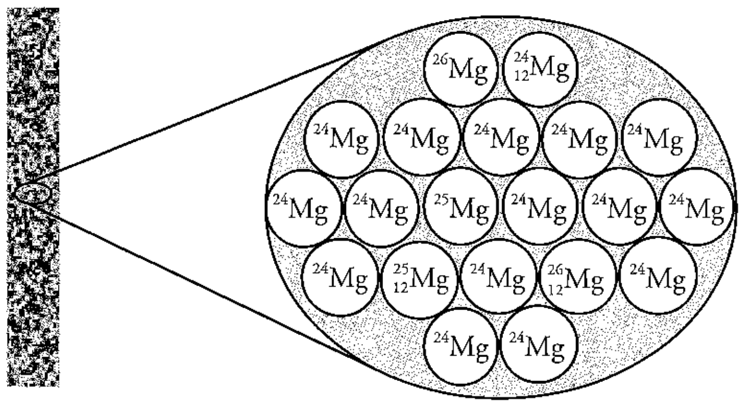
Average Atomic Mass

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.

   Three atoms have been labeled in Model 1.

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

   24, 25, 26

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

   No—since the mass numbers of the atoms are different, their atomic masses also differ.

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.

	^{24}Mg	^{25}Mg	^{26}Mg
Number of Atoms	*16*	*2*	*2*

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

   ^{24}Mg

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?

   In a goup of 10 magnesium atoms, there will be approximately one ^{25}Mg, one ^{26}Mg, and eight ^{24}Mg atoms.

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!

      78.99% of 20 atoms = 15.8 or 16 atoms *10.00% of 20 atoms = 2 atoms*

      11.01% of 20 atoms = 2.2 or 2 atoms

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

      Yes, for the limited number of atoms shown, the percentage is accurate.

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 __23.9850__ amu. Explain your reasoning.

   That isotope is the most common (most abundant), so chances are better you would pick up an atom of that mass.

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

      24.305 amu

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

      No.

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.

       There is not enough room in the boxes on the periodic table to put information about 2, 3, or several isotopes.

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

       No. In most cases a scientist will be working with a mixture of all the isotopes so information about individual isotopes is not necessary.

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?

    Calculate an average.

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.

    Add up the masses of 100 atoms of magnesium and divide by 100.

$$\frac{(78.99)(23.9850) + (10.00)(24.9858) + (11.01)(25.9826)}{100}$$

Model 3 – Proposed Average Atomic Mass Calculations

Mary's Method

$$\frac{(78.99)(23.9850\text{ amu}) + (10.00)(24.9858\text{ amu}) + (11.01)(25.9826\text{ amu})}{100} = \underline{\textit{24.305 amu}}$$

Jack's Method

$$(0.7899)(23.9850\text{ amu}) + (0.1000)(24.9858\text{ amu}) + (0.1101)(25.9826\text{ amu}) = \underline{\textit{24.305 amu}}$$

Alan's Method

$$\frac{23.9850\text{ amu} + 24.9858\text{ amu} + 25.9826\text{ amu}}{3} = \underline{\textit{24.984 amu}}$$

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?

       Mary and Jack's methods give answers that match.

    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).

       Alan found the average for only 3 atoms. Alan's method assumes equal representation of all isotopes.

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

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

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

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

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

(0.9976)(15.9949 amu) +
(0.0004)(16.9991 amu) +
(0.0020)(17.9992 amu) = 15.999 amu

Read This!

Recall that all isotopes of an element have the same physical and chemical properties, with the exception of atomic mass (and for unstable isotopes, radioactivity). Therefore, the periodic table lists a weighted **average atomic mass** for each element. In order to calculate this quantity, the natural abundance and atomic mass of each isotope must be provided.

16. Consider the individual atomic masses for magnesium isotopes given in Model 2.

    a. Which isotope has an atomic mass closest to the average atomic mass listed on the periodic table?

    ^{24}Mg

    b. Give a mathematical reason for your answer to part *a.*

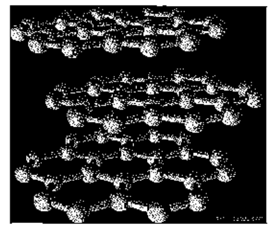
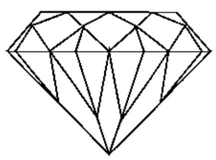
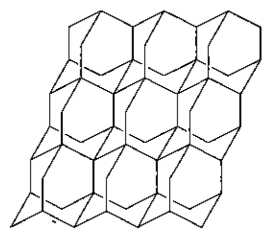
    ^{24}Mg is the most common isotope and is thus most heavily "weighted" in the equation for average atomic mass.

17. Boron has two naturally occurring isotopes: boron-10 and boron-11. Which isotope is more abundant on Earth? Use grammatically correct sentences to explain how your group determined the answer.

    The average atomic mass listed for boron in the periodic table is 10.811. This is numerically closer to the expected mass of ^{11}B than ^{10}B. Therefore we conclude that ^{11}B is more abundant on Earth than ^{10}B.

Extension Questions

Model 4 – Allotropes of Carbon

Natural Sample	Properties	Structure	Composition
 Graphite	Black Soft Conductive		98.89% Carbon-12 1.11% Carbon-13
 Diamond	Colorless Very hard Insulator		98.89% Carbon-12 1.11% Carbon-13

18. Consider the information about carbon provided in Model 4.

    a. Are diamonds and graphite made from the same element?

    Yes, they are both made of carbon.

    b. Can the existence of isotopes explain the difference in properties between diamond and graphite? Explain.

    No, isotopes have the same physical and chemical properties, and each of the samples in Model 4 has the same composition of carbon-12 and carbon-13.

    c. Propose an explanation for the difference in properties between diamond and graphite.

    The three dimensional structure of the substance is different. The atoms are bonded together in a different structure.

19. O_2 and O_3 (ozone) are allotropes of oxygen. Buckminsterfullerene (C_{60}) is another allotrope of carbon. Based on these statements and the information in Model 4, propose a definition for **allotrope**.

    Samples of the same element that have different properties because of bonding and/or structure.

20. Two common forms of phosphorus are red and white. Red phosphorus is fairly stable at room temperature in air, but white phosphorus can ignite easily when exposed to air. Is this difference in properties due to the existence of different isotopes of phosphorus or different allotropes? Explain.

    The difference in properties is because red and white phosphorus are two different allotropes of phosphorus. Isotopes have the same chemical and physical properties, so that could not explain the difference.