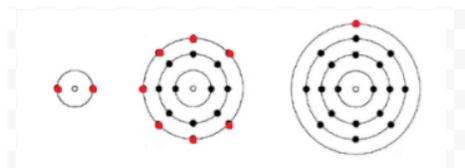


## 5.3: Lewis Diagrams

Lewis used simple diagrams (now called **Lewis diagrams**) to keep track of how many electrons were present in the outermost, or valence, shell of a given atom. The **kernel** of the atom, i.e., the nucleus together with the inner electrons, is represented by the chemical symbol, and only the valence electrons are drawn as dots surrounding the chemical symbol. Thus the three atoms shown in [Figure 1 from Electrons and Valence](#) can be represented by the following Lewis diagrams:



Atomic shells of helium, chlorine, and potassium showing all shells and the corresponding number of electrons.

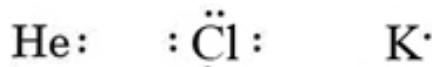
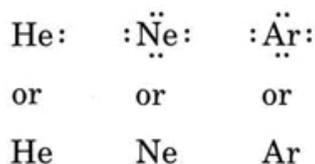


Figure 5.3.1 The figure above shows the electron shells of He (Helium), Cl (Chlorine), and K (Potassium) as well as their Lewis dot structures below. Notice how both the electron shell and the Lewis dot structures have the same number of valence electrons. The Lewis dot structure ignores the nucleus and all non-valence electrons, displaying only the valence electrons of an atom.

Lewis structures are shown as element symbols with black dots shown around the symbol. The number of black dots corresponding to the valence number. Helium is He with two black dots to the right. Chlorine is Cl with 2 on the left, top and the right with 1 single dot at the bottom. Potassium is K with one dot on the right.

If the atom is a noble-gas atom, two alternative procedures are possible. Either we can consider the atom to have zero valence electrons or we can regard the outermost filled shell as the valence shell. The first three noble gases can thus be written as:



Helium is shown as He alone or He with two dots on the right. Neon is shown as Ne alone or Ne with two dots on the left, top, right, and bottom respectively. Argon is shown as Ar alone or Ar with two dots on the left, top, right, and bottom respectively.

### ✓ Example 5.3.1: Lewis Structures

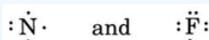
Draw Lewis diagrams for an atom of each of the following elements: Li, N, F, Na

#### Solution

We find from the periodic table inside the front cover that Li has an atomic number of 3. It thus contains three electrons, one more than the noble gas He. This means that the outermost, or valence, shell contains only one electron, and the Lewis diagram is



Following the same reasoning, N has seven electrons, five more than He, while F has nine electrons, seven more than He, giving



Nitrogen is N with two dots on the left and one dot on the top, right, and bottom respectively. Fluorine is F with two dots on the left, top, and right, and 1 dot below.

Na has nine more electrons than He, but eight of them are in the kernel, corresponding to the eight electrons in the outermost shell of Ne. Since Na has only 1 more electron than Ne, its Lewis diagram is

Notice from the preceding example that the Lewis diagrams of the **alkali metals** are identical except for their chemical symbols. This agrees nicely with the very similar chemical behavior of the alkali metals. Similarly, Lewis diagrams for all elements in other groups, such as the **alkaline earths** or **halogens**, look the same.

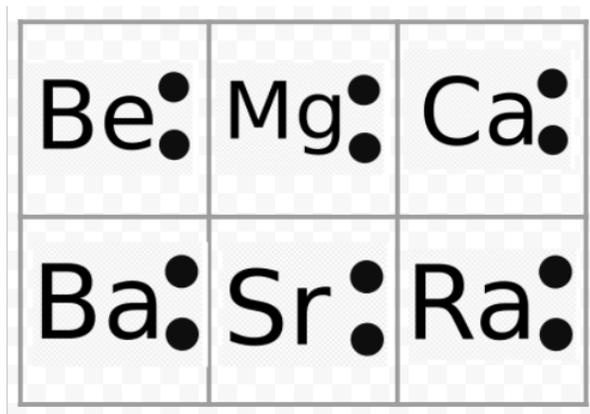


Figure 5.3.1 The image above demonstrates that for elements in the same group (like the alkali earth metals shown above), the Lewis dot structure will be the same, except of course for the different element name. In the image above you see that every alkali earth metal has 2 valence electrons, each represented by a dot in the Lewis dot structure.

The Lewis diagrams may also be used to predict the **valences** of the elements. Lewis suggested that the number of valences of an atom was equal to the number of electrons in its valence shell or to the number of electrons which would have to be added to the valence shell to achieve the electronic shell structure of the next noble gas. As an example of this idea, consider the elements Be and O. Their Lewis diagrams and those of the noble gases He and Ne are



The Lewis structures are He, Be with two dots on its right, O with two dots on the left, top and bottom respectively. Ne with two dots on the left, top, right and bottom respectively.

Comparing Be with He, we see that the former has two more electrons and therefore should have a valence of 2. The element O might be expected to have a valence of 6 or a valence of 2 since it has six valence electrons—two less than Ne. Using rules of valence developed in this way, Lewis was able to account for the regular increase and decrease in the subscripts of the compounds in the table found in the Valence section, and reproduced here. In addition he was able to account for more than 50 percent of the formulas in the table. (Those that agree with his ideas are shaded in color in the table. You may wish to refer to that table now and verify that some of the indicated formulas follow Lewis' rules.) Lewis' success in this connection gave a clear indication that electrons were the most important factor in holding atoms together when molecules formed.

Despite these successes, there are also difficulties to be found in Lewis' theories, in particular for elements beyond calcium in the periodic table. The element Br ( $Z = 35$ ), for example, has 17 more electrons than the noble-gas Ar ( $Z = 18$ ). This leads us to conclude that Br has 17 valence electrons, which makes it awkward to explain why Br resembles Cl and F so closely even though these two atoms have only seven valence electrons.

Table 5.3.1 Common Compounds

Element	Atomic Weight	Hydrogen Compounds	Oxygen Compounds	Chlorine Compounds
Hydrogen	1.01	H <sub>2</sub>	H <sub>2</sub> O, H <sub>2</sub> O <sub>2</sub>	HCl
Helium	4.00	None formed	None formed	None formed
Lithium	6.94	LiH	Li <sub>2</sub> O, Li <sub>2</sub> O <sub>2</sub>	LiCl
Beryllium	9.01	BeH <sub>2</sub>	BeO	BeCl <sub>2</sub>
Boron	10.81	B <sub>2</sub> H <sub>6</sub>	B <sub>2</sub> O <sub>3</sub>	BCl <sub>3</sub>

Element	Atomic Weight	Hydrogen Compounds	Oxygen Compounds	Chlorine Compounds
Carbon	12.01	CH <sub>4</sub> , C <sub>2</sub> H <sub>6</sub> , C <sub>3</sub> H <sub>8</sub>	CO <sub>2</sub> , CO, C <sub>2</sub> O <sub>3</sub>	CCl <sub>4</sub> , C <sub>2</sub> Cl <sub>6</sub>
Nitrogen	14.01	NH <sub>3</sub> , N <sub>2</sub> H <sub>4</sub> , HN <sub>3</sub>	N <sub>2</sub> O, NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>5</sub>	NCl <sub>3</sub>
Oxygen	16.00	H <sub>2</sub> O, H <sub>2</sub> O <sub>2</sub>	O <sub>2</sub> , O <sub>3</sub>	<Cl <sub>2</sub> O, ClO <sub>2</sub> , Cl <sub>2</sub> O <sub>7</sub>
Fluorine	19.00	HF	OF <sub>2</sub> , O <sub>2</sub> F <sub>2</sub>	ClF, ClF <sub>3</sub> , ClF <sub>5</sub>
Neon	20.18	None formed	None formed	None formed
Sodium	22.99	NaH	Na <sub>2</sub> O, Na <sub>2</sub> O <sub>2</sub>	NaCl
Magnesium	24.31	MgH <sub>2</sub>	MgO	MgCl <sub>2</sub>
Aluminum	26.98	AlH <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	AlCl <sub>3</sub>
Silicon	28.09	SiH <sub>4</sub> , Si <sub>2</sub> H <sub>6</sub>	SiO <sub>2</sub>	SiCl <sub>4</sub> , Si <sub>2</sub> Cl <sub>6</sub>
Phosphorus	30.97	PH <sub>3</sub> , P <sub>2</sub> H <sub>4</sub>	P <sub>4</sub> O <sub>10</sub> , P <sub>4</sub> O <sub>6</sub>	PCl <sub>3</sub> , PCl <sub>5</sub> , P <sub>2</sub> Cl <sub>4</sub>
Sulfur	32.06	H <sub>2</sub> S, H <sub>2</sub> S <sub>2</sub>	SO <sub>2</sub> , SO <sub>3</sub>	S <sub>2</sub> Cl <sub>2</sub> , SCl <sub>2</sub> , SCl <sub>4</sub>
Chlorine	35.45	HCl	Cl <sub>2</sub> O, ClO <sub>2</sub> , Cl <sub>2</sub> O <sub>7</sub>	Cl <sub>2</sub>
Potassium	39.10	KH	K <sub>2</sub> , K <sub>2</sub> O <sub>2</sub> , KO <sub>2</sub>	KCl
Argon	39.95	None formed	None formed	None formed
Calcium	40.08	CaH <sub>2</sub>	CaO, CaO <sub>2</sub>	CaCl <sub>2</sub>
Scandium	44.96	Relatively Unstable	Sc <sub>2</sub> O <sub>3</sub>	ScCl <sub>3</sub>
Titanium	47.90	TiH <sub>2</sub>	TiO <sub>2</sub> , Ti <sub>2</sub> O <sub>3</sub> , TiO	TiCl <sub>4</sub> , TiCl <sub>3</sub> , TiCl <sub>2</sub>
Vanadium	50.94	VH <sub>2</sub>	V <sub>2</sub> O <sub>5</sub> , V <sub>2</sub> O <sub>3</sub> , VO <sub>2</sub> , VO	VCl <sub>4</sub> , VCl <sub>3</sub> , VCl <sub>2</sub>
Chromium	52.00	CrH <sub>2</sub>	Cr <sub>2</sub> O <sub>3</sub> , CrO <sub>2</sub> , CrO <sub>3</sub>	CrCl <sub>3</sub> , CrCl <sub>2</sub>

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