**Information:** Structure of the Atom

Note the following symbols: (they are not to scale)

- ○ = proton (positive charge)
- ● = electron (negative charge)
- ● = neutron (no charge)

The following three diagrams are hydrogen atoms:

The following three diagrams are carbon atoms:

(6 protons, 6 neutrons) (6 protons, 7 neutrons) (6 protons, 8 neutrons)

Notice the type of notation used for atoms: \[ \frac{A}{Z} X \]

- X = chemical symbol of the element
- Z = "atomic number"
- A = "mass number"

\[ ^{12}_6 \text{C}, \; ^{13}_6 \text{C}, \; ^{14}_6 \text{C} \] are notations that represent isotopes of carbon.

\[ ^1_1 \text{H}, \; ^2_1 \text{H}, \; ^3_1 \text{H} \] are notations that represent isotopes of hydrogen.

The part of the atom where the protons and neutrons are is called the nucleus.
**Critical Thinking Questions**

1. How many protons are found in each of the following: $^1\text{H}$? in $^2\text{H}$? in $^3\text{H}$? 
   - one in each

2. How many neutrons are found in each of the following: $^1\text{H}$? in $^2\text{H}$? in $^3\text{H}$? 
   - 0 in $^1\text{H}$, 1 in $^2\text{H}$, 2 in $^3\text{H}$

3. How many electrons are found in each of the following: $^1\text{H}$? in $^2\text{H}$? in $^3\text{H}$? 
   - one in each

4. What structural characteristics do all hydrogen atoms have in common? 
   - one proton, one electron

5. What structural characteristics do all carbon atoms have in common? 
   - six protons, six electrons

6. What does the mass number tell you? Can you find the mass number of an element on the periodic table? 
   - # of protons + # of neutrons 
   - You cannot find this on the PT (must be a whole #)

7. What does the atomic number tell you? Can you find the atomic number of an element on the periodic table? 
   - # protons, yes

8. Define the term **isotope**. 
   - atoms of the same element with different # of neutrons

9. How does one isotope of carbon differ from another isotope of carbon? 
   - different number of neutrons
**Information**: Atoms, Ions, Masses of Subatomic Particles

The atomic mass unit (amu) is a special unit for measuring the mass of very small particles such as atoms. The relationship between amu and grams is the following: $1.00 \text{ amu} = 1.66 \times 10^{-24} \text{ g}$

Note the following diagrams comparing atoms and ions.

![Atom and Ion Diagrams]

$$^{19}_{9} \text{F}$$  
mass = 18.9980 amu  
$$^{19}_{9} \text{F}^{-1}$$  
mass = 18.9985 amu  

$$^{24}_{12} \text{Mg}$$  
mass = 23.9978 amu  
$$^{24}_{12} \text{Mg}^{+2}$$  
mass = 23.9968 amu

**Critical Thinking Questions**

10. What is structurally different between an atom and an ion? Note: This is the ONLY structural difference between an atom and an ion.

11. In atomic mass units (amu), what is the mass of an electron?

   0.0005 amu

12. Is most of the mass of an atom located in the nucleus or outside the nucleus? How do you know?

   inside the nucleus, the e- on the outside have very little mass

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13. If protons and neutrons have the same mass, what is the approximate mass of a proton and neutron in atomic mass units (amu)?

\[ \sim 1 \text{ amu} \]

14. The mass of $^{14}_6\text{C}$ is about 14 amu. Does this agree with what you determined in questions 11 and 13?

Yes

15. The charge (in the upper right hand corner of the element symbol) is $-1$ for a fluorine ion. Why isn't it $+1$ or some other number?

-e have a negative charge and it has one extra electron

16. What is the charge on every atom? Why is this the charge?

 Neutral, same \# of protons and electrons

17. How do you determine the charge on an ion?

Compare the \# of protons and electrons

18. An oxygen ion has a $-2$ charge. (Use your periodic table if necessary)
   a) How many protons does the oxygen ion have?

8

b) How many electrons does the oxygen ion have?

10

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<table>
<thead>
<tr>
<th>Chemical symbol</th>
<th>Mass number</th>
<th>Atomic number</th>
<th>Number of protons</th>
<th>Number of neutrons</th>
<th>Number of electrons</th>
<th>Net charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{7}_{3}\text{Li}$</td>
<td>7</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>$^{31}_{15}\text{P}$</td>
<td>31</td>
<td>15</td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>$^{45}_{21}\text{Sc}$</td>
<td>45</td>
<td>21</td>
<td>21</td>
<td>24</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>$^{64}_{29}\text{Cu}$</td>
<td>64</td>
<td>29</td>
<td>29</td>
<td>35</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>$^{131}_{54}\text{Xe}$</td>
<td>131</td>
<td>54</td>
<td>54</td>
<td>77</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>$^{237}_{93}\text{Np}$</td>
<td>237</td>
<td>93</td>
<td>93</td>
<td>144</td>
<td>93</td>
<td>0</td>
</tr>
<tr>
<td>$^{16}_{8}\text{O}^{2-}$</td>
<td>16</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>2-</td>
</tr>
<tr>
<td>$^{70}_{31}\text{Ga}^{3+}$</td>
<td>70</td>
<td>31</td>
<td>31</td>
<td>39</td>
<td>28</td>
<td>3+</td>
</tr>
<tr>
<td>$^{52}_{24}\text{Cr}^{5+}$</td>
<td>52</td>
<td>24</td>
<td>24</td>
<td>28</td>
<td>18</td>
<td>6+</td>
</tr>
<tr>
<td>$^{14}_{7}\text{N}^{3-}$</td>
<td>14</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>3-</td>
</tr>
<tr>
<td>$^{56}_{26}\text{Fe}^{2+}$</td>
<td>56</td>
<td>26</td>
<td>26</td>
<td>30</td>
<td>24</td>
<td>2+</td>
</tr>
<tr>
<td>$^{89}_{39}\text{Y}$</td>
<td>89</td>
<td>39</td>
<td>39</td>
<td>50</td>
<td>39</td>
<td>0</td>
</tr>
<tr>
<td>$^{108}_{47}\text{Ag}^{+}$</td>
<td>108</td>
<td>47</td>
<td>47</td>
<td>61</td>
<td>46</td>
<td>1+</td>
</tr>
<tr>
<td>$^{137}_{56}\text{Ba}^{2+}$</td>
<td>137</td>
<td>56</td>
<td>56</td>
<td>81</td>
<td>54</td>
<td>2+</td>
</tr>
<tr>
<td>$^{119}_{50}\text{Sn}$</td>
<td>119</td>
<td>50</td>
<td>50</td>
<td>69</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>$^{80}_{34}\text{Se}^{2-}$</td>
<td>80</td>
<td>34</td>
<td>34</td>
<td>46</td>
<td>36</td>
<td>2-</td>
</tr>
</tbody>
</table>
Atomic Structure

1. Consider the three fundamental particles: electrons (e⁻), protons (p⁺), and neutrons (n°)
   a. Which has the smallest mass? e⁻
   b. Which is uncharged? n°
   c. Which is found outside the nucleus? p⁺
   d. Which 2 have nearly the same mass? p⁺ and n°

2. Complete the following table using the information given

<table>
<thead>
<tr>
<th>Chemical symbol</th>
<th>Atomic number</th>
<th>Number of protons</th>
<th>Mass number</th>
<th>Number of electrons</th>
<th>Number of neutrons</th>
<th>Net charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>²²²²Rn</td>
<td>86</td>
<td>86</td>
<td>222</td>
<td>86</td>
<td>136</td>
<td>0</td>
</tr>
<tr>
<td>¹³³Ba⁺</td>
<td>56</td>
<td>56</td>
<td>137</td>
<td>54</td>
<td>81</td>
<td>2⁺</td>
</tr>
<tr>
<td>⁴⁸Ti</td>
<td>22</td>
<td>22</td>
<td>48</td>
<td>22</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>⁸⁰Br⁻</td>
<td>35</td>
<td>35</td>
<td>80</td>
<td>36</td>
<td>45</td>
<td>1⁻</td>
</tr>
<tr>
<td>³⁹K⁺</td>
<td>19</td>
<td>19</td>
<td>39</td>
<td>18</td>
<td>20</td>
<td>1⁺</td>
</tr>
</tbody>
</table>

3. Consider the table below

<table>
<thead>
<tr>
<th>Atom (ion) of element</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of electrons</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>7</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Number of protons</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Number of neutrons</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Mass number</td>
<td>10</td>
<td>14</td>
<td>20</td>
<td>20</td>
<td>15</td>
<td>11</td>
<td>19</td>
</tr>
</tbody>
</table>

a. Which of the species above are electrically neutral? a, b, e, g
b. Which are negatively charged? d, f

c. Which are isotopes of the same element? a + f, b + e

d. Using the periodic table, write the conventional symbol for b, d, and f

\[
\begin{align*}
  b &= \frac{14}{7}N \\
  d &= \frac{20}{10}Ne²⁻ \\
  f &= \frac{11}{5}B⁻
\end{align*}
\]

4. How does the number of protons compare to the number of electrons in:
   a. An anion? more e⁻ than p⁺
   b. A cation? more p⁺ than e⁻

5. How do the chemical properties of carbon-12 and carbon-14 compare?

6. How do the physical properties of carbon-12 and carbon-14 compare?

\text{physical + chemical properties are the same for isotopes}
7. Consider the data table below

<table>
<thead>
<tr>
<th>Atom (ion) of element</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of electrons</td>
<td>12</td>
<td>13</td>
<td>11</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Number of protons</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>Number of neutrons</td>
<td>12</td>
<td>14</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>10</td>
</tr>
</tbody>
</table>

a. Which of the above species are negatively charged? b, c
b. Which species are isotopes of the same element? a, d

c. Give the conventional chemical symbol (including charge) for species A, B, and F.

\[ a = \frac{24}{12} \text{Mg} \quad b = \frac{24}{10} \text{Ne}^{3-} \quad f = \frac{34}{18} \text{Ar}^{3+} \]

8. What must be done to a neutral chlorine atom in order for it to change into a Cl\(^-\) ion? Be specific.

must gain 1 electron

9. Complete the following table

<table>
<thead>
<tr>
<th>Chemical symbol</th>
<th>Atomic number</th>
<th>Number of neutrons</th>
<th>Mass number</th>
<th>Number of electrons</th>
<th>Net charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{39}{19} \text{K}^+)</td>
<td>19</td>
<td>20</td>
<td>39</td>
<td>18</td>
<td>1+</td>
</tr>
<tr>
<td>(\frac{106}{46} \text{Pd}^{2+})</td>
<td>46</td>
<td>60</td>
<td>106</td>
<td>44</td>
<td>2+</td>
</tr>
<tr>
<td>(\frac{83}{32} \text{S}^{2-})</td>
<td>16</td>
<td>16</td>
<td>32</td>
<td>18</td>
<td>2-</td>
</tr>
<tr>
<td>(\frac{83}{83} \text{Bi}^{3+})</td>
<td>83</td>
<td>126</td>
<td>209</td>
<td>80</td>
<td>3+</td>
</tr>
</tbody>
</table>

10. Which two fundamental particles (\(e^+, p^-, n^0\)) have the same mass? \(p^+ + n^0\)

11. Which particle accounts for virtually all of any atom's volume? \(e^-\)

12. Exactly how does an atom of P differ from \(P^3-\) ? \(P^3-\) has three more electrons

must lose two electrons

Average atomic mass

14. The element X consists of three isotopes \(^{10}X\) (25%), \(^{11}X\) (65%), and \(^{12}X\) (10%).

a. Calculate the average atomic mass (using correct units!)

\[
\left(0.25 \times 10\right) + \left(0.65 \times 11\right) + \left(0.10 \times 12\right) = 10.85 \text{ amu}
\]

b. Are there any atoms of X that weigh your reported average atomic mass? Explain your answer.

No, it is an average

15. The element neon (Ne) is found in three isotopic forms: \(^{19}\text{Ne}\) (10% abundant), \(^{20}\text{Ne}\) (80% abundant), and \(^{21}\text{Ne}\) (10% abundant). Calculate the average atomic mass of Ne. Include proper units with your answer.

\[
\left(0.1 \times 19\right) + \left(0.80 \times 20\right) + \left(0.10 \times 21\right) = 20 \text{ amu}
\]
Average Atomic Mass

Calculate the average atomic masses. Round all answers to two decimal places. Record your answer with the correct units.

1. Iodine is 80% $^{127}$I, 17% $^{126}$I, and 3% $^{128}$I. Calculate the average atomic mass of iodine.

$$\left(0.80 \times 127\right) + \left(0.17 \times 126\right) + \left(0.03 \times 128\right) = 126.86 \text{ amu}$$

2. Calculate the average atomic mass of lithium, which occurs as two isotopes that have the following atomic masses and abundances in nature: 6 amu, 7.30% and 7 amu, 92.70%.

$$\left(0.073 \times 6\right) + \left(0.927 \times 7\right) = 6.927 \text{ amu}$$

3. Hydrogen is 99% $^1$H, 0.8% $^2$H, and 0.2% $^3$H. Calculate its average atomic mass.

$$\left(0.99 \times 1\right) + \left(0.008 \times 2\right) + \left(0.002 \times 3\right) = 1.012 \text{ amu}$$

4. Calculate the average atomic mass of magnesium using the following data for three magnesium isotopes.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>mass (u)</th>
<th>relative abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg-24</td>
<td>23.985</td>
<td>0.7870</td>
</tr>
<tr>
<td>Mg-25</td>
<td>24.986</td>
<td>0.1013</td>
</tr>
<tr>
<td>Mg-26</td>
<td>25.983</td>
<td>0.1117</td>
</tr>
</tbody>
</table>

$$\left(0.187 \times 23.985\right) + \left(0.1013 \times 24.986\right) + \left(0.1117 \times 25.983\right) = 24.31 \text{ amu}$$

5. Calculate the average atomic mass of iridium using the following data for two iridium isotopes.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>mass (u)</th>
<th>relative abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ir-191</td>
<td>191.0</td>
<td>0.3758</td>
</tr>
<tr>
<td>Ir-193</td>
<td>193.0</td>
<td>0.6242</td>
</tr>
</tbody>
</table>

$$\left(0.3758 \times 191\right) + \left(0.6242 \times 193\right) = 192.25 \text{ amu}$$

6. Lithium has two naturally occurring isotopes: lithium-6 and lithium-7. If the average atomic mass of lithium is 6.941 amu, which isotope is the most abundant? How do you know?

7 because 6.941 is closer to 7 than 6