

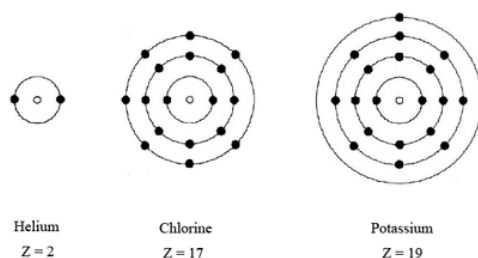
5.3.1: Lewis Diagrams and Biological and Chemical Properties

Lewis Diagrams in Biology

A first step toward gaining some insight into the biological properties of atoms or compounds is to draw their **Lewis diagrams**. For example, we'll explore lithium fluoride and sodium chloride below. Lithium fluoride and sodium chloride are similar in some ways: The both contain 1+ alkali metal ions and 1- halogen ions; they both are high melting, white, crystalline solids; and they both dissolve in water to make conducting solutions.

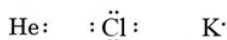
But as we have come to suspect, the biological properties are quite different, and must be considered along with chemical properties. Lithium Fluoride is very toxic^[1] Because of the lithium ion's small size, it causes ion (electrolyte) imbalances, and, of course, is a strong sedative. Fluoride ion forms hydrofluoric acid in the stomach which is very corrosive, and disrupts metabolism^[2]. Sodium chloride (table salt) is much less toxic, with high doses leading to chronic high blood pressure.

G.N. 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 here from Figure 1 from [Electrons and Valence](#) can be represented by the following Lewis diagrams:



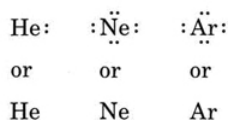
Helium has one shell filled by two red dots. Chlorine has 2 red dots on its inner most shell, followed by 8 red dots on the next shell. The outer most shell has 7 red dots. Potassium has 2 dots on its inner most shell followed by 8 red dots respectively for the next two shells. The outermost shell has 1 red dot.

Figure 5.3.1.1 The shell structure of atoms of He, Cl, and K, as suggested by Lewis.



Helium is H e with two black dots to the right. Chlorine is C l 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 H e alone or H e with two dots on the right. Neon is shown as N e alone or N e with two dots on the left, top, right, and bottom respectively. Argon is shown as A r alone or A r with two dots on the left, top, right, and bottom respectively.

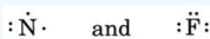
✓ Example 5.3.1.1: Lewis Diagrams

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

Li· 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

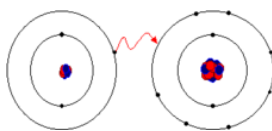


Notice from the preceding example that the Lewis diagrams of the [alkali metals](#) are identical except for their chemical symbols. This agrees nicely with the very similar chemical behavior of the alkali metals. Similarly, Lewis diagrams for all elements in other groups, such as the [alkaline earths](#) or [halogens](#), look the same. 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 below. For example, he reasoned that lithium would lose an electron to fluorine, forming toxic Li^+F^- :



Atomic orbitals of Li and F are shown. The electron on lithium's most outer shell has an arrow pointing towards the outermost orbital of fluorine, indicating transfer of electrons.

Figure 5.3.1.2 Formation of ions by achieving inert gas structures^[3]

Or that chlorine would gain an electron from sodium to form Na^+Cl^- :

□ [Ionic Bonding](#) [chemwiki.ucdavis.edu]

Figure 5.3.1.3 Formation of ions by achieving inert gas structures^[4]

Similarly, oxygen would gain one electron from each of two sodium ions to form nontoxic Na_2^+O^- , another of the successfully predicted compounds in the table.

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 or gray 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.

Table 5.3.1.1 Compounds of Hydrogen, Oxygen, and Chlorine

Element	Atomic Weight	Hydrogen Compounds	Oxygen Compounds	Chlorine Compounds
Hydrogen	1.01	H ₂	H ₂ O, H ₂ O ₂	HCl
Helium	4.00	None formed	None formed	None formed
Lithium	6.94	LiH	Li ₂ O, Li ₂ O ₂	LiCl
Beryllium	9.01	BeH ₂	BeO	BeCl ₂
Boron	10.81	B ₂ H ₆	B ₂ O ₃	BCl ₃
Carbon	12.01	CH ₄ , C ₂ H ₆ , C ₂ H ₄ , . . . †	CO ₂ , CO, C ₂ O ₃	CCl ₄ , C ₂ Cl ₆
Nitrogen	14.01	NH ₃ , N ₂ H ₄ , HN ₃	N ₂ O, NO, NO ₂ , N ₂ O ₅	NCl ₃
Oxygen	16.00	H ₂ O, H ₂ O ₂	O ₂ , O ₃	Cl ₂ O, ClO ₂ , Cl ₂ O ₇
Fluorine	19.00	HF	OF ₂ , O ₂ F ₂	ClF, ClF ₃ , ClF ₅
Neon	20.18	None formed	None formed	None formed
Sodium	22.99	NaH	Na ₂ O, Na ₂ O ₂	NaCl
Magnesium	24.31	MgH ₂	MgO	MgCl ₂
Aluminum	26.98	AlH ₃	Al ₂ O ₃	AlCl ₃
Silicon	28.09	SiH ₄ , Si ₂ H ₆	SiO ₂	SiCl ₄ , Si ₂ Cl ₆
Phosphorus	30.97	PH ₃ , P ₂ H ₄	P ₄ O ₁₀ , P ₄ O ₆	PCl ₃ , PCl ₅ , P ₂ Cl ₄
Sulfur	32.06	H ₂ S, H ₂ S ₂	SO ₂ , SO ₃	S ₂ Cl ₂ , SCl ₂ , SCl ₄
Chlorine	35.45	HCl	Cl ₂ O, ClO ₂ , Cl ₂ O ₇	Cl ₂
Potassium	39.10	KH	K ₂ O, K ₂ O ₂ , KO ₂	KCl
Argon	39.95	None formed	None formed	None formed
Calcium	40.08	CaH ₂	CaO, CaO ₂	CaCl ₂
Scandium	44.96	Relatively unstable	Sc ₂ O ₃	ScCl ₃
Titanium	47.90	TiH ₂	TiO ₂ , Ti ₂ O ₃ , TiO	TiCl ₄ , TiCl ₃ , TiCl ₂
Vanadium	50.94	VH ₂	V ₂ O ₅ , V ₂ O ₃ , VO ₂ , VO	VCl ₄ , VCl ₃ , VCl ₂
Chromium	52.00	CrH ₂	Cr ₂ O ₃ , CrO ₂ , CrO ₃	CrCl ₃ , CrCl ₂

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.

From ChemPRIME: [5.2: Lewis Diagrams](#)

References

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