

5.2: Electrons and Valence

On a chemical level, an important clue to the unraveling of [the electronic structure of atoms](#) is the existence of noble gases, which are almost completely unable to form chemical compounds. This lack of reactivity suggests that the atoms of these elements have structures which do not permit interaction with the structures of other atoms. A second clue is the close correspondence between the valence of an element and the extent to which its atomic number differs from that of the nearest noble gas. Elements which have a valence of 1, for instance, have atomic numbers *one more* or *one less* than that of a noble gas. Thus the atoms of [the alkali metals](#) Li, Na, K, Rb, and Cs all contain one [electron](#) more than the corresponding noble gases He, Ne, Ar, Kr, and Xe, while atoms of hydrogen H and [the halogens](#) F, Cl, Br, and I all contain one electron less. Similar remarks apply to a valence of 2. [The alkaline-earth metal atoms](#) Be, Mg, Ca, Sr, and Ba all contain two electrons more than a noble-gas atom, while the elements O, S, Se, and Te all contain two electrons less. Exactly the same pattern of behavior also extends to elements with a valence of 3 or 4.

As early as 1902, Lewis began to suggest (in his lectures to general chemistry students, no less) that the behavior just described could be explained by assuming that the electrons in atoms were arranged in **shells**, all electrons in the same shell being approximately the same distance from the nucleus. The pictures which he eventually developed for helium, chlorine, and potassium atoms are illustrated below. In the helium atom the two electrons occupy only one shell, in the chlorine atom the 17 electrons are arranged in three shells, and in the potassium atom the 19 electrons occupy four shells. Lewis suggested that each shell can only accommodate so many electrons. Once this number has been reached, the shell must be regarded as *filled*, and any extra electrons are accommodated in the next shell, somewhat farther from the nucleus. Once a shell is filled, moreover, it is assumed to have a particularly stable structure which prevents the electrons in the shell from any involvement with other atoms. Thus it is only the electrons in the *outermost incompletely filled shell* (called **valence electrons**) that have any chemical importance. Furthermore, if the outermost shell is filled, then the resulting atom will have little or no tendency to react with other atoms and form compounds with them. Since this is exactly the behavior exhibited by the noble gases, Lewis concluded that the characteristic feature of an atom of a noble gas is a *filled outer shell* of electrons.

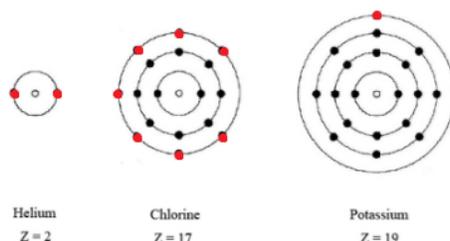


Figure 5.2.1 The shell structure of atoms of He, Cl, and K, as suggested by Lewis. Note the valence electrons are in red. Helium has one shell filled by two red dots. Chlorine has 2 red dots on its inner most shell, followed by 8 red dots on the next shell. The outer most shell has 7 red dots. Potassium has 2 dots on its inner most shell followed by 8 red dots respectively for the next two shells. The outermost shell has 1 red dot.

Assuming that the noble gases all contain an outermost filled shell, it is now quite simple to work out how many electrons can be accommodated in each shell. Since the first noble gas helium has two electrons, we know that only two electrons are needed to fill the first shell. A further eight electrons brings us to the next noble gas neon ($Z = 10$). Accordingly we deduce that the second shell can accommodate a maximum of eight electrons. A similar argument leads to the conclusion that the third shell also requires eight electrons to fill it and that an atom of argon has two electrons in the first shell, eight in the second, and eight in the third, a total of 18 electrons.

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