1.4.7: Calculating Atomic Mass

Figure 1.4.7.1 (Credit: George M. Groutas; Source: Flickr Boulders beach, Cape Peninsula(opens in new window) [www.flickr.com]; License: CC by 2.0(opens in new window))

Have you ever tried to move a boulder?

You have a pile of rocks to move and need to decide what equipment you want to rent to move them. If the rocks are fairly small, you can get a shovel to pick them up. Larger rocks could be moved by hand, but big boulders will need some sort of mechanical scoop. The amount of each kind of rock will also determine how much time you will need to get the job done. Knowing the relative amounts of large, medium, and small rocks can be very useful in deciding how to approach the job.

Percent Natural Abundance

Most elements occur naturally as a mixture of two or more isotopes. The table below shows the natural isotopes of several elements, along with the **percent natural abundance** of each.

Table 1.4.7.1: Atomic Masses and Percents of Abundance of Some Natural Isotopes

Element	**Isotope (Symbol)**	**Percent Natural Abundance**	**Atomic Mass** (amu)	**Average Atomic Mass** (amu)
Hydrogen	$^{1}_{1}H$	99.985	1.0078	1.0080
	$^{2}_{1}H$	0.015	2.0141	
	$^{3}_{1}H$	negligible	3.0160	
Carbon	$^{12}_{6}C$	98.89	12.000	12.011
	$^{13}_{6}C$	1.11	13.003	
	$^{14}_{6}C$	trace	14.003	
Oxygen	$^{16}_{8}O$	99.759	15.995	15.999
	$^{17}_{8}O$	0.037	16.995	
	$^{18}_{8}O$	0.204	17.999	
Chlorine	$^{35}_{17}Cl$	75.77	34.969	35.453
	$^{37}_{17}Cl$	24.23	36.966	
Copper	$^{63}_{29}Cu$	69.17	62.930	63.546
	$^{65}_{29}Cu$	30.83	64.928	

For some elements, one particular isotope predominates greatly over the other isotopes. Naturally occurring hydrogen is nearly all hydrogen-1 and naturally occurring oxygen is nearly all oxygen-16. For many other elements, however, more than one isotope may exist in more substantial quantities. Chlorine (atomic number 17) is a yellowish-green toxic gas. About three quarters of all chlorine atoms have 18 neutrons, giving those atoms a mass number of 35. About one quarter of all chlorine atoms have 20 neutrons, giving those atoms a mass number of 37. Were you to simply calculate the arithmetic average of the precise **atomic masses**, you would get 36.

$$\frac{(34.969 + 36.966)}{2} = 35.968 \text{ amu}$$

Clearly the actual average atomic mass from the last column of the table is significantly lower. Why? We need to take into account the percent natural abundance of each isotope, in order to calculate the weighted average. The atomic mass of an element is the weighted average of the atomic masses of the naturally occurring isotopes of that element. The sample problem below demonstrates how to calculate the atomic mass of chlorine.

Example 1.4.7.1

Use the atomic masses of each of the two isotopes of chlorine along with their respective percent abundances to calculate the average atomic mass of chlorine.

Solution

Step 1: List the known and unknown quantities and plan the problem.

Known

- Chlorine-35: atomic mass $= 34.969 \text{ amu}$ and percent abundance $= 75.77\%$
- Chlorine-37: atomic mass $= 36.966 \text{ amu}$ and percent abundance $= 24.23\%$

Unknown

- Average atomic mass of chlorine

Change each percent abundance into decimal form by dividing by 100. Multiply this value by the atomic mass of that isotope. Add together for each isotope to get the average atomic mass.

Step 2: Calculate.

$$\begin{array}{ll} \text{chlorine-35} & 0.7577 \times 34.969 = 26.50 \text{ amu} \\ \text{chlorine-37} & 0.2423 \times 36.966 = 8.957 \text{ amu} \\ \text{average atomic mass} & 26.50 + 8.957 = 35.46 \text{ amu} \end{array}$$

Note: Applying significant figure rules results in the 35.45 amuresult without excessive rounding error. In one step:

$$(0.7577 \times 34.969) + (0.2423 \times 36.966) = 35.46 \text{ amu}$$

Step 3: Think about your result.

The calculated average atomic mass is closer to 35 than to 37 because a greater percentage of naturally occurring chlorine atoms have the mass number of 35. It agrees with the value from the table above.

Summary

- The atomic mass of an element is the weighted average of the atomic masses of the naturally occurring isotopes of that element.
- Calculations of atomic mass use the percent abundance of each isotope.

Review

1. Define atomic mass.
2. What information do you need to calculate atomic mass for an element?
3. Calculate the atomic mass for carbon using the data provided in the table below.

Isotope	Atomic Mass	Percent Abundance
carbon-12	12.000000	98.90
carbon-13	13.003355	1.100