8 protons) is an oxygen atom, and any atom with a different number of protons would be a different element. The periodic table (see figure below) displays all of the known elements and is arranged in order of increasing atomic number. In this table, an element's atomic number is indicated above the elemental symbol. Hydrogen, at the upper left of the table, has an atomic number of 1. Every hydrogen atom has one proton in its nucleus. Next on the table is helium, whose atoms have two protons in the nucleus. Lithium atoms have three protons, beryllium atoms have four, and so on.

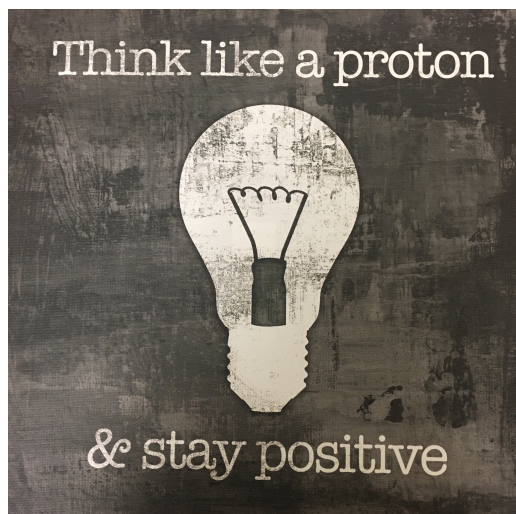


Figure 15.6.1: The social security number subatomic-the proton.

Since atoms are neutral, the number of electrons in an atom is equal to the number of protons. Hydrogen atoms all have one electron occupying the space outside of the nucleus. Helium, with two protons, will have two electrons. In the chemical classroom, the proton count will always be equivalent to an atom's atomic number. This value will not change unless the nucleus decays or is bombarded (nuclear physics).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|--------------------------------|---------------------------------|---------------------------------|---------------------------------|------------------------------------|----------------------------------|---------------------------------|---------------------------------|----------------------------------|------------------------------------|-----------------------------------|-----------------------------------|----------------------------------|---------------------------------|-----------------------------------|-----------------------------------|----------------------------------|---------------------------------|
| ① | Hydrogen 1 H 1.008 | | | | | | | | | | | | | | | | | Helium 2 He 4.0026 |
| ② | Lithium 3 Li 6.94 | Beryllium 4 Be 9.0122 | | | | | | | | | | | Boron 5 B 10.81 | Carbon 6 C 12.011 | Nitrogen 7 N 14.007 | Oxygen 8 O 15.999 | Fluorine 9 F 18.998 | Neon 10 Ne 20.180 |
| ③ | Sodium 11 Na 22.990 | Magnesium 12 Mg 24.305 | | | | | | | | | | | Aluminum 13 Al 26.982 | Silicon 14 Si 28.085 | Phosphorus 15 P 30.974 | Sulfur 16 S 32.06 | Chlorine 17 Cl 35.45 | Argon 18 Ar 39.948 |
| ④ | Potassium 19 K 39.098 | Calcium 20 Ca 40.078 | Scandium 21 Sc 44.956 | Titanium 22 Ti 47.867 | Vanadium 23 V 50.942 | Chromium 24 Cr 51.996 | Manganese 25 Mn 54.938 | Iron 26 Fe 55.845 | Cobalt 27 Co 58.933 | Nickel 28 Ni 58.693 | Copper 29 Cu 63.546 | Zinc 30 Zn 65.38 | Gallium 31 Ga 69.723 | Germanium 32 Ge 72.630 | Arsenic 33 As 74.922 | Selenium 34 Se 78.971 | Bromine 35 Br 79.904 | Krypton 36 Kr 83.798 |
| ⑤ | Rubidium 37 Rb 85.468 | Strontium 38 Sr 87.62 | Yttrium 39 Y 88.906 | Zirconium 40 Zr 91.224 | Niobium 41 Nb 92.906 | Molybdenum 42 Mo 95.95 | Technetium 43 Tc [98] | Ruthenium 44 Ru 101.07 | Rhodium 45 Rh 102.91 | Palladium 46 Pd 106.42 | Silver 47 Ag 107.87 | Cadmium 48 Cd 112.41 | Indium 49 In 114.82 | Tin 50 Sn 118.71 | Antimony 51 Sb 121.76 | Tellurium 52 Te 127.60 | Iodine 53 I 126.90 | Xenon 54 Xe 131.29 |
| ⑥ | Cesium 55 Cs 132.91 | Barium 56 Ba 137.33 | Lanthanum 57 La 138.91 | * 72 Hf 178.49 | Tantalum 73 Ta 180.95 | Tungsten 74 W 183.84 | Rhenium 75 Re 186.21 | Osmium 76 Os 190.23 | Iridium 77 Ir 192.22 | Platinum 78 Pt 195.08 | Gold 79 Au 196.97 | Mercury 80 Hg 200.59 | Thallium 81 Tl 204.38 | Lead 82 Pb 207.2 | Bismuth 83 Bi 208.98 | Polonium 84 Po [209] | Astatine 85 At [210] | Radon 86 Rn [222] |
| ⑦ | Francium 87 Fr [223] | Radium 88 Ra [226] | Actinium 89 Ac [227] | * 104 Rf [267] | Dubnium 105 Db [268] | Seaborgium 106 Sg [269] | Bohrium 107 Bh [270] | Hassium 108 Hs [270] | Meitnerium 109 Mt [278] | Darmstadtium 110 Ds [281] | Roentgenium 111 Rg [282] | Copernicium 112 Cn [285] | Nihonium 113 Nh [286] | Flerovium 114 Fl [289] | Moscovium 115 Mc [290] | Livermorium 116 Lv [293] | Tennessine 117 Ts [294] | Oganesson 118 Og [294] |
| | | | | * 58 Ce 140.12 | Praseodymium 59 Pr 140.91 | Neodymium 60 Nd 144.24 | Promethium 61 Pm [145] | Samarium 62 Sm 150.36 | Europium 63 Eu 151.96 | Gadolinium 64 Gd 157.25 | Terbium 65 Tb 158.93 | Dysprosium 66 Dy 162.50 | Holmium 67 Ho 164.93 | Erbium 68 Er 167.26 | Thulium 69 Tm 168.93 | Ytterbium 70 Yb 173.05 | Lutetium 71 Lu 174.97 | |
| | | | | * 90 Th 232.04 | Protactinium 91 Pa 231.04 | Uranium 92 U 238.03 | Neptunium 93 Np [237] | Plutonium 94 Pu [244] | Americium 95 Am [243] | Curium 96 Cm [247] | Berkelium 97 Bk [247] | Californium 98 Cf [251] | Einsteinium 99 Es [252] | Fermium 100 Fm [257] | Mendelevium 101 Md [258] | Nobelium 102 No [259] | Lawrencium 103 Lr [260] | |

Figure 15.6.3: The periodic table of the elements. (CC BY-SA 4.0 International; DePiep via Wikipedia).

Mass Number

Experimental data showed that the vast majority of the mass of an atom is concentrated in its nucleus, which is composed of protons and neutrons. The **mass number (represented by the letter A)** is defined as the total number of protons and neutrons in an atom. Consider the table below, which shows data from the first six elements of the periodic table.

Table 15.6.1: Atoms of the First Six Elements

| Name | Symbol | Atomic Number (Z) | Protons | Neutrons | Electrons | Mass Number (A) (rounded to two decimals) |
|-----------|--------|-------------------|---------|----------|-----------|---|
| hydrogen | H | 1 | 1 | 0 | 1 | 1.01 |
| helium | He | 2 | 2 | 2 | 2 | 4.00 |
| lithium | Li | 3 | 3 | 4 | 3 | 6.94 |
| beryllium | Be | 4 | 4 | 5 | 4 | 9.01 |
| boron | B | 5 | 5 | 6 | 5 | 10.18 |
| carbon | C | 6 | 6 | 6 | 6 | 12.01 |

Consider the element helium. Its atomic number is 2, so it has two protons in its nucleus. Its nucleus also contains two neutrons. Since $2 + 2 = 4$, we know that the mass number of the helium atom is 4. Finally, the helium atom also contains two electrons, since the number of electrons must equal the number of protons. This example may lead you to believe that atoms have the same number of protons and neutrons, but a further examination of the table above will show that this is not the case. Lithium, for example, has three protons and four neutrons, giving it a mass number of 7.

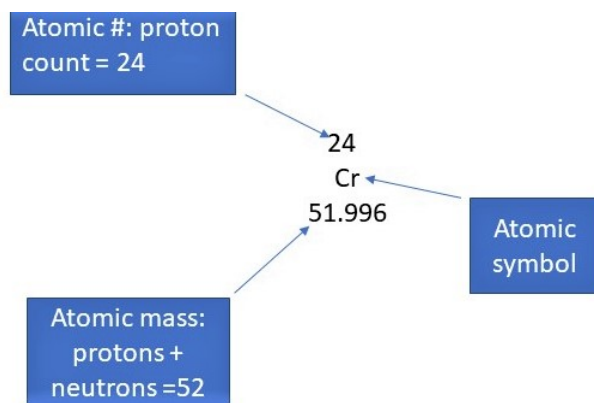


Figure 15.6.4: A/Z format and finding subatomic particles for element Chromium (Copyright; Elizabeth R. Gordon)

Knowing the mass number and the atomic number of an atom allows you to determine the number of neutrons present in that atom by subtraction.

$$\text{Number of neutrons} = \text{rounded mass number} - \text{atomic number}$$

Atoms of the element chromium (Cr) have an atomic number of 24 and a mass number of 52. How many neutrons are in the nucleus of a chromium atom? To determine this, you would subtract as shown:

$$52 - 24 = 28 \text{ neutrons in a chromium atom}$$

The composition of any atom can be illustrated with a shorthand notation called A/Z format. Both the atomic number and mass are written to the **left** of the chemical symbol. The "A" value is written as a superscript while the "Z" value is written as a subscript. For an example of this notation, look to the chromium atom shown below:



Another way to refer to a specific atom is to write the mass number of the atom after the name, separated by a hyphen. Symbol-mass format for the above atom would be written as Cr-52. In this notation, the atomic number is not included. You will need to refer to a periodic table for proton values.

✓ Example 15.6.1

Calculate each of the three subatomic particles and give specific group or period names for each atom.

- mercury
- platinum
- bromine

Solutions

- Hg (transition metal)- has 80 electrons, 80 protons, and 121 neutrons
- Pt (transition metal)- has 78 electrons, 78 protons, and 117 neutrons
- Br (halogen)- has 35 electrons, 35 protons, and 45 neutrons

✓ Example 15.6.2

Write both A/Z and symbol-mass formats for the atoms in Example 15.6.1.

Solutions

- ${}^{201}_{80}\text{Hg}$ and Hg-201
- ${}^{195}_{78}\text{Pt}$ and Pt-195
- ${}^{80}_{35}\text{Br}$ and Br-80

✓ Example 15.6.3

Identify the elements based on the statements below.

- Which element has 25 protons?
- Which element has 0 neutrons?
- Which element has 83 electrons?

Solutions

- manganese
- hydrogen
- bismuth

Need More Practice?

- Turn to section 3.E of this OER and answer questions #1-#2, #4, and #8.

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