6.9: Binary Ionic Compounds and Their Properties

All ionic compounds have numerous properties in common. Consequently, the ability to recognize an ionic compound from its formula will allow you to predict many of its properties. This is often possible in the case of a **binary compound** (one which contains only two elements), because formation of a binary ionic compound places quite severe restrictions on the elements involved. One element must be a metal and must have a very low ionization energy (see Figure **6.9.1** for the IE of various metals). The other element must be a nonmetal and must have a very high electron affinity.

In the following paragraphs, many references will be made to groups on the periodic table. Use the figure below for reference to keep track of the groups referred to in the paragraph.

Even though metals in general have low ionization energies, not all of them are low enough to form binary ionic compounds with a large fraction of the nonmetals. Although it is impossible to draw an exact line of demarcation, a good working rule is that essentially all binary compounds involving metals from periodic group 1, group 2, group 3 (Sc, Y, Lu), and the lanthanoids will be ionic. (Hydrogen is not a metal and is, therefore, an exception to the rule for group 1. Beryllium, whose ionization energy of 899 kJ mol^{-1} is quite high for a metal, also forms many binary compounds which are not ionic. Beryllium is the only exception to the rule from group 2.)

The transition metals to the right of group 3 in the periodic table form numerous binary compounds which involve covalent bonding, so they cannot be included in our rule. The same is true of the metals in periodic groups 13, 14, and 15.

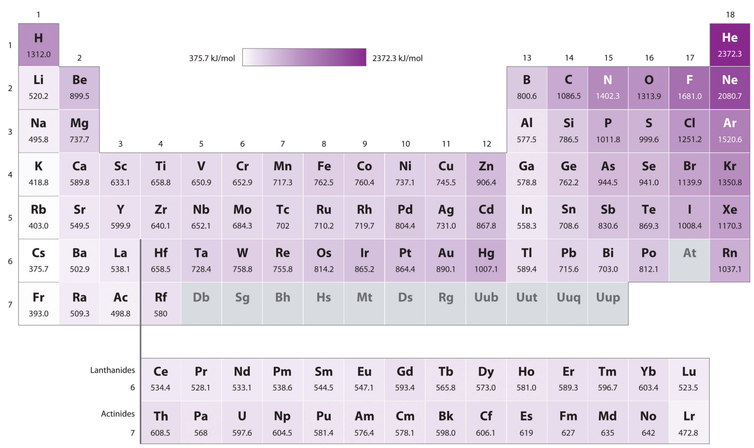

Figure 6.9.1 The image above shows the ionization energy of elements, with darker shades representing higher ionization energies. (CC-SA_BY-NC 3.0; anonymous)

The periodic table is colored with different shades of purple. The general trend observed here is that the purple gets darker across a period. All of the lightest colors are found on the left side of the periodic table and the darkest colors are found among the noble gas group.

The number of nonmetals with which a group 1, 2, 3, or lanthanoid metal can combine to form a binary ionic compound is even more limited than the number of appropriate metals. Such nonmetals are found mainly in periodic groups 16 and 17. The only other elements which form monatomic anions under normal circumstances are hydrogen (which forms H^{-}ions) and nitrogen (which forms N^{3-} ions).

In addition to combining with metals to form ionic compounds, all of the nonmetals can combine with other nonmetals to form covalent compounds as well. Therefore, presence of a particular nonmetal does not guarantee that a binary compound is ionic. It is necessary, however, for a group 16 or 17 nonmetal, nitrogen, or hydrogen to be present if a binary compound is to be classified as definitely ionic.

✓ Example 6.9.1 : Ionic Compounds

Which of the following compounds can be identified as definitely ionic? Which are definitely not ionic?

a) CuO **d)** $HgBr_2$ **g)** H_2S

b) CaO **e)** $BaBr_2$ **h)** InF_3

c) MgH_2 **f)** B_2H_2 **i)** $BrCl$

Solution

According to the guidelines in the previous two paragraphs, only compounds containing metals from groups IA, IIA, and IIIB, or the lanthanoids are definitely ionic, as long as the metal is combined with an appropriate nonmetal. CaO, MgH_2 and $BaBr_2$ fall into this category.

Compounds which do not contain a metallic element, such as B_2H_6, H_2S, and $BrCl$, cannot possibly be ionic. This leaves CuO, $HgBr_2$, and InF_3 in the category of possibility, but not definitely, ionic.