Valence Electrons

Unit: Electronic Structure

MA Curriculum Frameworks (2016): HS-PS1-1

Mastery Objective(s): (Students will be able to…)

- Determine the number of valence electrons for representative elements.
- Draw Lewis dot diagrams for representative elements.

Success Criteria:

- Elements are drawn with the correct number of valence electrons.
- Dots representing electrons are spread around the element symbol in an appropriate fashion.

Language Objectives:

- Explain what valence electrons are and how to determine how many an element has.

Notes:

valence electrons: the outer electrons of an atom that are available to participate in chemical reactions.

In most atoms, these are the electrons in the s and p sub-levels of the highest (numbered) energy level.

For example, phosphorus (P) has the electron configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$, or [Ne] $3s^2\ 3p^3$. The highest energy level is level 3.

The $3s^2\ 3p^3$ at the end of its electron configuration tells us that phosphorus has 2 electrons in the 3s sub-level plus 3 in the 3p sub-level, for a total of 5 electrons in level 3. This means that phosphorus has 5 valence electrons.

Note that only electrons in s and p sub-levels can be valence electrons. For example, arsenic (As) has the electron configuration [Ar] $4s^2\ 3d^{10}\ 4p^3$. The highest energy level is 4, so only the electrons in level 4 count. Arsenic has 2 electrons in the 4s sub-level, and 3 electrons in the 4p sub-level, for a total of 5 valence electrons. The 10 electrons in the 3d sub-level are ***not*** in the highest level, so they don't count.

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Recall that full sub-levels give an atom extra stability. This means noble gases (the elements in the last column of the periodic table) are the most stable elements because all of their sub-levels are filled. This is why noble gases almost never react with other elements.

Because noble gases have all sub-levels filled, this means they have "full" valence shells. Helium has 2 valence electrons (because it has only a 1*s* sub-level), and all other noble gases have 8 valence electrons (because their highest-numbered *s* sub-level is full with 2 electrons, and their highest-numbered *p* sub-level is full with 6 electrons, for a total of 8.)

For other elements, *the atoms can become much more stable if they can form ions with filled valence shells*, which would give the ion the same electron configuration as a noble gas.

For example, phosphorus ([Ne] $3s^2\ 3p^3$) has 5 valence electrons. It could have a full valent shell by gaining 3 more electrons to fill its 3p sub-level (which would give it the same electron configuration as argon), or by losing 5 electrons (which would give it the same electron configuration as neon). Because it is easier to gain 3 electrons than to lose 5, phosphorus is most likely to gain 3 electrons, which means it's most likely to form an ion with a −3 charge.

Potassium ([Ar] $4s^1$) has only one valence electron. Potassium could either lose 1 electron (which would give it the same electron configuration as argon), or gain 7 electrons (which would give it the same electron configuration as krypton). Because it is easier to lose 1 electron than to gain 7, potassium is most likely to lose 1 electron, which means it's most likely to form an ion with a +1 charge.

Transition Metals

Because the energy of an *s* sub-level is so close to the energy of the *d* sub-level of the next lower energy level, transition metals can easily shift electrons between these *s* and *d* sub-levels. This means they can have different numbers of valence electrons, depending on the situation. For example, copper can have the electron configuration [Ar] $4s^2\ 3d^9$, or [Ar] $4s^1\ 3d^{10}$, meaning that copper can have either one or two valence electrons. This explains why copper is observed to sometimes form a +1 ion, and other times a +2 ion.

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Group Numbers

You can read the number of valence electrons that an element has directly from the periodic table, using the group numbers. For the "representative elements" (s and p block elements), the number of valence electrons is the last digit of the group number. Transition metals generally have two valence electrons, though there are exceptions. (See the section on "Exceptions to the Aufbau Principle" starting on page 226 for an explanation.)

Lewis Dot Diagrams

A Lewis dot diagram is a representation of an element surrounded by its valence electrons. The diagram consists of the element symbol (from the periodic table), with dots on the top, bottom, and sides representing the *s* and *p* sub-levels of its valence shell.

For example, aluminum has 3 valence electrons. The orbital-notation electron configuration for aluminum is:

1s	2s	2p	2p	2p	3s	3p	3p	3p
↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑	__	__

Its Lewis dot diagram is ·Al:

Notice that it shows three dots representing the 3 valence electrons.

The dots are placed in singles or pairs on the top, bottom, left, and right of the element symbol. The convention is to place the first two valence electrons (the ones in the s sub-level) to the right of the element symbol, and the remaining valence electrons (the ones in the p sub-levels) on the top, left, and bottom. Start with one dot on the top, left, and bottom, and then pair them up one at a time. (This corresponds with Hund's Law, which says that electrons in the p sub-level do not pair up until they have to.)

In our example, the Lewis dot diagram for aluminum has two dots on the right representing the two electrons in the 3s sub-level, and one dot on the left for the one electron in the 3p sub-level.

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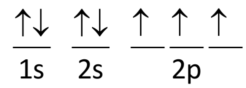
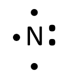
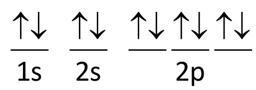
Nitrogen has 5 valence electrons. Its orbital-notation electron configuration is:

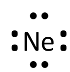


Its Lewis dot diagram would be 

Again, notice that there are 2 dots on the right for the 2s sub-level, and one dot each on the top, bottom, and left sides for the one electron in each of the orbitals of the 2p sub-level.

Neon has 8 valence electrons. Its orbital-notation electron configuration is:



Its Lewis dot diagram is 

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Homework Problems

Fill in the chart below. Use the first row as an example.

Element	Electron Configuration	Group #	Valence Electrons	Lewis Dot	Nearest Noble Gas	Charge of Ion
N	[He] $2s^2$ $2p^3$	15	5	·N: (with one dot above and one below)	Ne	−3
O						
Na						
P						
Ar						
Al						
Br						
B						
Ca						
C						
Cl						

Use this space for summary and/or additional notes: