Example Exercise 5.1 Atomic Notation

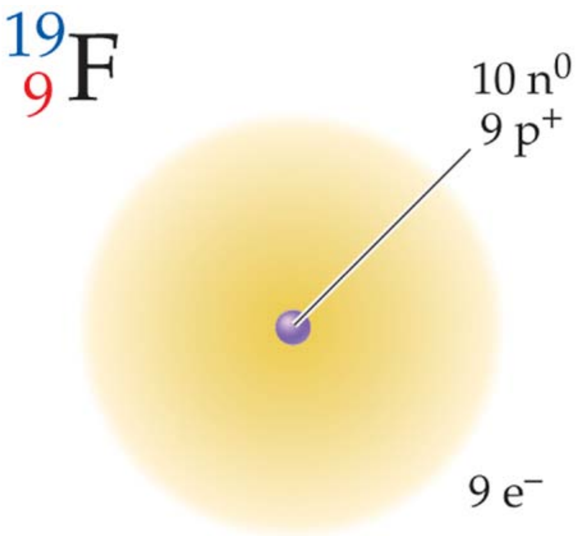
Given the atomic notation for the following atoms, draw a diagram showing the arrangement of protons, neutrons, and electrons.

(a) $^{19}_{9}F$ (b) $^{109}_{47}Ag$

Solution

We can draw a diagram of an atom by showing protons and neutrons in the nucleus surrounded by electrons.

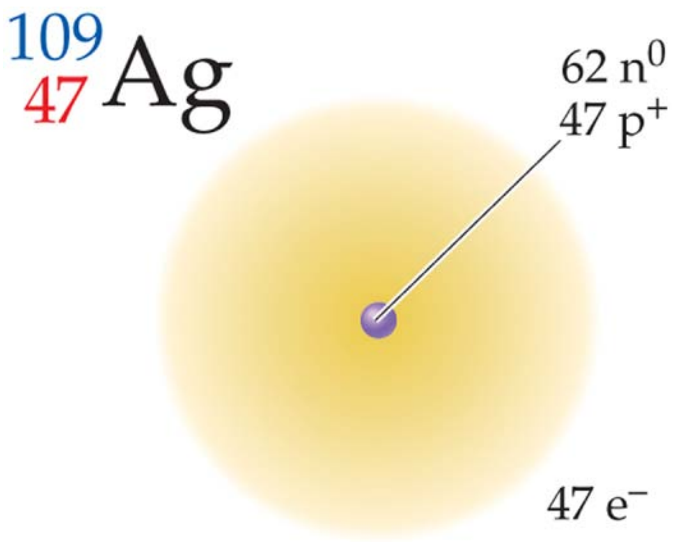
(a) Since the atomic number is 9 and the mass number is 19, the number of neutrons is 10 (19 – 9). If there are 9 protons, there must be 9 electrons.



Example Exercise 5.1 Atomic Notation

Continued

(b) Since the atomic number is 47 and the mass number is 109, the number of neutrons is 62 (109 – 47). If there are 47 protons, there must be 47 electrons.

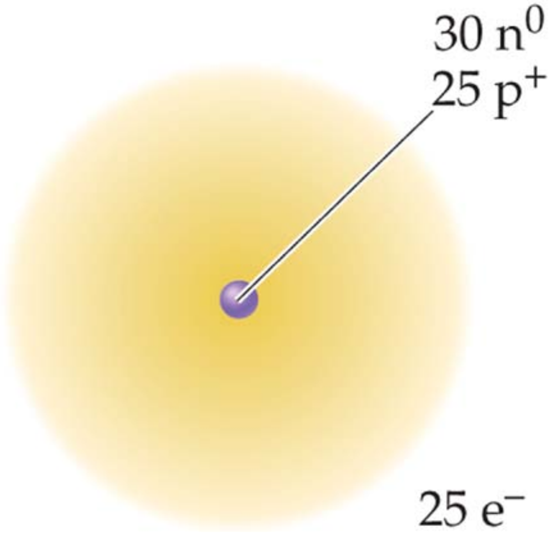


Example Exercise 5.1 Atomic Notation

Continued

Practice Exercise

Given the following diagram, indicate the nucleus using atomic notation.



Answer: $^{55}_{25}Mn$

Concept Exercise

Can atoms of different elements have the same atomic number?

Answer: See Appendix G.

Example Exercise 5.2 Nuclear Composition of Isotopes

State the number of protons and the number of neutrons in an atom of each of the following isotopes.

(a) $^{37}_{17}Cl$ (b) mercury-202

Solution

The subscript value refers to the atomic number (p^+), and the superscript value refers to the mass number (p^+ and n^0).

(a) Thus, $^{37}_{17}Cl$ has 17 p^+ and 20 n^0 (37 – 17 = 20).

(b) In the periodic table, we find that the atomic number of mercury is 80. Thus, the atomic notation, $^{202}_{80}Hg$, indicates 80 p^+ and 122 n^0 (202 – 80 = 122).

Practice Exercise

State the number of protons and the number of neutrons in an atom of each of the following isotopes.

(a) $^{120}_{50}Sn$ (b) uranium-238

Answers: (a) 50 p^+ and 70 n^0; (b) 92 p^+ and 146 n^0

Concept Exercise

Can atoms of different elements have the same mass number?

Answer: See Appendix G.

Example Exercise 5.3 Calculation of Atomic Mass

Silicon is the second most abundant element in Earth's crust. Calculate the atomic mass of silicon given the following data for its three natural isotopes:

ISOTOPE	MASS	ABUNDANCE
^{28}Si	27.977 amu	92.21%
^{29}Si	28.976 amu	4.70%
^{30}Si	29.974 amu	3.09%

Solution

We can find the atomic mass of silicon as follows:

$$^{28}\text{Si: } 27.977 \text{ amu} \times 0.9221 = 25.80 \text{ amu}$$
$$^{29}\text{Si: } 28.976 \text{ amu} \times 0.0470 = 1.36 \text{ amu}$$
$$^{30}\text{Si: } 29.974 \text{ amu} \times 0.0309 = \underline{0.926 \text{ amu}}$$
$$28.09 \text{ amu}$$

The average mass of a silicon atom is 28.09 amu, although we should note that there are no silicon atoms with a mass of 28.09 amu.

Example Exercise 5.3 Calculation of Atomic Mass

Continued

Practice Exercise

Calculate the atomic mass of copper given the following data:

ISOTOPE	MASS	ABUNDANCE
^{63}Cu	62.930 amu	69.09%
^{65}Cu	64.928 amu	30.91%

Answer: 63.55 amu

Concept Exercise

A bag of marbles has 75 large marbles with a mass of 2.00 g each, and 25 small marbles with a mass of 1.00 g each. Calculate (a) the simple average mass, and (b) the weighted average mass of the marble collection.

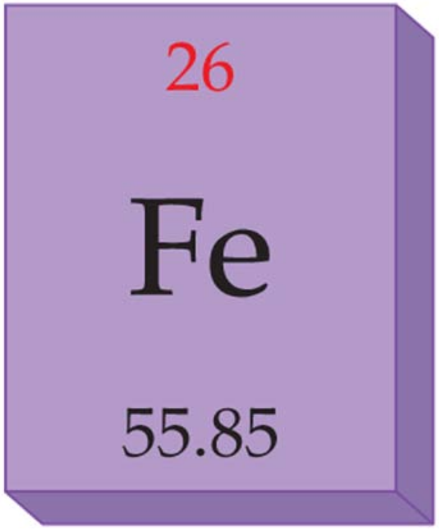
Answer: See Appendix G.

Example Exercise 5.4 Nuclear Composition from the Periodic Table

Refer to the periodic table on the inside cover of this textbook and determine the atomic number and atomic mass for iron.

Solution

In the periodic table we observe



The atomic number of iron is 26, and the atomic mass is 55.85 amu. From the periodic table information, we should note that it is not possible to determine the number of isotopes for iron or their mass numbers.

Example Exercise 5.4 Nuclear Composition from the Periodic Table

Continued

Practice Exercise

Refer to the periodic table on the inside cover of this text and determine the atomic number and mass number for the given radioactive isotope of radon gas.

Answers: 86 and (222)

Concept Exercise

Which of the following is *never* a whole number value: atomic number, atomic mass, or mass number?

Answer: See Appendix G.

Example Exercise 5.5 Properties of Light

Considering blue light and yellow light, which has the
(a) longer wavelength? (b) higher frequency?
(c) higher energy?

Solution

Referring to Figure 5.9, we notice that the wavelength of yellow light is about 600 nm and that of blue light is about 500 nm. Thus,

(a) *yellow light* has a longer wavelength than blue light.
(b) *blue light* has a higher frequency because it has a shorter wavelength.
(c) *blue light* has a higher energy because it has a higher frequency.

Practice Exercise

Considering infrared light and ultraviolet light, which has the
(a) longer wavelength? (b) higher frequency?
(c) higher energy?

Answers: (a) infrared; (b) ultraviolet; (c) ultraviolet

Concept Exercise

The energy of light (increases/decreases) as the wavelength increases. The energy of light (increases/decreases) as the frequency increases.

Answer: See Appendix G.

Example Exercise 5.6 Quantum Concept

State whether each of the following scientific instruments gives a continuous or a quantized measurement of mass:

(a) triple-beam balance (b) digital electronic balance

Solution

Refer to Figure 2.3 if you have not used these balances in the laboratory.

(a) On a triple-beam balance a small metal rider is moved along a beam. Since the metal rider can be moved to any position on the beam, a triple-beam balance gives a *continuous* mass measurement.

(b) On a digital electronic balance the display indicates the mass of an object to a particular decimal place, for example, 5.015 g. Since the last digit in the display must be a whole number, a digital balance gives a *quantized* mass measurement.

Figure 2.3 Balances for Measuring Mass (a) A platform balance having an uncertainty of ±0.1 g. (b) A beam balance having an uncertainty of ±0.01 g. (c) A digital electronic balance having an uncertainty of ±0.001 g.

Practice Exercise

State whether each of the following musical instruments produces continuous or quantized musical notes:

(a) acoustic guitar (b) electronic keyboard

Answers: (a) continuous; (b) quantized

Concept Exercise

Complete the following quantum analogy: a water wave is to a drop of water, as a light wave is to a ________.

Answer: See Appendix G.

Example Exercise 5.7 Emission Spectra and Energy Levels

Explain the relationship between an observed emission line in a spectrum and electron energy levels.

Solution

When an electron drops from a higher to a lower energy level, light is emitted. For each electron that drops, a single photon of light energy is emitted. The energy lost by the electron that drops equals the energy of the photon that is emitted. Several photons of light having the same energy are observed as a spectral line.

Practice Exercise

Indicate the number and color of the photons emitted for each of the following electron transitions in hydrogen atoms:

(a) 1 e^- dropping from energy level 3 to 2
(b) 10 e^- dropping from energy level 3 to 2
(c) 100 e^- dropping from energy level 4 to 2
(d) 500 e^- dropping from energy level 5 to 2

Answers: (a) 1 red photon; (b) 10 red photons; (c) 100 blue-green photons; (d) 500 violet photons

Concept Exercise

Which of the following statements are true according to the Bohr model of the atom?

(a) Electrons are attracted to the atomic nucleus.
(b) Electrons have fixed energy as they circle the nucleus.
(c) Electrons lose energy as they drop to an orbit closer to the nucleus.

Answer: See Appendix G.

Example Exercise 5.8 Energy Levels, Sublevels, and Electrons

What is the maximum number of electrons that can occupy the third energy level?

Solution

The third energy level is split into three sublevels: 3*s*, 3*p*, and 3*d*. The maximum number of electrons that can occupy each sublevel is as follows:

$$s \text{ sublevel} = 2\ e^-$$
$$p \text{ sublevel} = 6\ e^-$$
$$d \text{ sublevel} = 10\ e^-$$

The maximum number of electrons in the third energy level is found by adding the three sublevels together:

$$3s + 3p + 3d = \text{total electrons}$$
$$2\ e^- + 6\ e^- + 10\ e^- = 18\ e^-$$

The third energy level can hold a maximum of 18 electrons. Of course, in elements where the third energy level of an atom is not filled, there are fewer than 18 electrons.

Practice Exercise

What is the maximum number of electrons that can occupy the fourth energy level?

Answers: 4*s*, 4*p*, 4*d*, 4*f*; 32 e^- (2 e^- + 6 e^- + 10 e^- + 14 e^-)

Concept Exercise

What is the theoretical number of sublevels in the tenth energy level?

Answer: See Appendix G.

Example Exercise 5.9 Order of Sublevels

According to increasing energy, what is the next energy sublevel after each of the following sublevels?

(a) 3*p* (b) 4*d*

Solution

If you do not know the order of sublevels, refer to the filling diagram in Figure 5.16.

(a) Although the third energy level has 3*s* 3*p*, and 3*d* sublevels, the 3*d* sublevel does not immediately follow the 3*p*. Instead, the 4*s* sublevel follows the 3*p* and precedes the 3*d*. Thus,

3*s*, 3*p*, **4*s***

(b) Although the fourth energy level has 4*s*, 4*p*, 4*d*, and 4*f* sublevels, the 4*f* sublevel does not immediately follow the 4*d*. Instead, the 5*p* sublevel begins accepting electrons after the 4*d* is filled. Thus,

4*p*, 5*s*, 4*d*, **5*p***

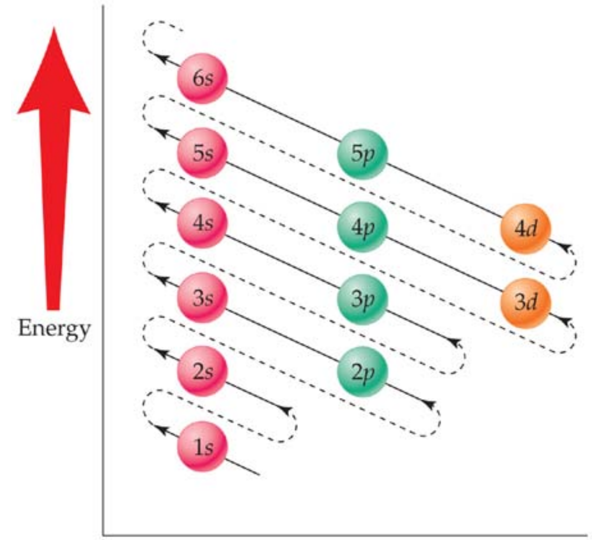


Figure 5.16 Filling Diagram for Energy Sublevels The order of sublevel filling is arranged according to increasing energy. Electrons first fill the 1s sublevel followed by the 2*s*, 2*p*, 3*s*, 3*p*, 4*s*, 3*d*, 4*p*, 5*s*, 4*d*, 5*p*, and 6*s* sublevels.

Practice Exercise

Which sublevel gains electrons after each of the following sublevels is filled?

(a) 2*s* (b) 5*p*

Answers: (a) 2*p*; (b) 6*s*

Concept Exercise

The energy difference between sublevels (increases/decreases) moving away from the nucleus.

Answer: See Appendix G.

Example Exercise 5.10 Electron Configuration

Write the predicted electron configuration for each of the following elements:

(a) F (b) Sr

Solution

Refer to the periodic table to find the atomic number of an element.

(a) The atomic number of fluorine is 9; therefore, the number of electrons is 9. We can fill sublevels with 9 electrons as follows.

$$\text{F:}\quad 1s^2\ 2s^2\ 2\text{p}^5$$

(b) The atomic number of strontium is 38; therefore, the number of electrons is 38. We can fill sublevels with 38 electrons as follows:

$$\text{Sr:}\quad 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2$$

To check your answer, find the total number of electrons by adding up the superscripts. The total is 38 e^-; this agrees with the atomic number for Sr.

Practice Exercise

Write the predicted electron configuration for each of the following elements:

(a) argon (b) cadmium

Answers: (a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$; (b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}$

Concept Exercise

Refer to the periodic table and state whether Cr or Mn has more electrons in the outermost *d* sublevel.

Answer: See Appendix G.

Example Exercise 5.11 Atomic Orbitals

Describe the relative size, energy, and shape for each of the following orbitals:
(a) 4*s* versus 3*s* and 5*s* (b) 4*p* versus 3*p* and 5*p*

Solution

The size and energy of an orbital is indicated by the number; the shape of the orbital is designated by the letter.

(a) Size and energy are greater for a 4*s* orbital than for a 3*s* orbital, but less than for a 5*s* orbital. The shape of a 4*s* orbital—and all *s* orbitals—is similar to the shape of a sphere.

(b) Size and energy are greater for a 4*p* orbital than for a 3*p* orbital, but less than for a 5*p* orbital. The shape of a 4*p* orbital—and all *p* orbitals—is similar to the shape of a dumbbell.

Practice Exercise

Select the orbital in each of the following pairs that fits the description:
(a) the higher energy orbital: 3*p* or 4*p* (b) the larger size orbital: 4*d* or 5*d*

Answers: (a) 4*p*; (b) 5*d*

Concept Exercise

Which of the following statements are true according to the quantum mechanical model of the atom?
(a) Orbitals represent quantum energy levels for electrons.
(b) Orbitals represent probability boundaries for electrons.
(c) Orbitals can have different shapes.

Answer: See Appendix G.