Physics: Atomic Structure and Bonding

ENGAGE: Atomic models

Atoms are depicted in many different ways in books or on the internet. Sometimes this is done to make the atom shown easier to understand. At other times, it is simply an artistic exercise.

1. In the space below, choose six models or depictions of atoms in books or on the internet. Draw them or print and paste them into the space below. Describe the similarities and differences between them:

ANS: Snip your drawing here
EXPLORE: Atomic structure

Earlier we studied how charged objects interact. Objects carrying charge of the same sign repelled while objects carrying charge of the opposite sign attracted. To understand the origins of the charge carried by different materials we need to examine the atoms they are made from.

An atom is composed of three types of subatomic particles: positively charged protons (+) found in the nucleus, neutral neutrons (0) found in the nucleus, and negatively charged electrons (−) orbiting the nucleus.

Although electrons and protons are vastly different in physical size, the charge they carry is equal in size but opposite in sign.

Atoms are neutral. They have no overall charge because they have equal numbers of protons and electrons.

A difference between the number of protons and electrons in an atom will result in the atom having an overall charge.

Protons are secure in the nucleus and remain constant in any one type of atom (element, e.g. carbon). Changing the number of protons changes the element (e.g. removing a proton from carbon produces boron).

In contrast, electrons can be lost or gained under certain conditions.

Gaining or losing electrons causes an overall negative or positive charge in the atom, producing an ion.

We will save the workings of the nucleus for a later chapter. To understand electrostatics, we need to concentrate on understanding electrons.

Electrons are found in shells. The higher the atomic number, the more electrons and shells an atom has.

Electrons

Electrons are the negatively charged particles of the atom. Together, all of the electrons of an atom create a negative charge that balances the positive charge of the protons in the atomic nucleus.

2. (a) If a neutral atom has 18 protons how many electrons would it have? __________________________

   (b) If a neutral atom has 10 protons how many electrons would it have? __________________________

ANS:

3. What would happen to the charge of an atom if it were to:
   (a) Lose an electron? __________________________
   (b) Gain an electron? __________________________

ANS:
4. (a) If an atom had 3 protons but only 2 electrons how would this atom be affected? 

(b) If an atom had 16 protons but 18 electrons how would this atom be affected? 

ANS:

EXPLAIN: Electrons, atoms, and ions

The electrons dictate the chemical behavior of an atom, and most importantly it is the electrons in the outer shell (the valence shell) that are gained or lost when an atom becomes an ion. The electrons in the valence shell also take part in chemical reactions.

Electrons are arranged around an atom's nucleus in specific ways (below). Electron shells only hold a certain number of electrons. The first shell can hold 2 and the second and third can hold 8 each. The diagram below shows an atom with 20 electrons.

1. Two electrons are found in the 1st (inner most) electron shell.
2. A maximum of eight electrons are found in the 2nd and 3rd shells.
3. Any remaining electrons are added to the 4th electron shell.

Electrons have a property called spin (either up or down). When an orbital is more than half full of electrons, the electrons pair up, cancelling out the spins.

Atoms with full valence shells are chemically stable (e.g. helium). They do not undergo chemical reactions. An atom without a full valence shell will undergo a chemical reaction in order to obtain a full valence shell. During the reaction electrons may be gained, lost, or shared between atoms, depending on the number of electrons in the valence shell.

5. What is the valence shell of an atom?

ANS:

6. Use the diagram above to predict the following:
   (a) Will lithium (3 protons) gain or lose electrons in a reaction? ______________________
   (b) Will chlorine (17 protons) lose or gain electrons in a reaction? ______________________
   (c) How reactive would you expect an atom with 18 electrons to be? ______________________
   (d) How many electrons would oxygen (8 protons) need to gain to become stable? ______________________

ANS:
Forming ions

- Remember neutral atoms have equal numbers of electrons and protons. Since the number of protons in an atom does not change, fewer or extra electrons can create a charged atom called an ion.
- Cations have fewer electrons than the original neutral atom and therefore have an overall positive charge.
- Anions have more electrons than the original neutral atom and therefore have an overall negative charge.
- Ions are not the same as the neutral atom. They have different properties due to carrying a charge and so behave differently.

In the example below, a sodium atom reacts with a chlorine atom. The sodium atom loses an electron, which is donated to the chlorine atom. The sodium atom now has one less negative charge than positive charges and so becomes a positive ion. The chlorine atom gains one extra negative charge and so become a negative ion.

7. Explain why sodium loses an electron during a reaction:

ANS:

8. Explain why chlorine gains an electron during a reaction:

ANS:

9. (a) Draw a diagram showing the magnesium ion (12 protons) (as above):

(b) Draw a diagram showing the oxide ion (8 protons): $\text{O}^-$ (as above)

ANS: SNIP HERE
10. In Investigation 2.5, when we rubbed the balloon with the wool/synthetic fabric, what was happening with the electrons between the two materials to produce the reactions we observed?

ANS:

11. Over time, the charges dissipated. What was happening with the electrons for the materials to neutralize?

ANS:

**EXPLAIN: Atoms, ions, and the periodic table**

- The periodic table is arranged in a specific way so we are able to gain a lot of information about an atom of an element just by looking at its position in the table.

<table>
<thead>
<tr>
<th>Period</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>Be</td>
<td>Mg</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>S</td>
</tr>
<tr>
<td>3</td>
<td>Li</td>
<td>Na</td>
<td>K</td>
<td>Rb</td>
<td>Cs</td>
<td>Fr</td>
</tr>
<tr>
<td>4</td>
<td>Mg</td>
<td>Ca</td>
<td>Sr</td>
<td>Ba</td>
<td>Ra</td>
<td>Lu</td>
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<tr>
<td>5</td>
<td>Al</td>
<td>Ga</td>
<td>In</td>
<td>Sn</td>
<td>Sb</td>
<td>Te</td>
</tr>
<tr>
<td>6</td>
<td>Si</td>
<td>Ge</td>
<td>As</td>
<td>Se</td>
<td>Br</td>
<td>Kr</td>
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<tr>
<td>7</td>
<td>P</td>
<td>As</td>
<td>Po</td>
<td>At</td>
<td>Rn</td>
<td>Lu</td>
</tr>
</tbody>
</table>

- Elements are arranged numerically based on the number of protons in an atom of that element's nucleus (hydrogen has one proton, helium has 2, carbon has 6, and oxygen has 8 for example).
- Elements are arranged in rows called periods which tells us how many electron shells the atoms have (the 1st period has one electron shell, the 2nd period has two, the 3rd has three and so on).
- Elements are arranged in columns called groups. All the atoms in a group have the same number of electrons in their valence shell.
- Elements on the left side of the periodic table (the metals) become positively charged ions (cations) and elements on the right side (the non metals) become negatively charged ions (anions).

12. (a) The atoms in group 1 of the periodic table form an ion with what charge? _______________________
(b) The atoms in group 2 of the periodic table form an ion with what charge? _______________________
(c) The atoms in group 17 of the periodic table form an ion with what charge? _______________________
(d) The atoms in group 16 of the periodic table form an ion with what charge? _______________________
(e) Would you expect the elements in group 18 to form ions? Explain: _______________________

ANS:
The number of valence electrons determines whether the atom is likely to gain or lose electrons to achieve a full valence shell.
- The fewer valence electrons an atom has, the more likely it is to give up an electron.
- The closer the atom is to having a full valence shell, the more likely it is to gain an electron.

13. Which would you expect to be more reactive: Sodium or magnesium?

14. Complete the following paragraph about chlorine by filling in the blank spaces:

Chlorine has an atomic number of _____ . It has ____ protons and ____ electrons. The first orbital around chlorine’s nucleus has ____ electrons, the second has ____ electrons, and, the third orbital has______ electrons for a total of ____ electrons. When chlorine forms an ion it will ________ ____ electron to become a ____________ ion.

ANS: rewrite the sentence above with the correct terms