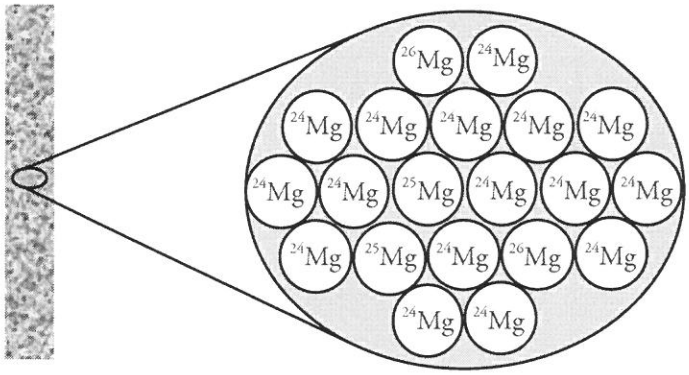
Average Atomic Mass

How are the masses on the periodic table determined?

Why?

Most elements have more than one naturally occurring isotope. As you learned previously, the atoms of those isotopes have the same atomic number (number of protons), making them belong to the same element, but they have different mass numbers (total number of protons and neutrons) giving them different atomic masses. So which mass is put on the periodic table for each element? Is it the most common isotope's mass? The heaviest mass? This activity will help answer that question.

Model 1 – A Strip of Magnesium Metal



1. Write in the atomic number for each Mg atom in Model 1.

2. What are the mass numbers of the naturally occurring isotopes of magnesium shown in Model 1?

3. Do all of the atoms of magnesium in Model 1 have the same atomic mass? Explain.

4. For the sample of 20 atoms of magnesium shown in Model 1, draw a table indicating the mass numbers of the three isotopes and the number of atoms of each isotope present.

5. Which isotope of magnesium is the most common in Model 1?

6. Based on Model 1 and the table you created in Question 4, for every 10 atoms of magnesium, approximately how many atoms of each isotope will be found?

Model 2 – Natural Abundance Information for Magnesium

Isotope	Natural Abundance on Earth (%)	Atomic Mass (amu)
^{24}Mg	78.99	23.9850
^{25}Mg	10.00	24.9858
^{26}Mg	11.01	25.9826

7. Consider the natural abundance information given in Model 2.
   a. Calculate the expected number of atoms of each isotope that will be found in a sample of 20 atoms of Mg. *Hint:* The number of atoms must be a whole number!

   b. Is Model 1 accurate in its representation of magnesium at the atomic level? Explain.

8. If you could pick up a single atom of magnesium and put it on a balance, the mass of that atom would most likely be _____ amu. Explain your reasoning.

9. Refer to a periodic table and find the box for magnesium.
   a. Write down the decimal number shown in that box.

   b. Does the decimal number shown on the periodic table for magnesium match any of the atomic masses listed in Model 2?

10. The periodic table does not show the atomic mass of every isotope for an element.
    a. Explain why this would be an impractical goal for the periodic table.

    b. Is it important to the average scientist to have information about a particular isotope of an element? Explain.

11. What would be a practical way of showing the mass of magnesium atoms on the periodic table given that most elements occur as a mixture of isotopes?

12. Propose a possible way to calculate the average atomic mass of 100 magnesium atoms. Your answer may include a mathematical equation, but it is not required.

Model 3 – Proposed Average Atomic Mass Calculations

Mary's Method

$$\frac{(78.99)(23.9850 \text{ amu}) + (10.00)(24.9858 \text{ amu}) + (11.01)(25.9826 \text{ amu})}{100} = \_\_\_\_\_$$

Jack's Method

$$(0.7899)(23.9850 \text{ amu}) + (0.1000)(24.9858 \text{ amu}) + (0.1101)(25.9826 \text{ amu}) = \_\_\_\_\_$$

Alan's Method

$$\frac{23.9850 \text{ amu} + 24.9858 \text{ amu} + 25.9826 \text{ amu}}{3} = \_\_\_\_\_$$

13. Complete the three proposed calculations for the average atomic mass of magnesium in Model 3.

14. Consider the calculations in Model 3.

    a. Which methods shown in Model 3 give an answer for average atomic mass that matches the mass of magnesium on the periodic table?

    b. Explain why the mathematical reasoning was incorrect for any method(s) in Model 3 that did not give the correct answer for average atomic mass (the one on the periodic table).

    c. For the methods in Model 3 that gave the correct answer for average atomic mass, show that they are mathematically equivalent methods.

15. Use one of the methods in Model 3 that gave the correct answer for average atomic mass to calculate the average atomic mass for oxygen. Isotope information is provided below. Show all of your work and check your answer against the mass listed on the periodic table.

Isotope	Natural Abundance on Earth (%)	Atomic Mass (amu)
^{16}O	99.76	15.9949
^{17}O	0.04	16.9991
^{18}O	0.20	17.9992

ChemActivity 2

Atomic Number and Atomic Mass

(Are All of an Element's Atoms Identical?)

Model 1: Isotopes.

Each element found in nature occurs as a mixture of isotopes. The isotopic abundance can vary appreciably on an astronomical scale—in the Sun and on Earth, for example. On Earth, however, the abundance shows little variation from place to place.

Table 1. Natural abundance and atomic masses for various isotopes.

Isotope	Natural Abundance on Earth (%)	Atomic Mass (amu)
^{1}H	99.985	1.0078
^{2}H	0.015	2.0140
^{12}C	98.89	12.0000
^{13}C	1.11	13.0034
^{35}Cl	75.77	34.9689
^{37}Cl	24.23	36.9659
^{24}Mg	78.99	23.9850
^{25}Mg	10.00	24.9858
^{26}Mg	11.01	25.9826

1 amu = 1.6606×10^{-24} g

Critical Thinking Questions

1. How many isotopes of magnesium occur naturally on Earth?

2. Describe what all isotopes of magnesium have in common and also how are they different.

3. If you select one carbon atom at random, the mass of that atom is most likely to be _____ amu.

4. What is the mass (in amu) of

   a) 1000 ^{12}C atoms?

   b) 1000 ^{13}C atoms?

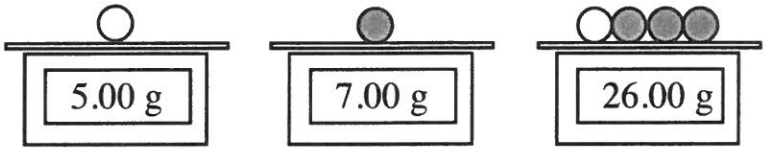
5. If you select 1000 carbon atoms at random, the total mass will most likely be ___ .

   a) 12000.0 amu
   b) slightly more than 12000.0 amu
   c) slightly less than 12000.0 amu
   d) 13003.4 amu
   e) slightly less than 13003.4 amu

   Explain your reasoning.

Model 2: The Average Mass of a Marble.

In a collection of four marbles, 25% of the marbles have a mass of 5.00 g and 75% of the marbles have a mass of 7.00 g.



The average mass of a marble can be determined by dividing the total mass of the marbles by the total number of marbles:

$$\text{average mass of a marble} = \frac{1 \times 5.00\ \text{g} + 3 \times 7.00\ \text{g}}{4} = 6.50\ \text{g} \qquad (1)$$

Or, the average mass of a marble in this collection can be determined by (a) multiplying the fraction of marbles of a particular type by the mass of a marble of that type and (b) taking a sum over all types of marbles:

$$\text{average mass of a marble} = 0.2500 \times 5.00\ \text{g} + 0.7500 \times 7.00\ \text{g} = 6.50\ \text{g} \qquad (2)$$

Critical Thinking Questions

6. How many of the four marbles in Model 2 have the same mass as the average mass?

7. For a large number of marbles (assume that the actual number of marbles is unknown), 37.2% have a mass of 10.0 g and 62.8% have a mass of 12.00 g. Which of the two methods in Model 2 should be used to determine the average mass of this collection? Explain your answer.

8. a) Use the method of equation (2) in Model 2 to calculate the average mass of a chlorine atom in amu.

   b) What fraction or percentage of chlorine atoms has this average mass?

9. For any large collection of (randomly selected) chlorine atoms:

   a) What is the average atomic mass of chlorine in amu?

   b) What is the average mass of a chlorine atom in grams?

10. Individually, use your answer to CTQ 9b to calculate the mass (in grams) of 6.022×10^{23} (randomly selected) chlorine atoms. Once all group members have completed the calculation, compare your answers and come to consensus.

11. For a large collection of (randomly selected) magnesium atoms:

    a) What is the average atomic mass of magnesium, Mg, in amu?

    b) What is the average mass of a Mg atom in grams?

12. Individually, use your answer to CTQ 11b to calculate the mass (in grams) of 6.022×10^{23} (randomly selected) magnesium atoms. Confirm that all group members have the same answer.