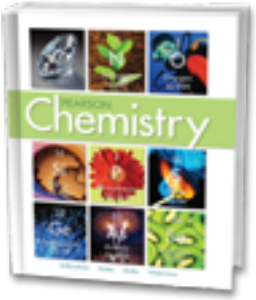

Chapter 7
Ionic and Metallic Bonding

7.1 Ions

7.2 Ionic Bonds and Ionic Compounds
7.3 Bonding in Metals

What is fool's gold?

Pyrite (FeS_2) is often mistaken for gold—hence its nickname, "fool's gold." Pyrite is an example of a crystalline solid.

Valence Electrons

How do you find the number of valence electrons in an atom of a representative element?

Valence electrons are the electrons in the highest occupied energy level of an element's atoms.

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- The number of valence electrons largely determines the chemical properties of an element.

Determining the Number of Valence Electrons

To find the number of valence electrons in an atom of a representative element, simply look at its group number.

Determining the Number of Valence Electrons

- Atoms of the Group 1A elements (hydrogen, lithium, sodium, and so forth) all have one valence electron, corresponding to the 1 in 1A.
- Carbon and silicon atoms, in Group 4A, have four valence electrons.
- The noble gases (Group 8A) are the only exceptions to the group-number rule: Atoms of helium have two valence electrons, and atoms of all the other noble gases have eight valence electrons.

Determining the Number of Valence Electrons

Valence electrons are usually the only electrons involved in chemical bonds.

Determining the Number of Valence Electrons

Valence electrons are usually the only electrons involved in chemical bonds.

- As a general rule, only the valence electrons are shown in electron dot structures.
- **Electron dot structures** are diagrams that show valence electrons in the atoms of an element as dots.

Electron Dot Structures of Some Group A Elements								
	Group							
Period	1A	2A	3A	4A	5A	6A	7A	8A
1	H·							He:
2	Li·	·Be·	·B·	·C·	·N·	:O·	:F·	:Ne:
3	Na·	·Mg·	·Al·	·Si·	·P·	:S·	:Cl·	:Ar:
4	K·	·Ca·	·Ga·	·Ge·	·As·	:Se·	:Br·	:Kr:

This table shows electron dot structures for atoms of some Group A elements.

- Notice that all the electrons within a given group (with the exception of helium) have the same number of electron dots in their structures.

The Octet Rule

Noble gases, such as neon and argon, are nonreactive in chemical reactions.

- That is, they are stable.

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Noble gases, such as neon and argon, are nonreactive in chemical reactions.

- That is, they are stable.
- In 1916, chemist Gilbert Lewis used this fact to explain why atoms form certain kinds of ions and molecules.
- He called his explanation the octet rule.

The Octet Rule

The **octet rule** states that in forming compounds, atoms tend to achieve the electron configuration of a noble gas.

The Octet Rule

The **octet rule** states that in forming compounds, atoms tend to achieve the electron configuration of a noble gas.

- An octet is a set of eight.
- Atoms of each of the noble gases (except helium) have eight electrons in their highest occupied energy levels and the general electron configuration of ns^2np^6.

The Octet Rule

- Atoms of metals tend to lose their valence electrons, leaving a complete octet in the next-lowest energy level.
- Atoms of some nonmetals tend to gain electrons or share electrons with another nonmetal atom or atoms to achieve a complete octet.

Checkpoint

Draw the electron dot structure for bismuth.

Checkpoint

Draw the electron dot structure for bismuth.

PEARSON

Formation of Cations

How are cations formed?

Formation of Cations

How are cations formed?

- An atom is electrically neutral because it has equal numbers of protons and electrons.
- An ion forms when an atom or group of atoms loses or gains electrons.

- A positively charged ion, or cation, is produced when an atom loses one or more valence electrons.

A positively charged ion, or cation, is produced when an atom loses one or more valence electrons.

- A sodium atom (Na) forms a sodium cation (Na^+).
- A calcium atom (Ca) forms a calcium cation (Ca^+).

Group 1A Cations

The most common cations are those produced by the loss of valence electrons from metal atoms.

- Most of these atoms have one to three valence electrons, which are easily removed.

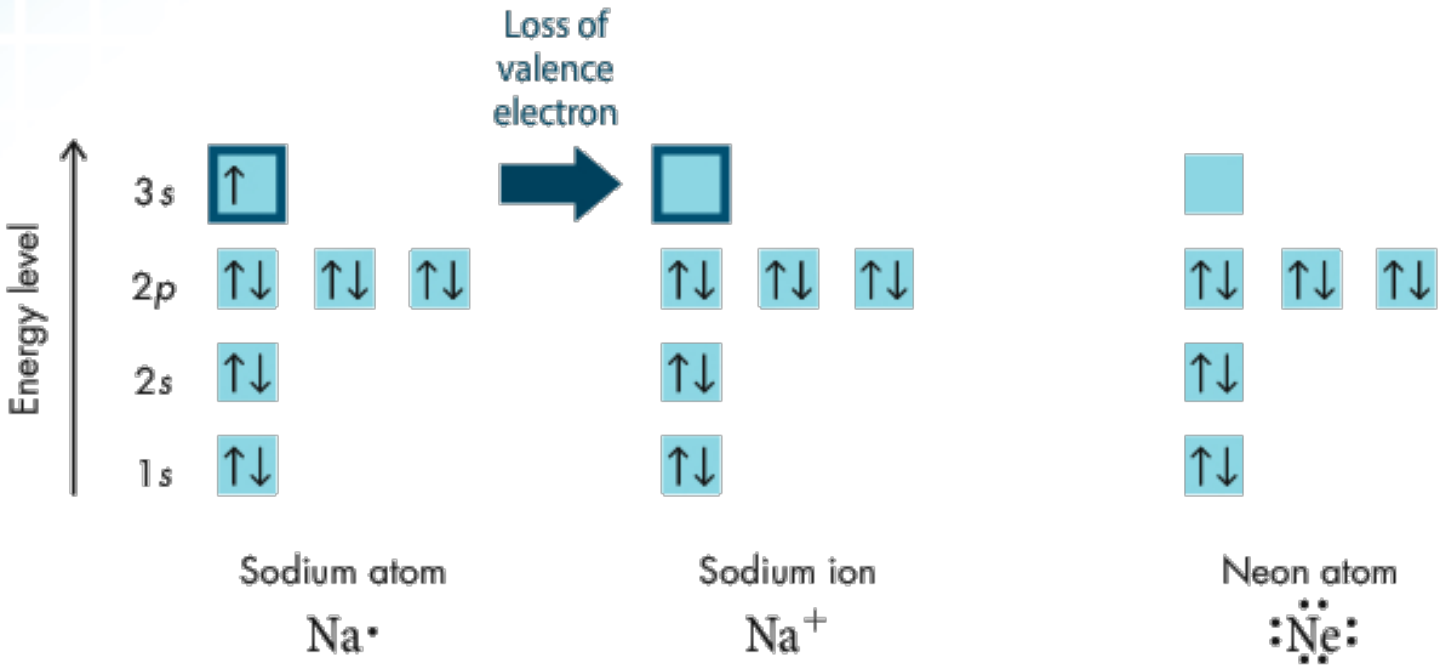
Group 1A Cations

When forming a compound, a sodium atom loses its one valence electron and is left with an octet in what is now its highest occupied energy level.

- The number of protons in the sodium nucleus is still eleven, so the loss of one unit of negative charge produces a cation with a charge of 1+.

$$\mathrm{Na}\ \ 1s^2 2s^2 2p^6 3s^1 \xrightarrow{-e^-} \mathrm{Na^+}\ \ \underbrace{1s^2 2s^2 2p^6}_{\text{octet}}$$

Group 1A Cations



Both the sodium ion and the neon atom have eight electrons in their valence shells (highest occupied energy levels).

Group 2A Cations

Magnesium (atomic number 12) belongs to Group 2A of the periodic table, so magnesium atoms have two valence electrons.

$\cdot Mg \cdot$

Magnesium atom
(electrically neutral,
charge = 0)

Group 2A Cations

Magnesium (atomic number 12) belongs to Group 2A of the periodic table, so magnesium atoms have two valence electrons.

- A magnesium atom attains the electron configuration of a neon atom by losing both valence electrons and producing a magnesium cation with a charge of 2+.

$$\bullet\,Mg\,\bullet \xrightarrow{\text{loses all its valence electrons}} Mg^{2+} + 2e^-$$

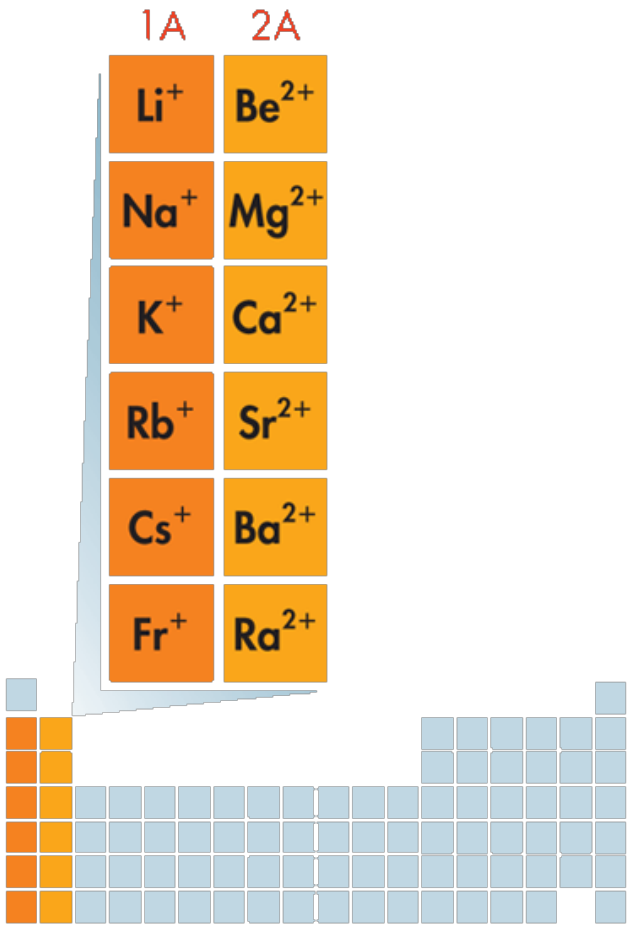
Magnesium atom (electrically neutral, charge = 0)

Magnesium ion (2+ indicates two units of positive charge)

(2 in front of e^- indicates two units of negative charge)

The figure at right lists the symbols of the cations formed by metals in Groups 1A and 2A.

- Cations of Group 1A elements always have a charge of 1+.
- Cations of Group 2A elements always have a charge of 2+.



Transition Metal Cations

The charges of cations of the transition metals may vary.

- An atom of iron may lose two valence electrons, forming the Fe^{2+} cation, or three valence electrons, forming the Fe^{3+} cation.

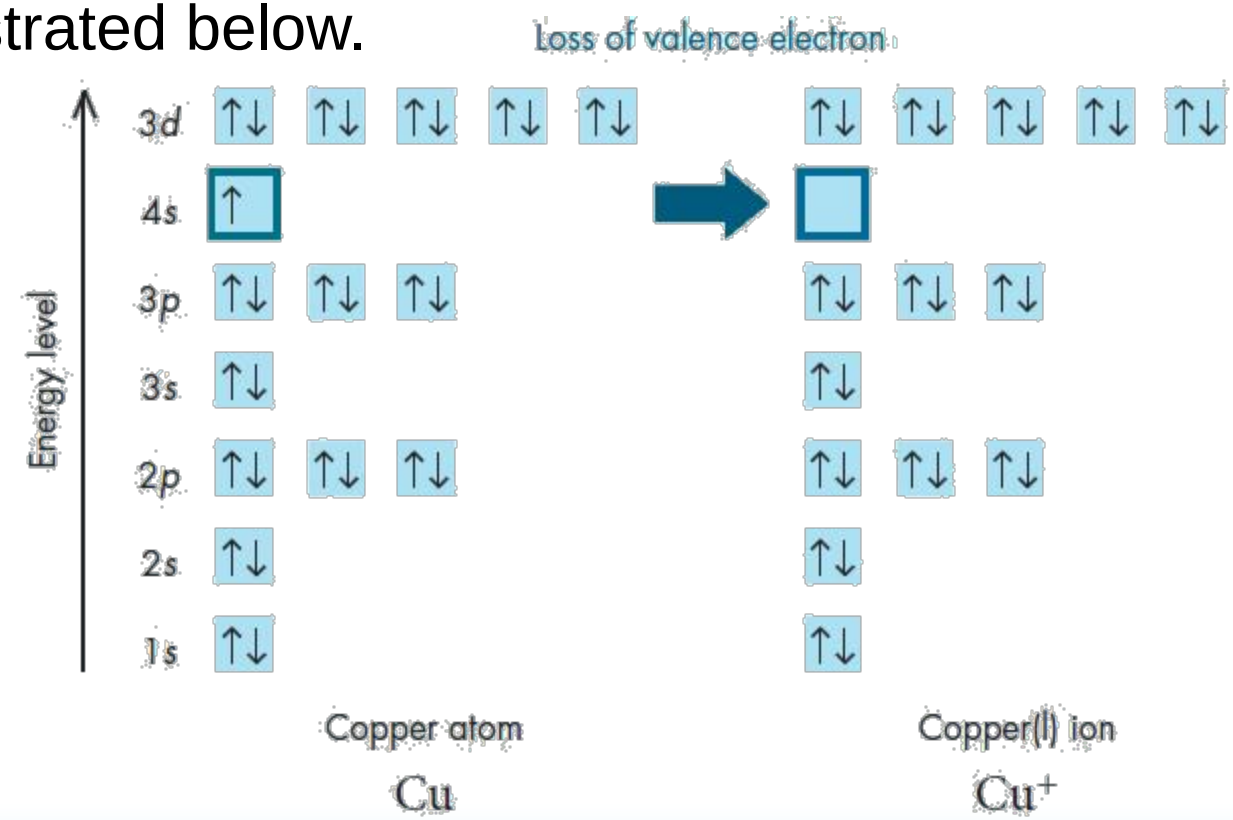
Transition Metal Cations

Some ions formed by transition metals do not have noble-gas electron configurations (ns^2np^6) and are therefore exceptions to the octet rule.

- Silver, with the electron configuration of $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^1$, is an example.
- To achieve the structure of krypton, a silver atom would have to lose eleven electrons.
- To acquire the electron configuration of xenon, a silver atom would have to gain seven electrons.
- Ions with charges of three or greater are uncommon.

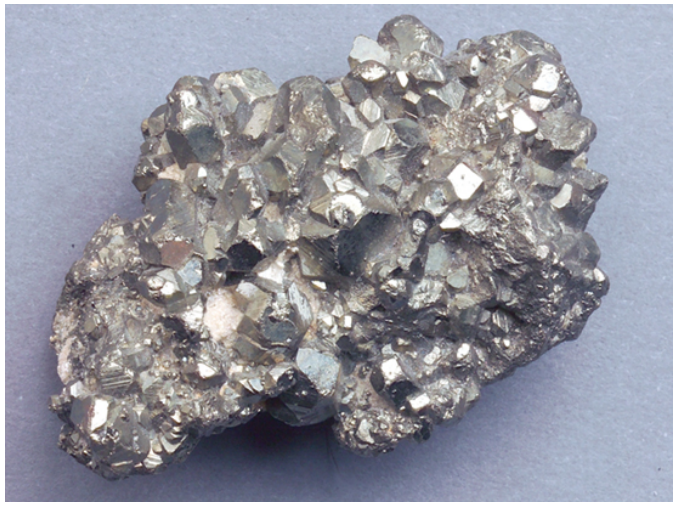
Transition Metal Cations

A copper atom loses its lone 4*s* electron to form a copper ion (Cu^+) with a pseudo noble-gas electron configuration, as illustrated below.

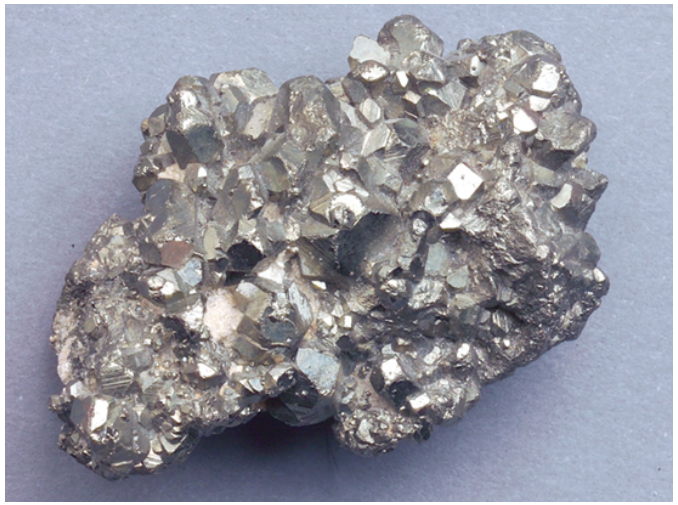


CHEMISTRY & YOU

Fool's gold is composed of iron(II) cations (Fe^{2+}) and disulfide anions (S_2^{2-}). Write the electron configuration of the Fe^{2+} ion.



Fool's gold is composed of iron(II) cations (Fe^{2+}) and disulfide anions (S_2^{2-}). Write the electron configuration of the Fe^{2+} ion.



Fe: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$

Fe^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

Checkpoint

How does a cesium atom form a cation?

A. By losing 2 electrons

B. By gaining 1 electron

C. By losing 1 electron

D. By gaining 2 electrons

Checkpoint

How does a cesium atom form a cation?

A. By losing 2 electrons

B. By gaining 1 electron

C. **By losing 1 electron**

D. By gaining 2 electrons

Formation of Anions

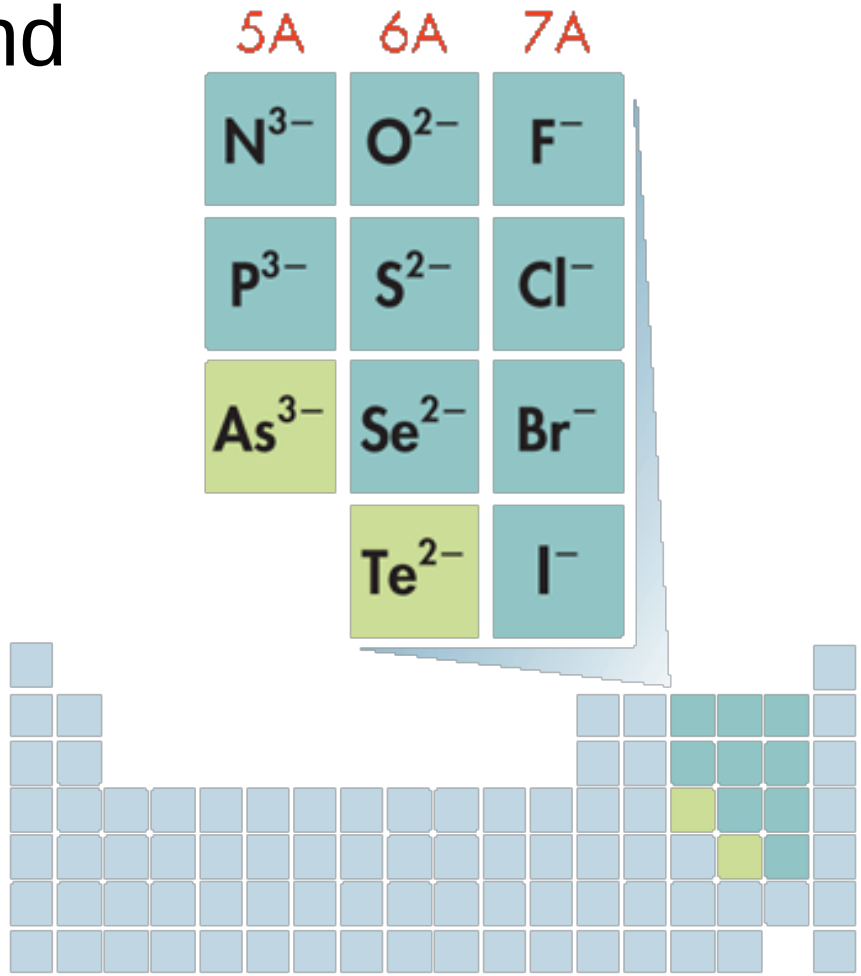
How are anions formed?

- An anion is produced when an atom gains one or more valence electrons.

An anion is produced when an atom gains one or more valence electrons.

- Note that the name of an anion of a nonmetallic element is *not* the same as the element name.
  - The name of the anion typically ends in *-ide*.
  - Thus, a chlorine atom (Cl) forms a chloride anion (Cl^-).
  - An oxygen atom (O) forms an oxide anion (O^{2-}).

Atoms of nonmetals and metalloids form anions by gaining enough valence electrons to attain the electron configuration of the nearest noble gas.



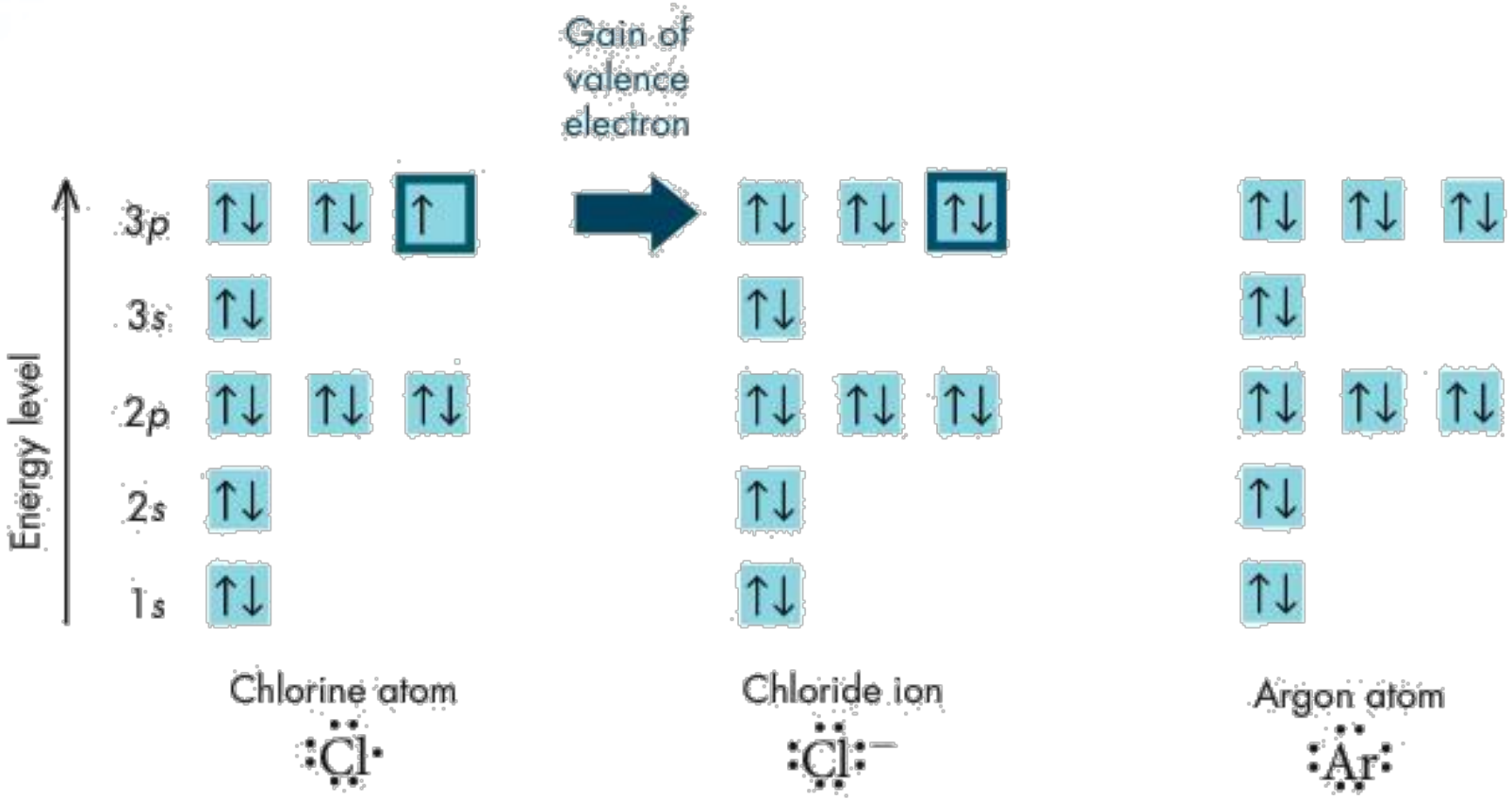
Atoms of nonmetallic elements attain noble-gas electron configurations more easily by gaining electrons than by losing them because these atoms have relatively full valence shells.

Atoms of nonmetallic elements attain noble-gas electron configurations more easily by gaining electrons than by losing them because these atoms have relatively full valence shells.

- Atoms of chlorine have seven valence electrons.
  - A gain of one electron gives a chlorine atom an octet and converts a chloride atom into a chloride atom.

$$\text{Cl}\ \ 1s^2 2s^2 2p^6 3s^2 3p^5 \xrightarrow{+e^-} \text{Cl}^-\ \ 1s^2 2s^2 2p^6 \underbrace{3s^2 3p^6}_{\text{octet}}$$

Chlorine atoms need one more valence electron to achieve the electron configuration of the nearest noble gas.

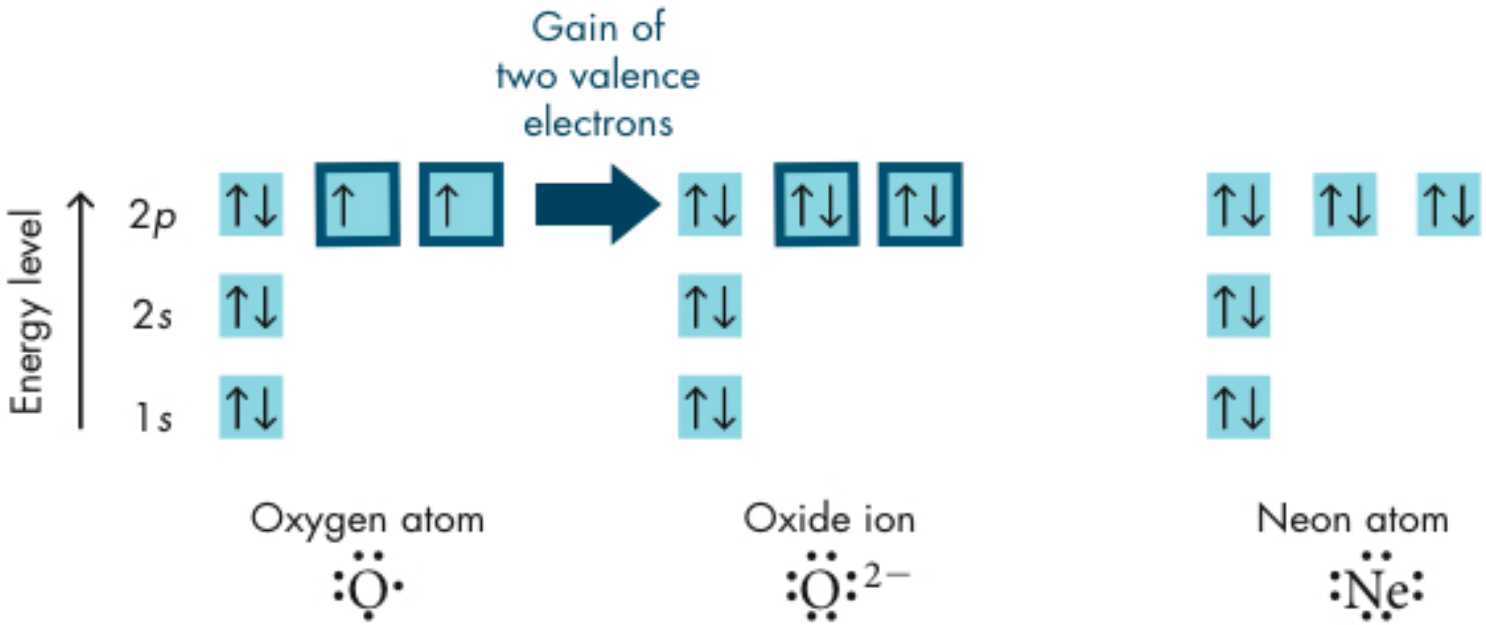


The ions produced when atoms of chlorine and other halogens gain electrons are called **halide ions**.

- All halogen atoms have seven valence electrons and need to gain only one electron to achieve the electron configuration of a noble gas.
  - All halide ions (F^-, Cl^-, Br^-, and I^-) have a charge of 1–.

Oxygen is in Group 6A, and an oxygen atom has six valence electrons.

- An oxygen atom attains the electron configuration of neon by gaining two electrons.



This table lists some common anions.

Some Common Anions		
Name	**Symbol**	**Charge**
Fluoride	F^-	1–
Chloride	Cl^-	1–
Bromide	Br^-	1–
Iodide	I^-	1–
Oxide	O^{2-}	2–
Sulfide	S^{2-}	2–
Nitride	N^{3-}	3–
Phosphide	P^{3-}	3–

Checkpoint

What is the electron configuration of a sulfide ion? What noble gas shares this configuration?

Checkpoint

What is the electron configuration of a sulfide ion? What noble gas shares this configuration?

S^{2-}: $1s^2 2s^2 2p^6 3s^2 3p^6$

This is the same configuration as Ar.

- **To find the number of valence electrons in an atom of a representative element, simply look at its group number.**
- **A positively charged ion, or cation, is produced when an atom loses one or more valence electrons.**
- **An anion is produced when an atom gains one or more valence electrons.**

- **valence electron:** an electron in the highest occupied energy level of an atom
- **electron dot structure:** a notation that depicts valence electrons as dots around the atomic symbol of the element; the symbol represents the inner electrons and atomic nucleus; also called Lewis dot structure

- **octet rule:** atoms react by gaining or losing electrons so as to acquire the stable electron structure of a noble gas, usually eight valence electrons
- **halide ion:** a negative ion formed when a halogen atom gains an electron

Bonding and Interactions

Atoms form positive ions (cations) by losing valence electrons and form negative ions (anions) by gaining valence electrons.

END OF 7.1