

# ChemActivity 1

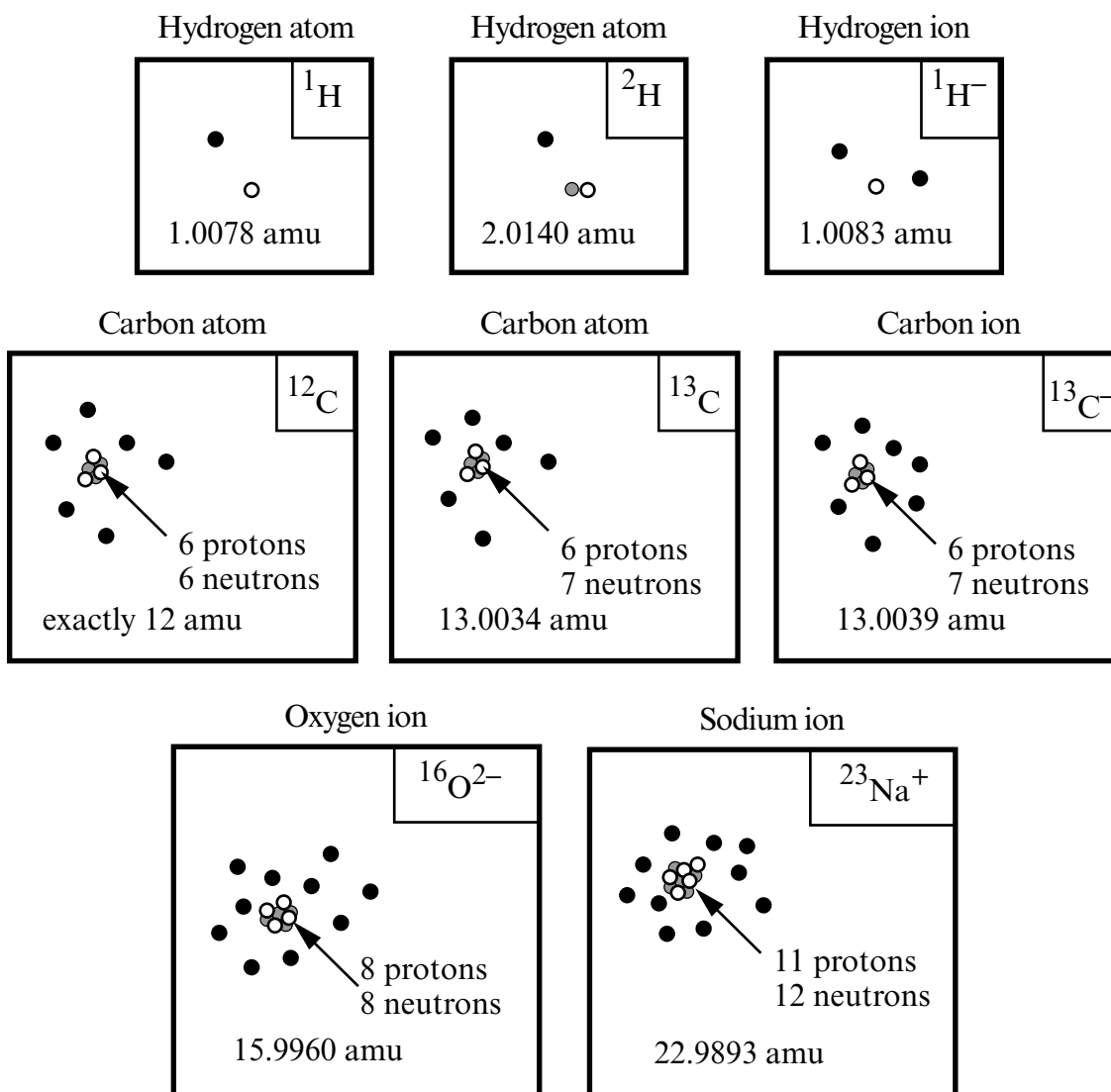
## What Makes an Atom?

### Model 1: Schematic Diagrams for Various Atoms and Ions.

- electron (-)
- proton (+)
- neutron (no charge)

$$1 \text{ amu} = 1.6606 \times 10^{-24} \text{ g}$$

The nucleus of an atom contains the protons and the neutrons.



${}^1\text{H}$  and  ${}^2\text{H}$  are **isotopes** of hydrogen.

${}^{12}\text{C}$  and  ${}^{13}\text{C}$  are **isotopes** of carbon.

## Critical Thinking Questions

- For each part, provide your own answer and then compare with your team.
  - Write the symbols for the four ions in Model 1.
  - Write the symbols for the four uncharged atoms in Model 1.
- Individually, complete the following table using information from Model 1. Then discuss your answers as a team and reach a consensus on all of the entries.

	number of protons	number of neutrons	number of electrons	charge
$^{12}\text{C}$				0
$^{13}\text{C}$				0
$^{13}\text{C}^-$				-1

- How did your team use Model 1 to determine the table entries for each of the table columns in CTQ 2?
  - number of protons
  - number of neutrons
  - number of electrons
- Based on the completed table in CTQ 2, what do all carbon atoms (and ions) have in common?
- Explain how your team reached a conclusion for CTQ 4 by specifically referring to information from the completed table in CTQ 2.

### Answer CTQs 6 – 10 as a team.

- Complete the following table using information from Model 1.

	number of protons	number of neutrons	number of electrons	charge
$^1\text{H}$				
$^2\text{H}$				
$^1\text{H}^-$				

- Based on Model 1 and the answers to part a above, what do all hydrogen atoms (and ions) have in common? Explain your reasoning.

#### 4 ChemActivity 1 What Makes an Atom?

7. Locate the atomic symbols for carbon and hydrogen in a periodic table. There is a number above each symbol in the periodic table, called the **atomic number**. Based on your answers to CTQs 4 and 6b, what is the significance of the atomic number above each atomic symbol in the periodic table?
8. Based on the answer to CTQ 7, what do all nickel (Ni) atoms have in common?
9. In terms of the numbers of protons, neutrons and electrons:
- Why does the notation  $^{13}\text{C}^-$  have a negative sign in the upper right-hand corner?
  - What feature distinguishes a neutral atom from an ion?
  - Provide a mathematical expression for calculating the charge on an ion from the number of protons and the number of electrons.
10. a) What are the two isotopes of carbon shown in the model?
- b) Based on the information in Model 1, what structural feature is different in isotopes of a particular element?

### Information

The left-hand superscript next to the atomic symbol as shown in the Model is known as the **mass number**, often represented by the symbol  $A$ . Surprisingly, the mass number is *not* determined from the mass of the atom.

The **atomic number**, which we have identified as the number of protons in the nucleus of an atom or ion, is often represented by the symbol  $Z$ .

Many textbooks use the following representation for an atom:  $^A_Z\text{X}$ . In this case, X is the atomic symbol for the element. Often, the atomic number  $Z$  is omitted (as in Model 1) because the atomic number for an element does not change.

### Critical Thinking Questions

11.     a)    Based on the Information, what is the value of  $Z$  for a carbon atom?  
       b)    What is the mass number for the carbon ion in Model 1?  
       c)    Use the data in the completed tables from CTQs 2 and 6a to describe how the mass number is obtained.
12.    As a team, determine the number of protons, neutrons, and electrons in one  ${}^1\text{H}^+$  ion. Describe the thinking your team used to determine each value.
13.    Show that the mass number and charge given for  ${}^{16}\text{O}^{2-}$  and  ${}^{23}\text{Na}^+$  are correct in Model 1. Check your answers with your team.
14.    Using information from Model 1, where is most of the mass of an atom or ion: within the nucleus or outside of the nucleus? Explain your reasoning in a few sentences. Include examples from Model 1 to support your answer.
- Read your answers to each other and then make any needed changes to your response so that you have the best overall team answer recorded.
- (Hint: The **mass number** is not relevant to answering this question.)

**Exercises**

1. Complete the following table.

Isotope	Atomic Number $Z$	Mass Number $A$	Number of Electrons
$^{31}\text{P}$	15		
$^{18}\text{O}$			8
	19	39	18
$^{58}\text{Ni}^{2+}$		58	

2. What is the mass (in grams) of:
- one  $^1\text{H}$  atom?
  - one  $^{12}\text{C}$  atom?
3. What is the mass (in grams) of  $4.35 \times 10^6$  atoms of  $^{12}\text{C}$ ?
4. What is the mass (in grams) of  $6.022 \times 10^{23}$  atoms of  $^{12}\text{C}$ ?
5. What is the mass (in grams) of one molecule of methane which has one  $^{12}\text{C}$  atom and four  $^1\text{H}$  atoms,  $^{12}\text{C}^1\text{H}_4$ ?
6.
  - Define mass number.
  - Define atomic number.
7. Indicate whether the following statement is true or false and explain your reasoning.  
An  $^{18}\text{O}$  atom contains the same number of protons, neutrons, and electrons.
8. How many electrons, protons, and neutrons are found in each of the following?
- $^{24}\text{Mg}$
  - $^{23}\text{Na}^+$
  - $^{35}\text{Cl}$
  - $^{35}\text{Cl}^-$
  - $^{56}\text{Fe}^{3+}$
  - $^{15}\text{N}$
  - $^{16}\text{O}^{2-}$
  - $^{27}\text{Al}^{3+}$
9. The element with  $Z = 14$  has three isotopes with these numbers of neutrons: 14, 15, 16. Identify the element and provide the symbol for each isotope.
10. An element has  $A = 7$  and  $Z = 3$ . It forms a +1 ion.
- How many neutrons are present?
  - Provide the symbol for the ion.
  - Describe how you determined the answer for each part.

11. Complete the following table.

Isotope	Atomic Number Z	Mass Number A	Number of Electrons
	27	59	25
$^{14}\text{N}$	3	7	3
	3	6	3
$^{58}\text{Zn}^{2+}$			
$^{19}\text{F}^-$			

12. Describe what the isotopes of an element have in common and how they are different.
13. What makes an atom? Provide an answer in complete sentences that describes the components of an atom and how those components relate to the atomic symbol for the various isotopes of an atom.

## Problems

- Estimate the mass of one  $^{14}\text{C}$  atom (in amu) as precisely as you can (from the data in the model). Explain your reasoning.
- Use the data in Model 1 to estimate the values (in amu) of:
  - the mass of an electron
  - the mass of a proton
  - the mass of a neutron
- The mass values calculated in Problem 2 are only approximate because when atoms (up through iron) are made (mainly in stars) from protons, neutrons, and electrons, energy is released. Einstein's equation  $E = mc^2$  enables us to relate the energy released to the mass loss in the formation of atoms. Use the known values for the mass of a proton, 1.0073 amu, the mass of a neutron, 1.0087, and the mass of an electron,  $5.486 \times 10^{-4}$  amu, to show that the mass of a  $^{12}\text{C}$  atom is less than the sum of the masses of the constituent particles.