# Are all Atoms of the Same Element Identical?

## Why are we doing this?

When John Dalton proposed the first atomic theory, he stated "Atoms of the same element are identical." Today we know that is not true. Many elements contain several different isotopes. Isotopes are atoms of the same element that differ in mass.

### Your Learning Outcomes

You will be able to:

1. Identify how natural abundance and isotopic mass are used to determine the atomic mass of an element.
2. Relate the mass (in both amu and grams) of a collection of atoms to their atomic mass and the size of the collection.

## The Plan

1. Assign roles*.
    a. ***Manager*** – This person will keep the team on task and provide direction to the group. This person is responsible for uploading the group's work to Gradescope. Make sure you make a note of everyone in the group. You must add everyone's name when submitting your answers to Gradescope.
    b. ***Spokesperson*** – This person will represent the group be responsible for speaking for the group to the rest of the class.
    c. ***Recorder*** – This person will be responsible for recording the team's answers to the Critical Thinking Questions in an organized and coherent manner.
    d. ***Analyst*** – This person will be responsible for critical analysis of the team's work (i.e., the Devil's Advocate). This person should make sure everyone understands what is happening before the group moves forward.
2. Complete the Critical Thinking Questions as a group.
3. Submit your team's work via Gradescope. Groups may choose to work in a Word document or write out their answers on a separate sheet of paper. All work must be upload to Gradescope as a PDF file.

**Students may choose to complete this activity independently if they are unable to attend discussion due to illness or injury; in which case, the student must perform all roles and complete all aspect of the activity. To receive full credit, documentation as to the need for the absence from discussion must be included with the submission and your TA must be notified of the absence.*

**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 the masses for various isotopes.**

| Isotope | Natural Abundance on Earth (%) | Isotopic 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 = $1.6606 \times 10^{-24}$ g

**Critical Thinking Questions**

1. How many isotopes of magnesium occur naturally on Earth?
   3

2. Describe what all isotopes of magnesium have in common, and also how are they different.
   Same number of protons, different numbers of neutrons

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

   be 12.0000 amu.

4. What is the mass (in amu) of

   a. 1000 $^{12}C$ atoms?
      1200.00 amu

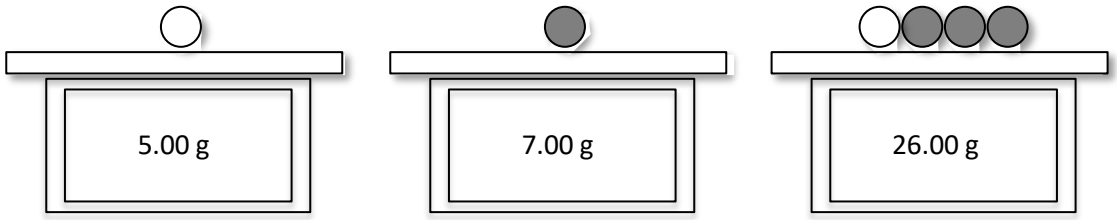
   b. 1000 $^{13}C$ atoms?
      1300.34 amu

5. If you select 1000 carbon atoms at random, the total mass will most likely be
   a. 12,000.0 amu.
   b. slightly more than 12,000.0 amu.
   c. slightly less than 12,000.0 amu.
   d. 13,003.4 amu.
   e. Slightly less than 13,003.4 amu.

   Explain your reasoning.
   Slightly more than 1200.00 amu because 1200 amu would be the minimum, and there is a 1.11 % change that a $^{13}C$ would be among the 1000 atoms.

**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?
   None

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.
   You must know the total number of marbles to use the first method. The second method must be used in this case.

8.
   a. Use the method of equation (2) in Model 2 to calculate the average mass of a chlorine atom in amu.
      $0.7577 \times 34.9689$ amu $+ 0.2423 \times 36.9659$ amu $= 35.45$ amu

   b. What fraction of percentage of chlorine atoms has this average mass?
      Zero

9. For any large collection of (randomly selected) chlorine atoms:
   a. What is the average atomic mass of chlorine in amu?
      35.45 amu

   b. What is the average mass of a chlorine atom in grams?
      $5.887 \times 10^{-23}$ g

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

11. For a large collection of (randomly selected) magnesium atoms:
    a. What is the average atomic mass of magnesium, Mg, in amu?
       24.31 amu

    b. What is the average mass of a Mg atom in grams?
       $4.037 \times 10^{-23}$ g

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

13. Examine the periodic table, and find the symbol for magnesium.
    a. How does the number given just below the symbol for magnesium (rounded to 0.01) compare with the average mass (in amu) of one magnesium atom?
       It is the same number.

    b. How does the number given just below the symbol for magnesium (rounded to 0.01) compare with the mass (in grams) of $6.022 \times 10^{23}$ magnesium atoms?
       It is the same number.

14. Find the symbol for chlorine on the periodic table:
    a. How does the number given just below the symbol for chlorine (rounded to 0.01) compare with the average mass (in amu) of one chlorine atom?
       It is the same number.

    b. How does the number given just below the symbol for chlorine (rounded to 0.01) compare with the mass (in grams) of $6.022 \times 10^{23}$ chlorine atoms?
       It is the same number.

15. Give two interpretations of the number "12.0107" found below the symbol for carbon on the periodic table.
    12.0107 is a) the average mass in amu of one C atom and b) the mass in grams of $6.022 \times 10^{23}$ C atoms.

16. What fraction or percentage of carbon atoms has a mass of 12.0107 amu?
    Zero

**Model 3: The Mole.**

1 dozen items = 12 items

1 mole of items = $6.022 \times 10^{23}$ items

17.

a. How many elephants are there in a dozen elephants?
12

b. Which has more animals—a dozen elephants or a dozen chickens?
They have the same number—12

c. How many elephants are there in a mole of elephants?
$6.022 \times 10^{23}$

d. Which has more animals—a mole of elephants or a mole of chickens?
They have the same number—$6.022 \times 10^{23}$

e. Which has more atoms—a dozen H atoms or a dozen Ar atoms?
They have the same number—12

f. Which has more atoms—a mole of hydrogen atoms or a mole of argon atoms?
They have the same number—$6.022 \times 10^{23}$

18. Without using a calculator:

a. Which weighs more—18 elephants or two dozen elephants? Explain your reasoning.
Two dozen elephants

b. Which weighs more—$5.136 \times 10^{23}$ sodium atoms or one mole of sodium atoms? Explain your reasoning.
One mole of sodium atoms

19. Which has more atoms—1.008 g of hydrogen or 39.95 g of argon? Explain your reasoning.
There is one mole of H atoms and one mole of argon atoms; they both have the same number of atoms.