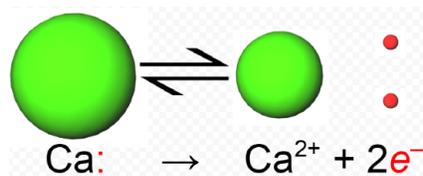
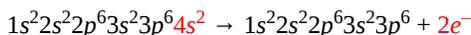


6.10: The Octet Rule

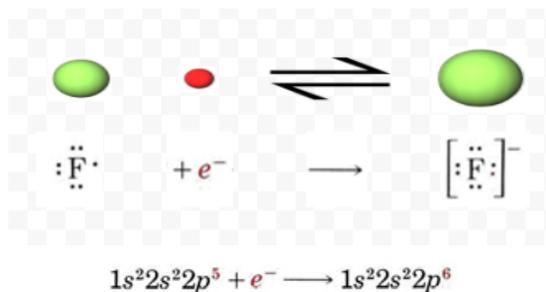
Because binary ionic compounds are confined mainly to [group 1](#) and [group 2](#) elements on the one hand and group VI and VII elements on the other, we find that they consist mainly of ions having an electronic structure which is the same as that of a noble gas. In calcium fluoride, for example, the calcium atom has lost *two* electrons in order to achieve the electronic structure of argon, and thus has a charge of +2:



Left side of the equation shows a large green sphere labeled Ca with two red dots representing valence electron. This turns into a smaller green sphere labeled Ca a superscript 2 positive in addition to two red dots labeled as 2 e.



By contrast, a fluorine atom needs to acquire but *one* electron in order to achieve a neon structure. The resulting fluoride ion has a charge of -1 :



1 s superscript 2, 2 s superscript 2, 2 p superscript 5, plus an electron produces 1 s superscript 2, 2 s superscript 2, 2 p superscript 6.

Left side of the equation shows a green sphere labeled F with seven dots representing the seven valence electrons. This F reacts with a small red sphere labeled e superscript negative. The resulting product is a larger green sphere labeled F with 8 electrons in a square bracket with a superscript negative sign.

The outermost shell of each of these ions has the electron configuration ns^2np^6 , where n is 3 for Ca^{2+} and 2 for F^{-} . Such an ns^2np^6 noble-gas electron configuration is encountered quite often. It is called an **octet** because it contains eight electrons. In a crystal of calcium fluoride, the Ca^{2+} and F^{-} ions are packed together in the lattice shown below. Careful study of the diagram shows that each F^{-} ion is surrounded by *four* Ca^{2+} ions, while each Ca^{2+} ion has *eight* F^{-} ions as nearest neighbors.

Thus there must be twice as many F^{-} ions as Ca^{2+} ions in the entire crystal lattice. Only a small portion of the lattice is shown, but if it were extended indefinitely in all directions, you could verify the ratio of two F^{-} for every Ca^{2+} . This ratio makes sense if you consider that two F^{-} ions (each with a -1 charge) are needed to balance the $+2$ charge of each Ca^{2+} ion, making the net charge on the crystal zero. The formula for calcium fluoride is thus CaF_2 .

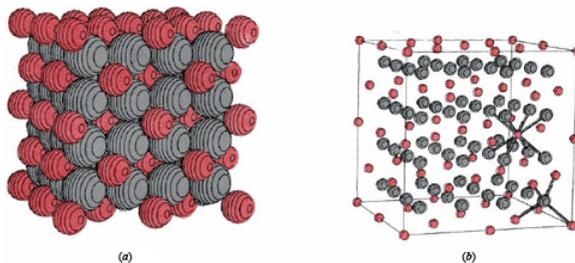


Figure 6.10.1: A portion of the ionic crystal lattice of fluorite, calcium fluoride. (a) Ca^{2+} ions (color) and F^{-} ions (gray) are shown full size. “Exploded” view shows that each F^{-} surrounded by four Ca^{2+} ions, while each Ca^{2+} ion is surrounded by eight F^{-} ions. The ratio of Ca^{2+} ions to F^{-} ions is thus 4:8 or 1:2, and the formula is CaF_2 . (Computer-generated). (Copyright © 1976 by W. G. Davies and J. W. Moore.)

Newcomers to chemistry often have difficulty in deciding what the formula of an ionic compound will be. A convenient method for doing this is to regard the compound as being formed from its atoms and to use Lewis diagrams. The **octet rule** can then be applied. Each atom must lose or gain electrons in order to achieve an octet. Furthermore, all electrons lost by one kind of atom must be gained by the other.

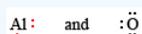
An exception to the octet rule occurs in the case of the three ions having the He $1s^2$ structure, that is, H^- , Li^+ and Be^{2+} . In these cases *two* rather than eight electrons are needed in the outermost shell to comply with the rule.

✓ Example 6.10.1: Ionic Formula

Find the formula of the ionic compound formed from O and Al.

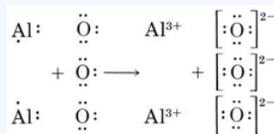
Solution

We first write down Lewis diagrams for each atom involved:



A $\overset{\cdot}{\underset{\cdot}{\text{Al}}}\cdot$ symbol with 2 red dots on its right and one red dot at the bottom. O symbol with two black dots on the top, left and bottom respectively.

We now see that each O atom needs 2 electrons to make up an octet, while each Al atom has 3 electrons to donate. In order that the same number of electrons would be donated as accepted, we need 2 Al atoms ($2 \times 3e^-$ donated) and 3 O atoms ($3 \times 2e^-$ accepted). The whole process is then



Equation shown in terms of Lewis diagrams. There are 2 Al symbols with three black dots to represent the valence electrons. These reacts with three O symbols with six valence electrons each. The resulting product is 2 moles of Al $3+$ positive ion and three moles of oxygen anion, shown with a full set of octet electrons with superscript of 2 negative.

The resultant oxide consists of aluminum ions, Al^{3+} , and oxide ions, O^{2-} , in the ratio of 2:3. The formula is Al_2O_3 .

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