The Nuclear Atom

Model: Schematic Diagrams for Various Atoms.

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

### Hydrogen

- \(^1\text{H}\)
- \(^2\text{H}\)

- \(0.0078 \text{ amu}\)
- \(2.0140 \text{ amu}\)

### Carbon

- \(^{12}\text{C}\)
- \(^{13}\text{C}\)

- 6 protons
- 6 neutrons
- exactly 12 amu

- 6 protons
- 7 neutrons
- 13.0034 amu

- 6 protons
- 7 neutrons
- 13.0039 amu

### Oxygen ion

- \(^{16}\text{O}^{2-}\)

- 8 protons
- 8 neutrons
- 15.9960 amu

### Sodium ion

- \(^{23}\text{Na}^+\)

- 11 protons
- 12 neutrons
- 22.9893 amu

\(^1\text{H}\) and \(^2\text{H}\) are isotopes of hydrogen.

\(^{12}\text{C}\) and \(^{13}\text{C}\) are isotopes of carbon.

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

Q1. How many **protons** are found in $^{12}$C? $^{13}$C? $^{14}$C?
   6 in each

Q2. How many **neutrons** are found in $^{12}$C? $^{13}$C? $^{14}$C?
   6, 7, 7

Q3. How many **electrons** are found in $^{12}$C? $^{13}$C? $^{14}$C?
   6, 6, 7

Q4. a) Which kind of particle distinguishes a neutral atom from a charged ion?
   
   Number of electrons ($6^- \text{ in } ^{13}\text{C}, vs \ 7^- \text{ in } ^{14}\text{C}$)

   b) Show using a mathematical equation how the charge on an ion can be determined.
   
   \[ \text{charge} = \text{# of protons} - \text{# of electrons} \]

Q5. Based on the model,

   a) What do all carbon atoms (and ions) have in common?
   
   6 protons

   b) What do all hydrogen atoms (and ions) have in common?
   
   1 proton

   c) How many protons, neutrons, and electrons are there in one atom of $^{1}$H$^{+}$?
   
   $^{1}\text{H}^{+}$: 1 proton, 0 neutrons, 0 electrons
   
   (Since 1H atom has 1 proton, 0 neutrons, and 1 electron)

Q6. Look at the periodic table. What does the **atomic number** (above each atomic symbol) represent in terms of an atom’s structure?

   ![Periodic Table]

   - atomic #

   represents the \# of protons

   in any atom/ion of that element

   (Both $^{1}\text{H}$ and $^{2}\text{H}$ have 1 proton, which makes them both hydrogen.)
Q7. Based on your answer to Q6, what do all nickel (Ni) atoms have in common? (Be as specific as possible).

All Ni atoms have 28 protons.

Q8. What structural feature is different in isotopes of a particular element?

$^{12}_C$ vs $^{13}_C$ isotopes —

# of neutrons is different.

Q9. In the Model, the mass number is shown as the left-hand superscript next to the atomic symbol. How is the mass number determined from the structure of the atom?

$^{12}_C$

mass # = # of protons + # of neutrons

Q10. An atomic mass unit (amu) is the unit of mass used for small particles like atoms and ions. The atomic masses are given in the Model for various atoms/ions.

Based on the Model, where is most of the mass of an atom, within the nucleus or outside of the nucleus?

Within the nucleus.

Using only the Model, how can you "prove" to someone that most of the mass of the atom is inside or outside of the nucleus? Explain in the space below.

Comparing $^1H$ + $^2H$: adding a neutron nearly doubles the mass (amu) → a neutron has a significant effect on the atom's mass, (a neutron adds ≈ 1 amu)

Comparing $^{13}_C$ + $^{13}_C^-$: adding an electron adds on ≈ 0.0005 amu → an electron does NOT have a significant effect on the atom's mass, $^{12}_C$ has 6 protons + 6 neutrons + weight 12 amu, if 1 electron ≈ 1 amu, a significant effect on the atom's mass.
Exercises  This activity covers some material in Tro, Chapter 4.3-4.5, 4.7-4.8. Refer to this text if you need help.

1. Complete the following table

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Atomic Number</th>
<th>Mass Number</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Number of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{40}$K</td>
<td>19</td>
<td>40</td>
<td>19</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>$^{32}$P</td>
<td>15</td>
<td>32</td>
<td>15</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>$^{30}$Zn$^{2+}$</td>
<td>30</td>
<td>68</td>
<td>30</td>
<td>38</td>
<td>66</td>
</tr>
<tr>
<td>$^{81}$Br$^{-}$</td>
<td>35</td>
<td>81</td>
<td>35</td>
<td>46</td>
<td>36</td>
</tr>
</tbody>
</table>

2. Indicate whether the following statement is true or false and explain your reasoning.

An $^{18}$O atom contains the same number of protons, neutrons, and electrons.

False. $^{18}$O contains 8 protons, 10 neutrons, and 8 electrons.

3. e$^-$ is the symbol for electrons. See if you can complete the following equations:

a) Mg $\rightarrow$ Mg$^{2+}$ $+$ 2e$^-$

b) F $+$ e$^-$ $\rightarrow$ F$^-$

c) Al $\rightarrow$ Al$^{3+}$ $+$ 3e$^-$

d) Ca$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Ca

4. How many protons, neutrons, and electrons are found in each of the following?

$^{24}$Mg $12$ protons, $12$ electrons, $12$ electrons
e$^{26}$Fe$^{5+}$ $12$ protons, $10$ neutrons, $23$ electrons
$^{22}$Na$^+$ $11$ protons, $10$ neutrons, $10$ electrons
$^{35}$Cl $17$ protons, $18$ neutrons, $18$ electrons
$^{35}$Cl$^-$ $17$ protons, $18$ neutrons, $18$ electrons

5. Using grammatically correct sentences, describe what the isotopes of an element have in common and how they are different.

Isotopes of an element will have the same # of protons but different # of neutrons.

6. Define the terms in bold from the activity. Memorize them.

7. For practice, try Chapter 4 problems in Tro: #71-77 (odd), 83-93 (odd), 107