**Units and Unit Conversions**

6. **Define the problem:** If the nucleus were scaled to a diameter of 4 cm, determine the diameter of the atom.

   **Develop a plan:** Find the accepted relationship between the size of the nucleus and the size of the atom. Use size relationships to get the diameter of the “artificially large” atom.

   **Execute the plan:** The atom is about 10,000 times bigger than the nucleus.

   \[ 10,000 \times 4 \text{ cm} = 40,000 \text{ cm} \]

   **Check your answer:** A much larger nucleus means a much larger atom. This large atomic diameter result looks right.

8. **Define the problem:** The pole vault record is a height of 6.14 m. Use conversion factors to change the units to centimeters, feet, and inches.

   **Develop a plan:** Use the metric relationship between m and cm to convert m into cm. Then, use the metric relationship between cm and inches to convert cm into inches. Then, use the relationship between inches and feet to convert from inches to feet.

   **Execute the plan:** If any one of these questions were asked separately, we would start with the given information and apply the appropriate conversion factors.

   \[
   6.14 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} = 614 \text{ cm} \\
   6.14 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 242 \text{ cm} \\
   6.14 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ ft}}{12 \text{ in}} = 20.1 \text{ ft}
   \]

   When answering all three questions, we can use the results of the previous calculation to make the next calculation faster:

   \[
   614 \text{ cm} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 242 \text{ in} \\
   242 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}} = 20.1 \text{ ft}
   \]

   **Check your answers:** The number of centimeters should be larger than the number of meters, since “centimeter” is a smaller unit of measure. The number of inches should be smaller than the number of centimeters, since “inch” is a larger unit of measure. The number of feet should be smaller than the number of inches, since “foot” is a larger unit of measure. These answers make sense.

10. **Define the problem:** Given the distance to the fence in feet, determine the distance in meters.

    **Develop a plan:** Use conversion factors between feet and inches, then inches and centimeters, then centimeters and meters to change the units from feet to meters.

    **Execute the plan:**

    \[
    404 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{2.54 \text{ cm}}{1 \text{ in}} \times \frac{1 \text{ m}}{100 \text{ cm}} = 123 \text{ m}
    \]

    **Check your answer:** Feet are shorter than meters, so the number of meters should be smaller than the number of feet. This answer looks right.

13. **Define the problem:** Given displacement volume of 250. in$^3$, determine the volume in cm$^3$ and liters.

    **Develop a plan:** Use conversion factor between inches and centimeters to change the units from cubic
inches to cubic centimeters. Then use conversion factors between cubic centimeters and milliliters, then milliliters and liters to change the units from cubic centimeters to liters.

**Execute the plan:**

\[
250. \text{ in}^3 \times \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 = 4.10 \times 10^3 \text{ cm}^3
\]

\[
250. \text{ in}^3 \times \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 4.10 \text{ L}
\]

**Notice:** The conversion between liters and milliliters used here indicates that a larger number (1000) of small things (mL) are equal to a smaller number (1) of large things (L). Conversely, you can use the conversion relating a smaller number \(10^{-3}\) of larger things (L) to a larger number (1) of small things.

**Check your answers:** Centimeters are smaller than inches, so a cubic centimeter is much smaller than a cubic inch. It makes sense that the number of cubic centimeters is larger than the number of cubic inches. A liter is larger than a cubic centimeter, so it makes sense that the number of liters is smaller than the number of cubic inches. These answers look right.

16. **Define the problem:** Given the length, width, and height of a room, determine the volume in metric units.

**Develop a plan:** Using the conversion factor between inches and feet, determine the height of the room in feet. Use those lengths to calculate the volume in cubic feet. Use conversion factors between feet and inches and between inches and centimeters to determine the volume in cubic centimeters. Use conversion factors between cubic centimeters and milliliters and between milliliters and liters to determine the volume in liters.

**Execute the plan:**

height = \(8 \text{ ft} + \left(6 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}}\right) = 8.5 \text{ ft}\)

\[
V = (\text{length}) \times (\text{width}) \times (\text{height})
\]

(then convert to m³)

\[
V = (18 \text{ ft}) \times (15 \text{ ft}) \times (8.5 \text{ ft}) \times \left(\frac{12 \text{ in}}{1 \text{ ft}}\right)^3 \times \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 \times \left(\frac{1 \text{ m}}{100 \text{ cm}}\right)^3 = 65 \text{ m}^3
\]

\[
65 \text{ m}^3 \times \left(\frac{100 \text{ cm}}{1 \text{ m}}\right)^3 \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 6.5 \times 10^4 \text{ L}
\]

**Check your answers:** A cubic meter is larger than a liter, so the number of cubic meters should be smaller than the number of liters. These answers make sense.

17. The symbols for the elements in this crystal are Ca (calcium) and F (fluorine).

**Define the problem:** Given the mass of the crystal as 2.83 grams, find the mass in kilograms and pounds.

**Develop a plan:** Using the conversion factor between grams and kilograms, determine the mass in kilograms. Using the conversion factor between grams and pounds, determine the mass in pounds.

**Execute the plan:**

\[
2.83 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.00283 \text{ kg}
\]
\[ 2.83 \text{ g} \times \frac{1 \text{ lb}}{453.59 \text{ g}} = 0.00624 \text{ lb} \]

*Check your answers:* Pounds and kilograms are both larger units than grams, so it makes sense that the number of kilograms and the number of pounds would be smaller than the number of grams.

**32. Define the problem:** Given the identity of an element (cobalt) and the atom’s mass number (60), find the number of electrons, protons, and neutrons in the atom.

*Develop a plan:* Look up the symbol for cobalt and find that symbol on the periodic table. The periodic table gives the atomic number. The atomic number is the number of protons. The number of electrons is equal to the number of protons since the atom has no charge. The number of neutrons is the difference between the mass number and the atomic number.

*Execute the plan:* The element technetium has the symbol Co. On the periodic table, we find it listed with the atomic number 27. So, the atom has 27 protons, 27 electrons and (60 – 27 =) 33 neutrons.

*Check your answers:* The number protons and electrons must be the same (27=27). The sum of the protons and neutrons is the mass number (27 + 33 = 60). This is correct.

**34.** Atoms of the same element have the same number of protons in the nucleus, and therefore all the atoms for any given element would have the same atomic number.

**38.** Mass number is the sum of the number of protons and neutrons. Atomic number is the number of protons. So, when you subtract the atomic number from the mass number, you obtain the number of neutrons.

**44. Define the problem:** Given the identity of an element and the number of neutrons in the atom, determine the atomic symbol \( \frac{A}{Z}X \).

*Develop a plan:* Look up the symbol for the element and find that symbol (X) on the periodic table. The periodic table gives the atomic number (Z), which represents the number of protons. Add the number of neutrons to the number of protons to get the mass number (A).

*Execute the plan:*

(a) The element nitrogen has the symbol N. On the periodic table, we find it listed with the atomic number 7. The given number of neutrons is 8. So, \( 7 + 8 = 15 \) is the mass number for this nitrogen atom. Its atomic symbol looks like this: \( ^{15}_7\text{N} \).

(b) The element zinc has the symbol Zn. On the periodic table, we find it listed with the atomic number 30. The given number of neutrons is 34. So, \( 30 + 34 = 64 \) is the mass number for this zinc atom. Its atomic symbol looks like this: \( ^{64}_{30}\text{Zn} \).

(c) The element xenon has the symbol Xe. On the periodic table, we find it listed with the atomic number 54. The given number of neutrons is 75. So, \( 54 + 75 = 129 \) is the mass number for this xenon atom. Its atomic symbol looks like this: \( ^{129}_{54}\text{Xe} \).

*Check your answers:* Mass number should be close to (but not exactly the same as) the atomic weight also given on the periodic table. Nitrogen’s atomic weight (14.01) is close to the 15 mass number. Zinc’s atomic weight (65.38) is close to the 64 mass number. Xenon’s atomic weight (131.3) is close to the 129 mass number. These numbers seem reasonable.

**46. Define the problem:** Given the atomic symbol \( \frac{A}{Z}X \) of the isotope, determine the number of electrons, protons, and neutrons.

*Develop a plan:* The atomic number (Z) represents the number of protons. In neutral atoms, the number of electrons are equal to the number of protons. To get the number of neutrons, subtract the number of protons from the mass number (A).
Execute the plan:

(a) The isotope given is $^{13}\text{C}_6$. That means $A = 13$ and $Z = 6$. So, the number of protons is 6, the number of electrons is 6, and the number of neutrons is $(13 - 6) = 7$.

(b) The isotope given is $^{50}\text{Cr}_{24}$. That means $A = 50$ and $Z = 24$. So, the number of protons is 24, the number of electrons is 24, and the number of neutrons is $(50 - 24) = 26$.

(c) The isotope given is $^{205}\text{Bi}_{83}$. That means $A = 205$ and $Z = 83$. So, the number of protons is 83, the number of electrons is 83, and the number of neutrons is $(205 - 83) = 122$.

Check your answers: The number of protons and electrons must be equal in neutral atoms. The mass number must be the sum of the protons and neutrons. These answers look okay.

Atomic Weight

54. Define the problem: Using the exact mass and the percent abundance of several isotopes of an element, determine the atomic weight.

Develop a plan: Calculate the weighted average of the isotope masses.

Execute the plan:

Every 1000 atoms of lithium contains 75.00 atoms of the $^6\text{Li}$ isotope.

Every 1000 atoms of lithium contains 925.0 atoms of the $^7\text{Li}$ isotope.

$$\frac{75.00 \text{ atoms}^6\text{Li}}{1000 \text{ Li atoms}} \times \left(\frac{6.015121 \text{ amu}}{1 \text{ atom}^6\text{Li}}\right) + \frac{925.0 \text{ atoms}^7\text{Li}}{1000 \text{ Li atoms}} \times \left(\frac{7.016003 \text{ amu}}{1 \text{ atom}^7\text{Li}}\right) = 6.941 \text{ amu/Li atom}$$

Check your answer: The periodic table value for the atomic weight is the same as this calculated value. This answer looks right.

92. Define the problem: A distance is given in angstroms (Å), which are defined. Determine the distance in nanometers and picometers.

Develop a plan: Use the given relationship between angstroms and meters as a conversion factor to get from angstroms to meters. Then use the metric relationships between meters and the other two units to find the distance in nanometers and picometers.

Execute the plan:

$$1.97 \times \frac{1 \times 10^{-10} \text{ m}}{1 \text{ Å}} \times \frac{1 \text{ nm}}{1 \times 10^{-9} \text{ m}} = 0.197 \text{ nm}$$

$$1.97 \times \frac{1 \times 10^{-10} \text{ m}}{1 \text{ Å}} \times \frac{1 \text{ pm}}{1 \times 10^{-12} \text{ m}} = 197 \text{ pm}$$

Check your answers: The unit nanometer is larger than an angstrom, so the distance in nanometers should be a smaller number. The unit picometer is smaller than an angstrom, so the distance in picometers should be a larger number. These answers look right.