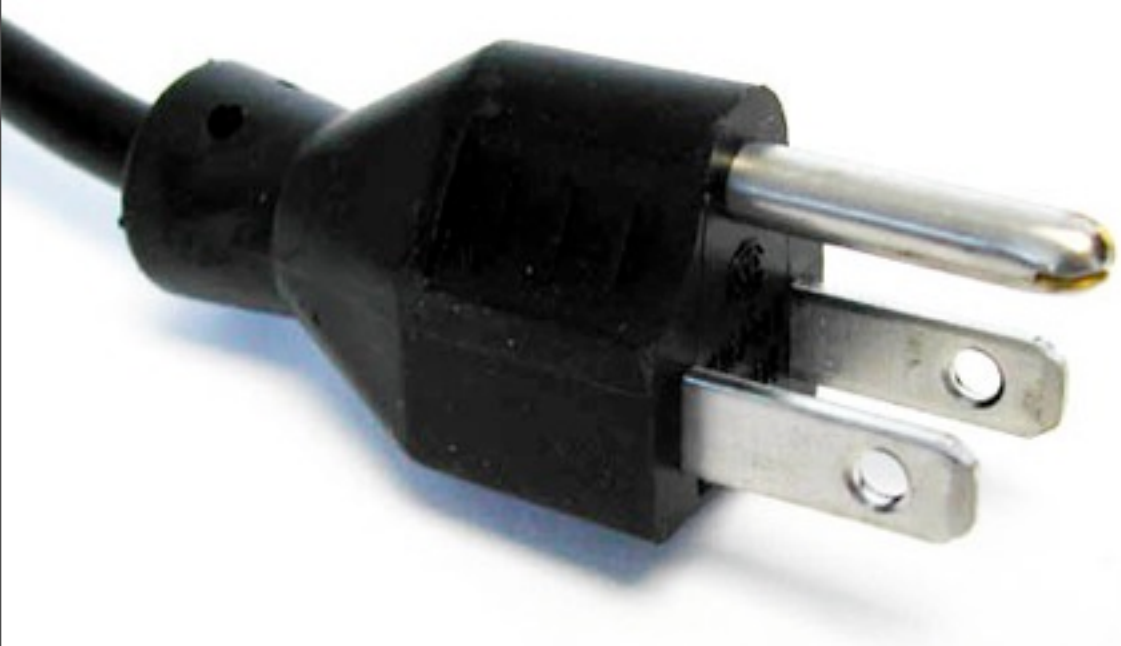
Ionic Compounds

Cations and anions
Ion reactivity
Ionic nomenclature
Properties of ionic compounds
Polyatomic nomenclature

Ion

- An ion is an atom or group of atoms that has either a positive charge or a negative charge

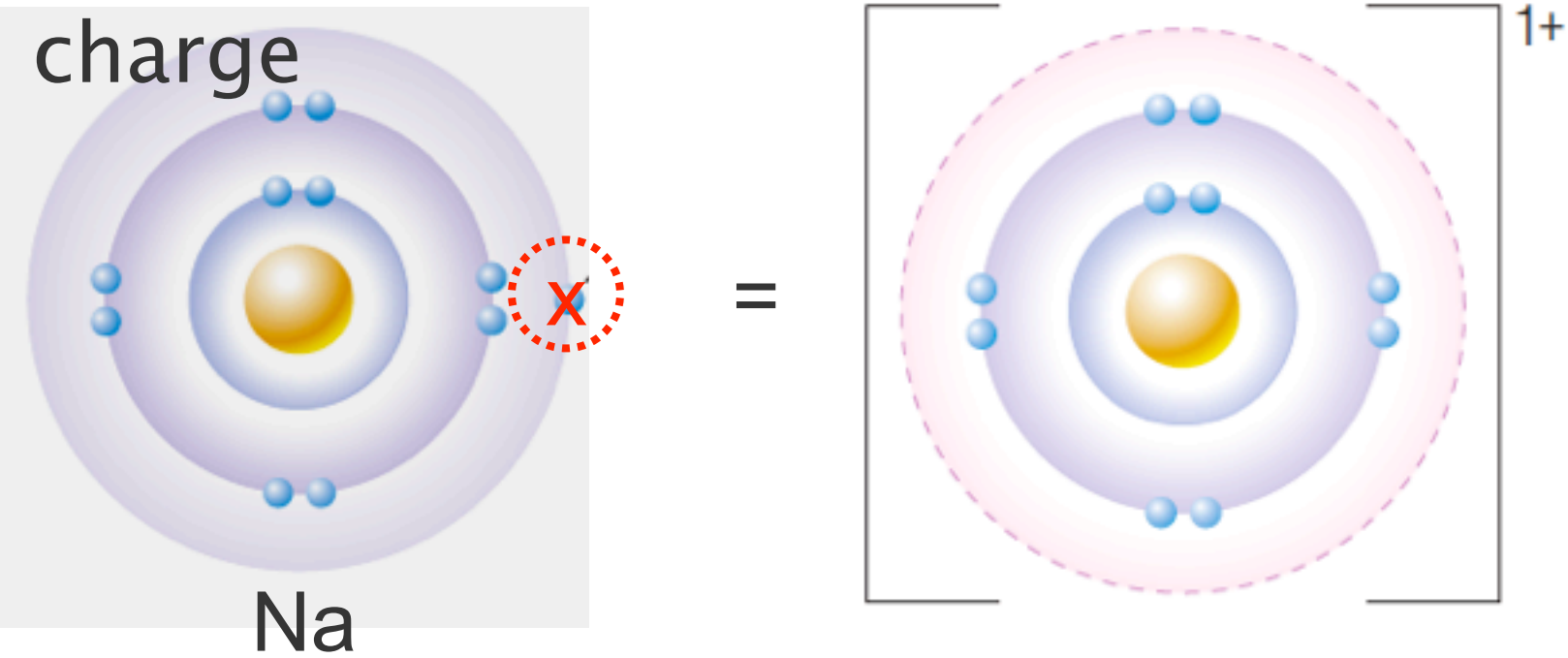


Ion

- Ions form when atoms gain or lose **electrons** to become **stable**
- A atom is stable when the **valence shell is full**

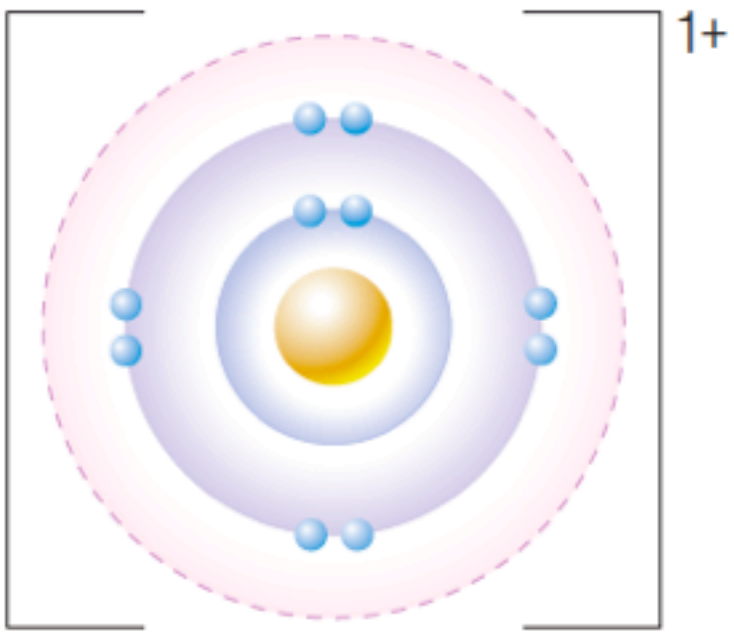
Positive Ion Example

- Sodium **loses** one electron to become stable
- Results in an ion that has a **positive** charge



Positive Ion Example

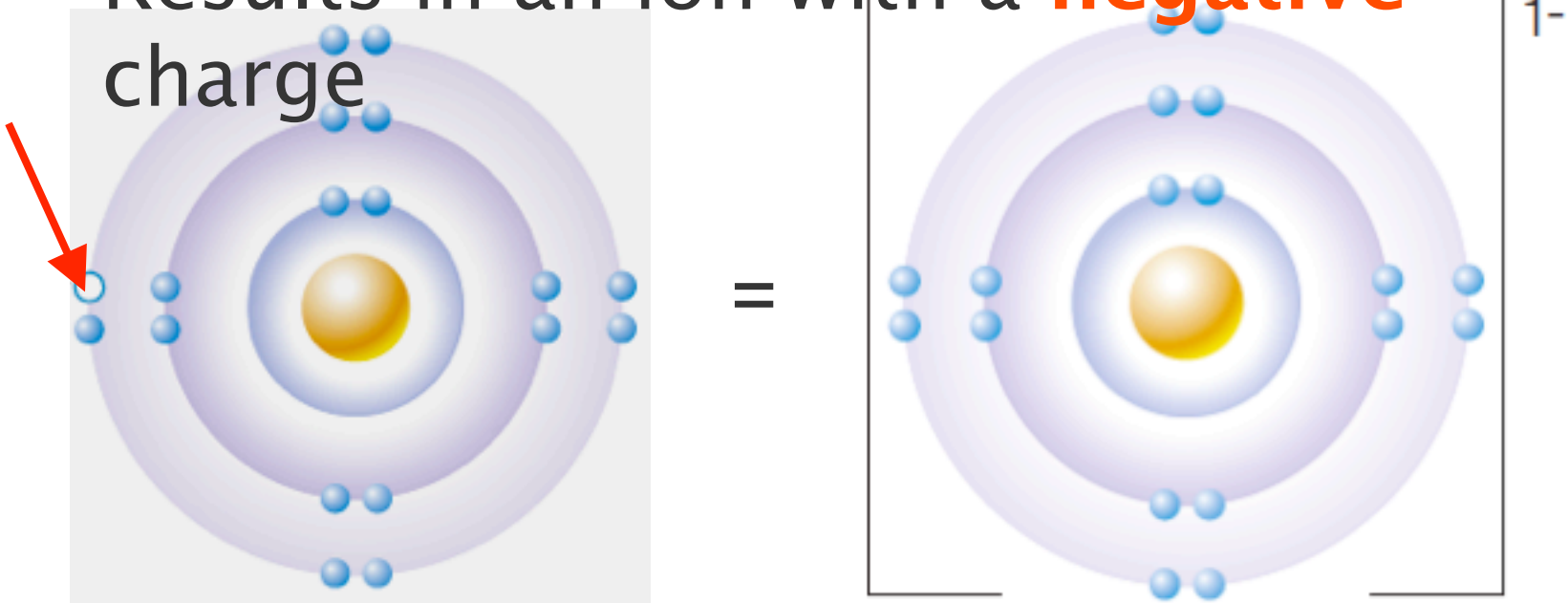
- The symbol "+" is written as a superscript to indicate that the sodium has a charge of 1+



Na^+

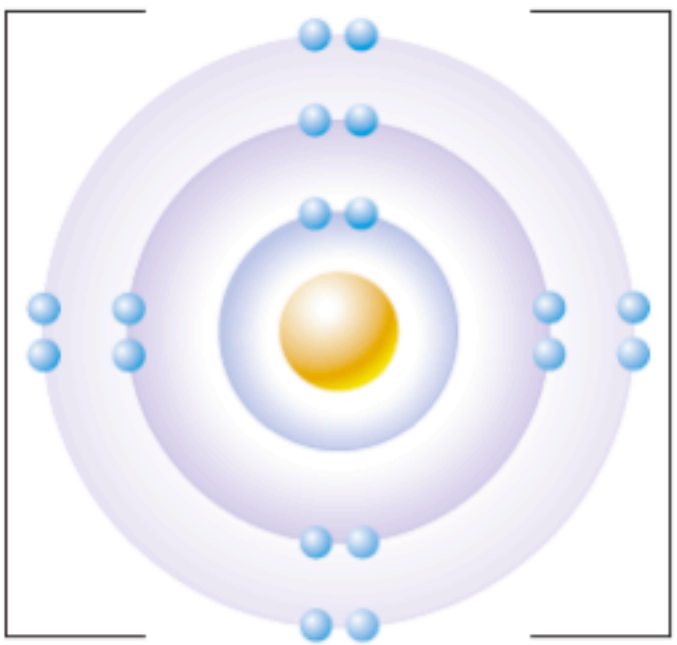
Negative Ion Example

- Chlorine **gains** one electron to become stable
- Results in an ion with a **negative** charge



Negative Ion Example

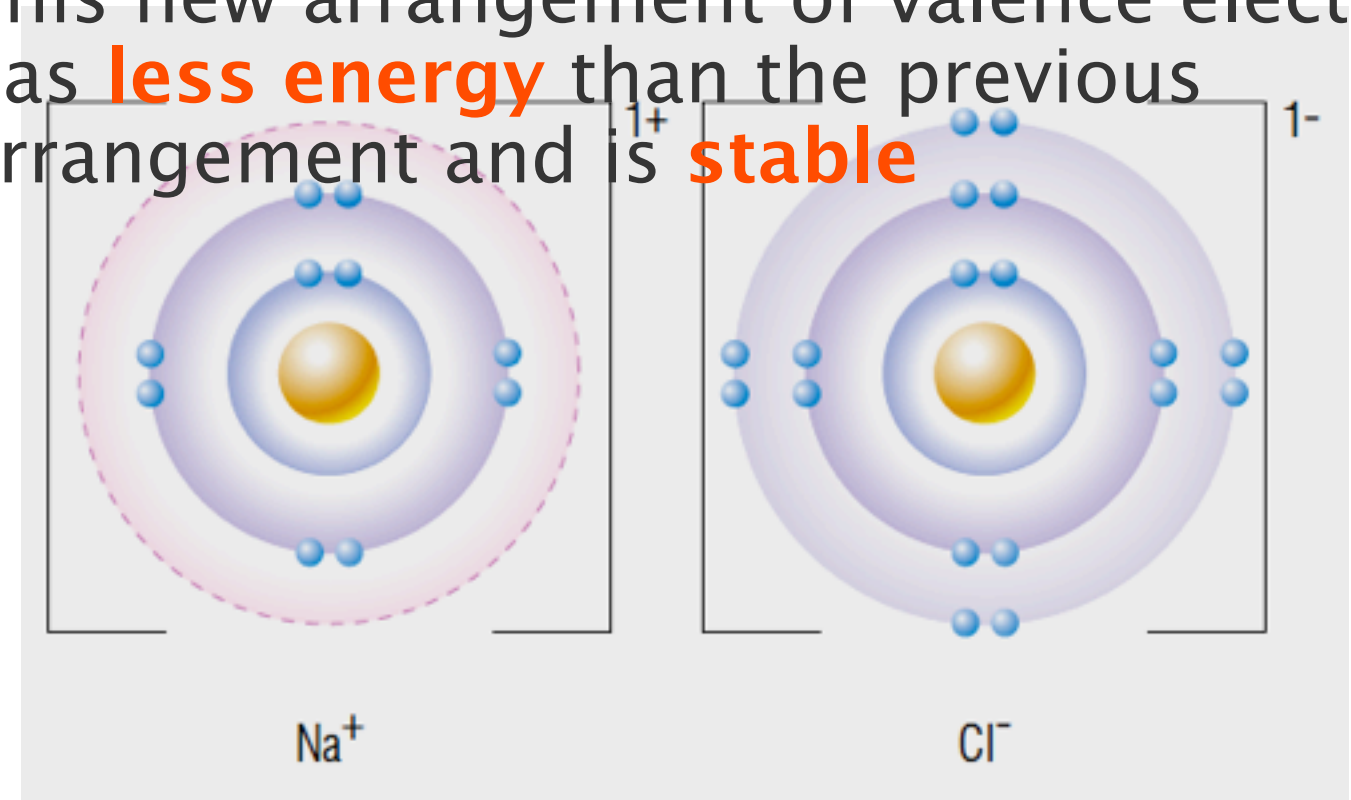
- The symbol "–" is written as a superscript to indicate that the chlorine ion has a charge of 1–



Cl^-

Ion

- Both ions have a full valence shell containing the **maximum** number of electrons possible
- This new arrangement of valence electrons has **less energy** than the previous arrangement and is **stable**



Cation

- When an atom gives up one or more electrons it becomes **positive**
- Called a **cation** "cat-eye-on"

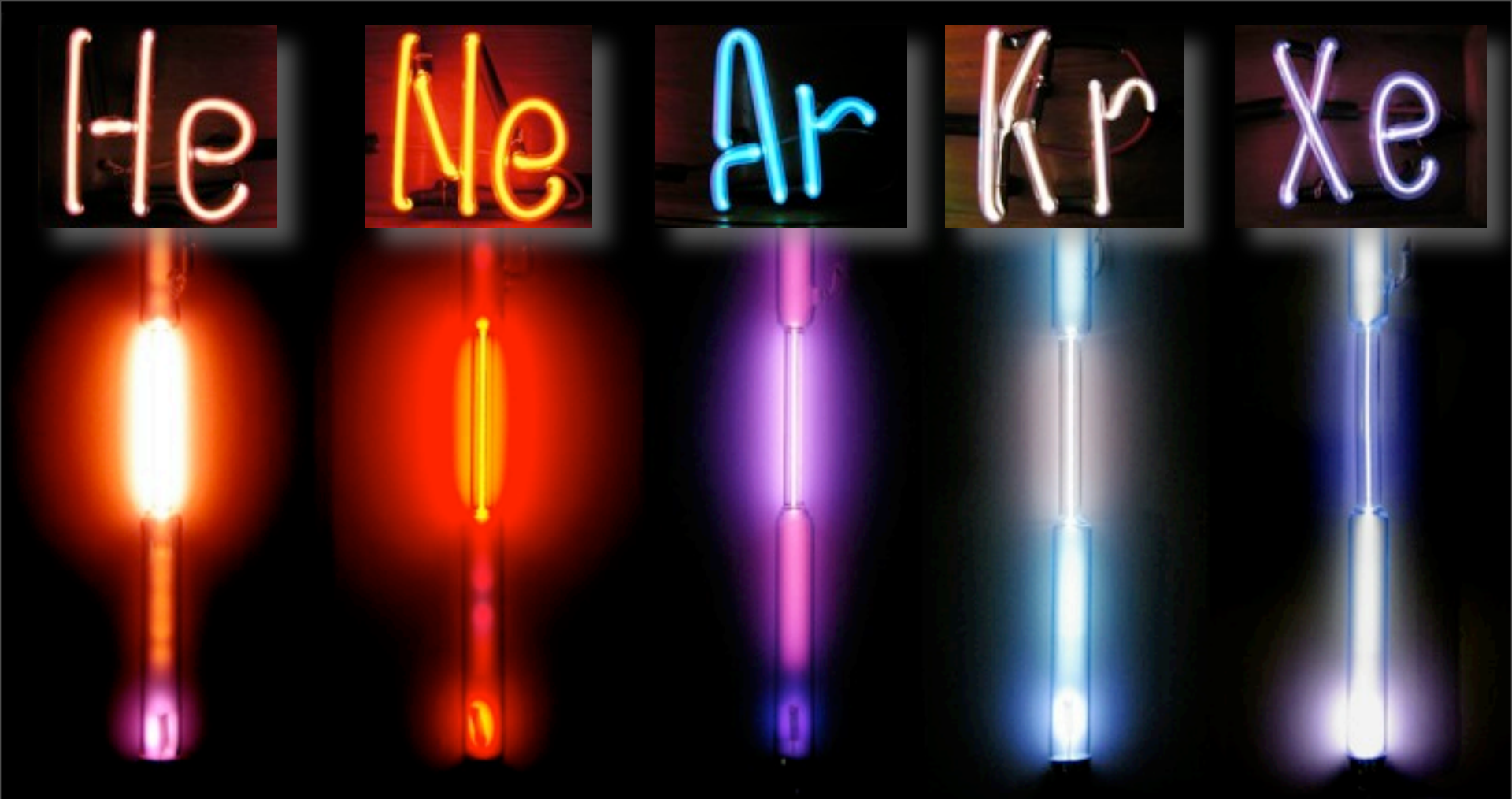
Anion

- When an atom **gains** one or more electron it become **negative**
- Called an **anion** (“an-eye-on”)

Ion

Ca+ions are posi +ive

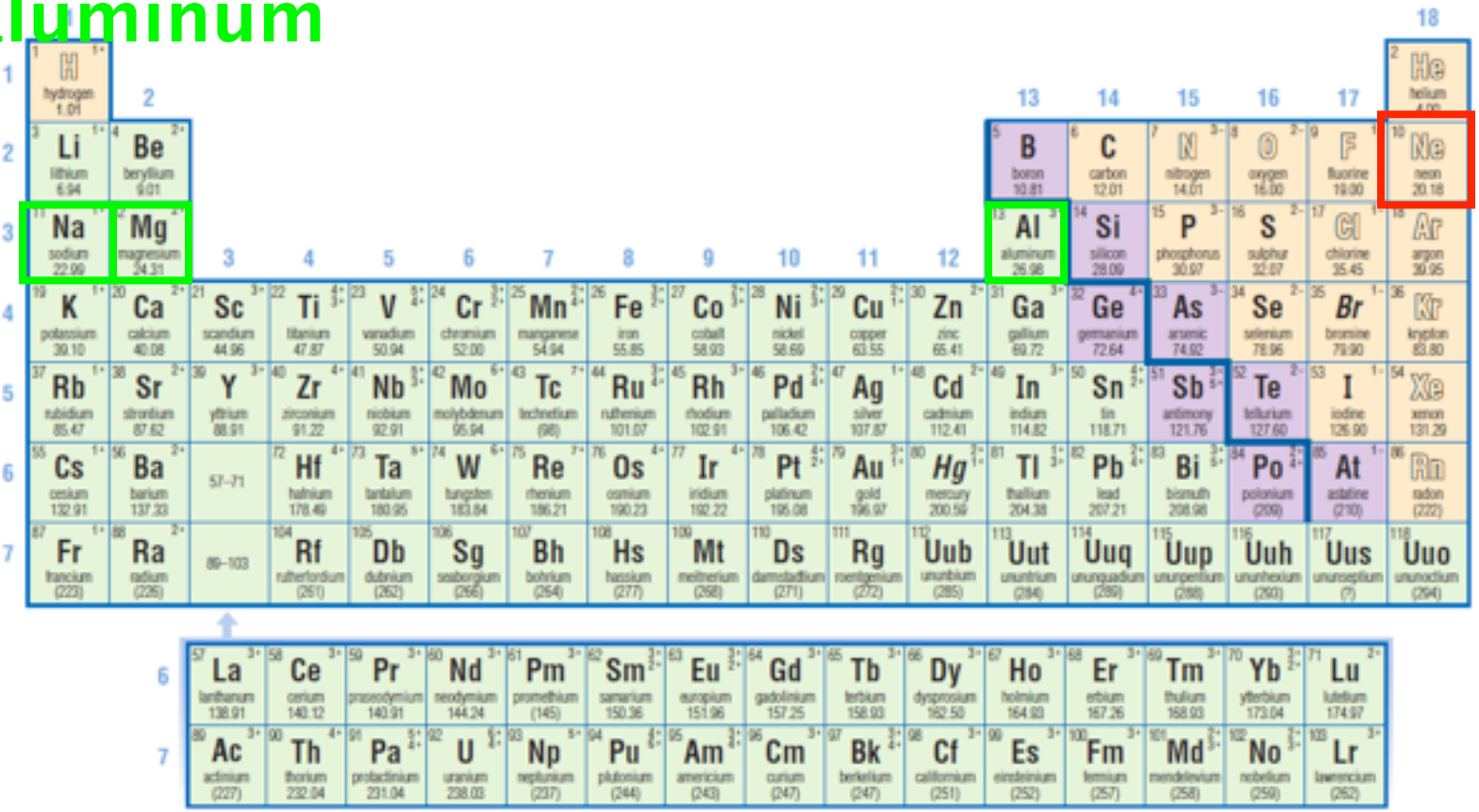
Anions are negative



An atom that has lost electrons (cation) or has gained electrons (anion) will have the same number of electrons as its nearest **noble gas**.

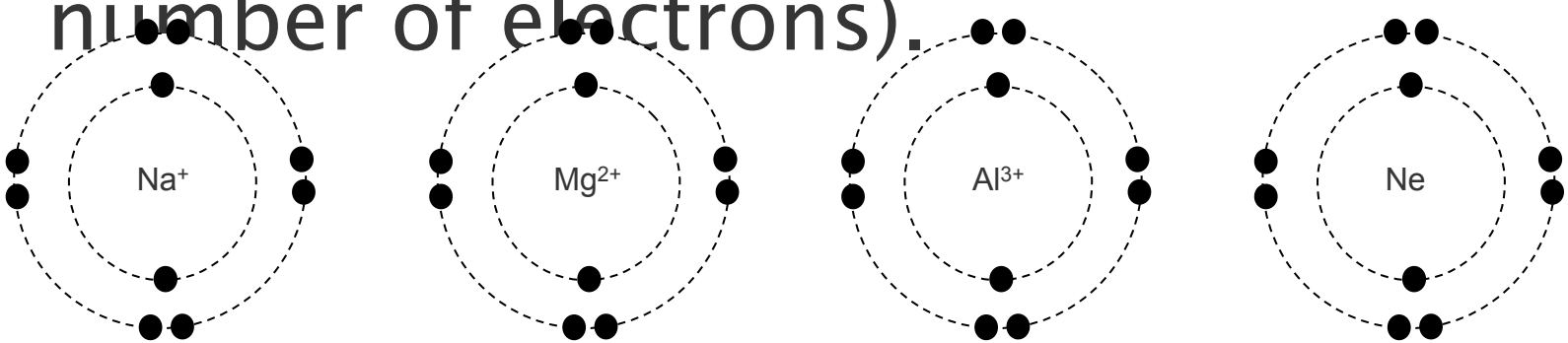
Cations

- For example, **neon** is the closest noble gas in the periodic table to **sodium, magnesium and aluminum**



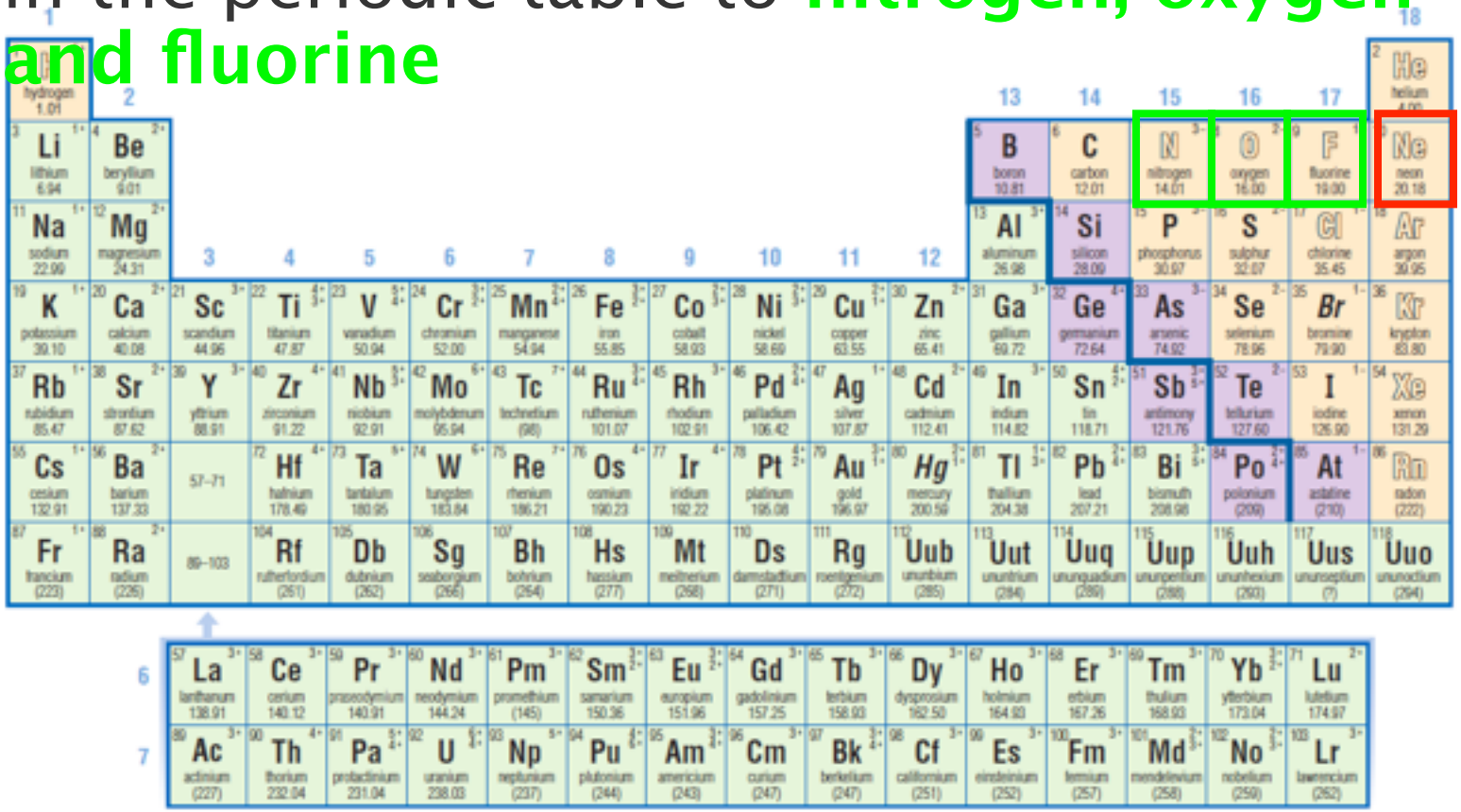
Cations

- The cations Na^+, Mg^{2+}, and Al^{3+} all have the same number of electrons as atoms of neon.
- This relationship is known as being **isoelectronic** (having the same number of electrons).



Anions

- Apply concept to anions
- For example, **neon** is the closest noble gas in the periodic table to **nitrogen, oxygen and fluorine**



Isoelectronic

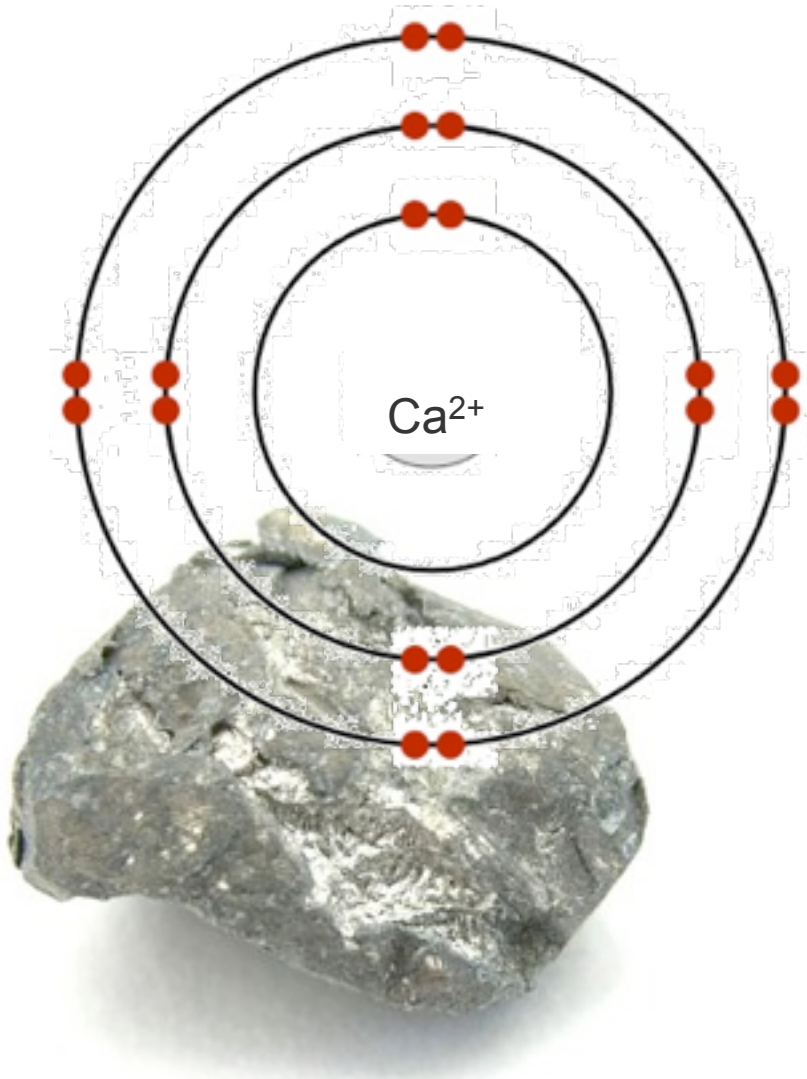
- Prove that these atoms are isoelectronic by drawing the Bohr diagrams.

Ne	N^{3-}	O^{2-}	F^{-}

How to write symbols for Ions

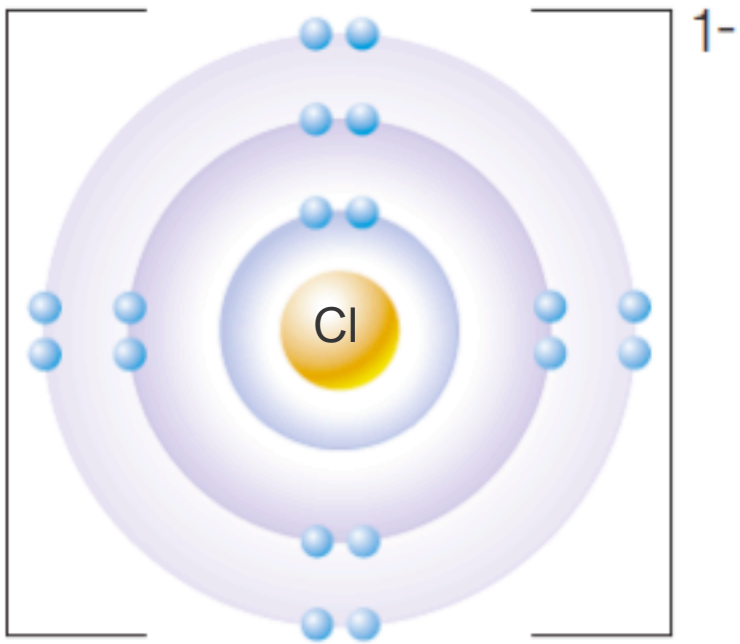
- Write the symbol of the element and show the ion charge as a superscript to the right of the element symbol
  - Example: the symbol of a calcium ion is Ca^{2+}
- When an ion has a charge of 1+ or 1– the symbol has no number in the superscript
  - Example: sodium ion is Na^{+} and not Na^{1+}

Naming Cations



- A metal that has lost electrons to become an ion has the same name as the element
- Eg: Ca^{2+} = calcium ion

Naming Anions



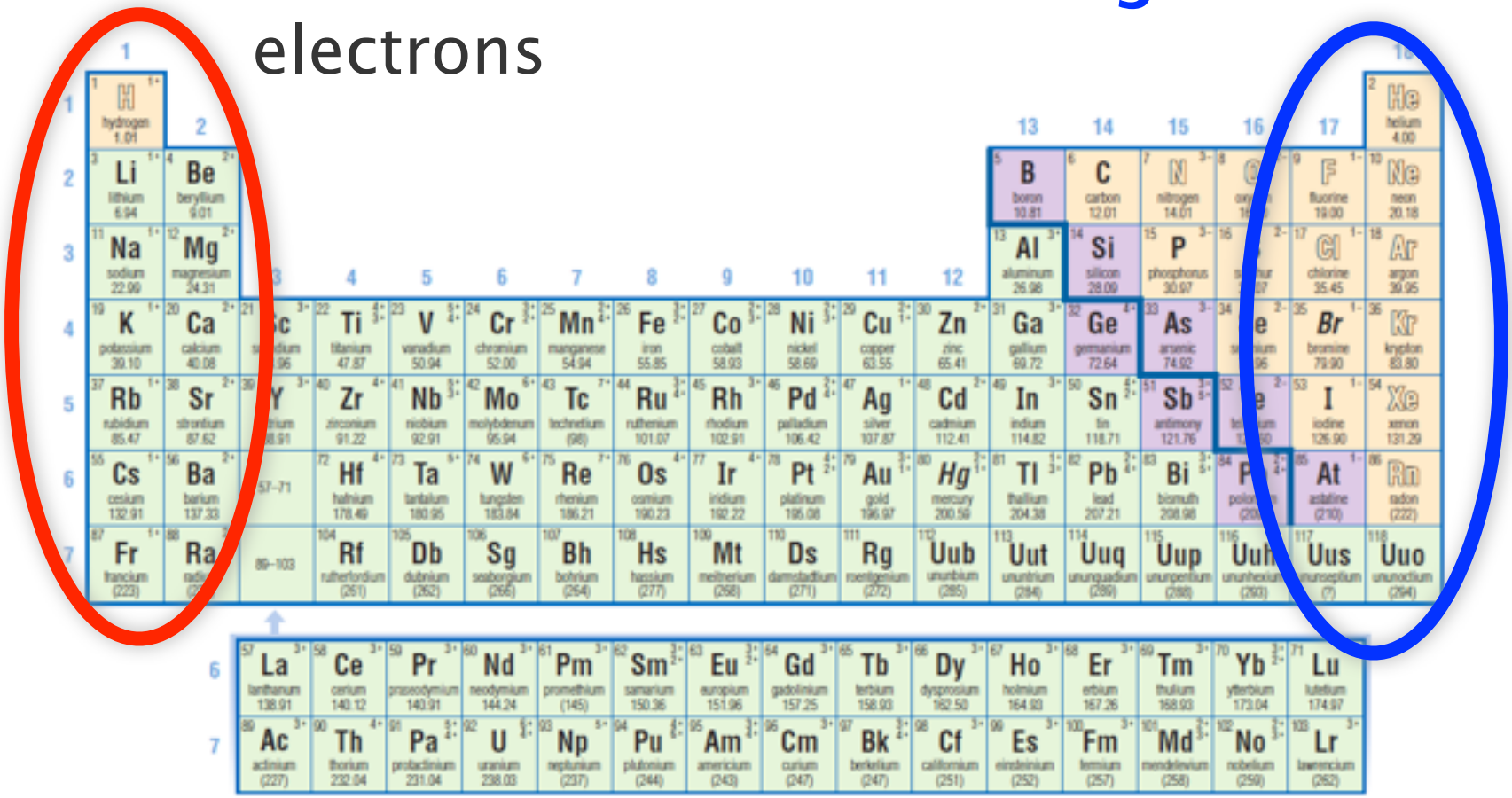
- A nonmetal that has gained electrons to become an ion has the the same name as the element but with the ending changed to **-ide**
- Eg: Cl^- = chloride ion

Naming Anions

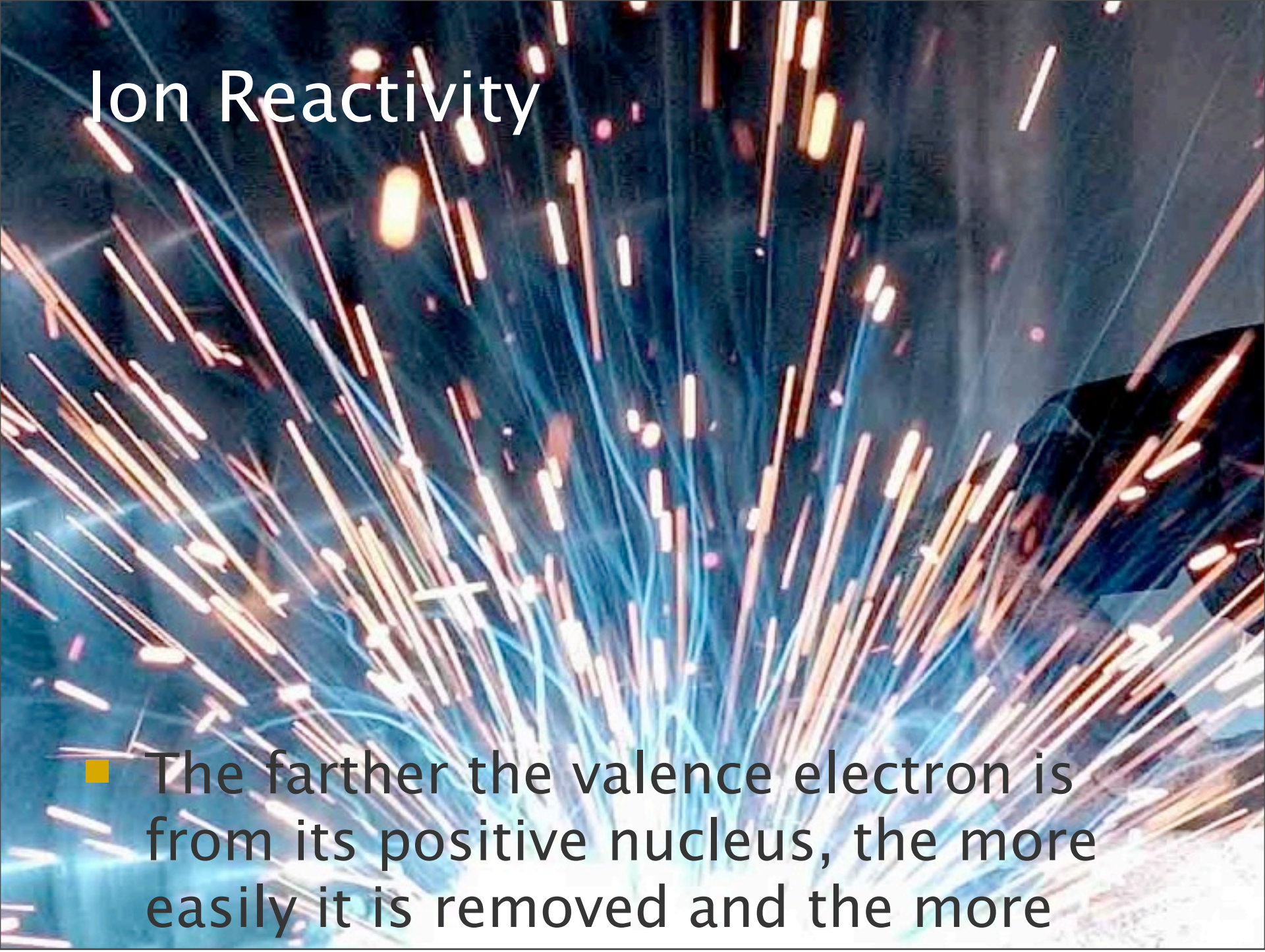
nitrogen	→	nitride
oxygen	→	oxide
fluorine	→	fluoride
phosphorous	→	phosphide
sulfur	→	sulfide
chlorine	→	chloride
selenium	→	selenide
bromine	→	bromide
iodine	→	iodide

Ion Reactivity

- **Metal** atoms tend to **lose** electrons
- **Non-metal** atoms tend to **gain** electrons



Ion Reactivity



- The farther the valence electron is from its positive nucleus, the more easily it is removed and the more

Cation Reactivity

- Reactivity generally increases for cations as you move down the periodic table
- Example: potassium is more reactive than sodium

Lithium

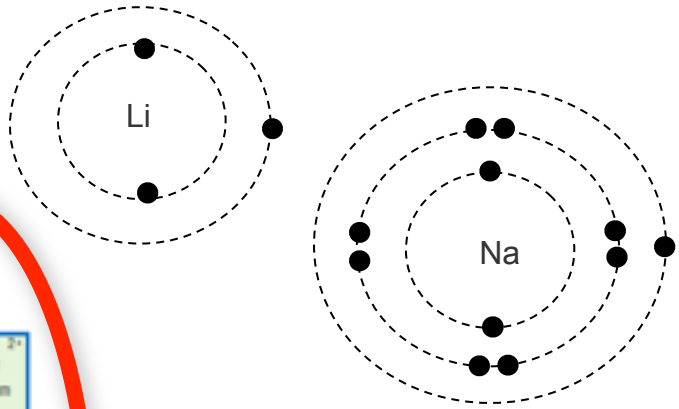
Sodium

Potassium

Rubidium

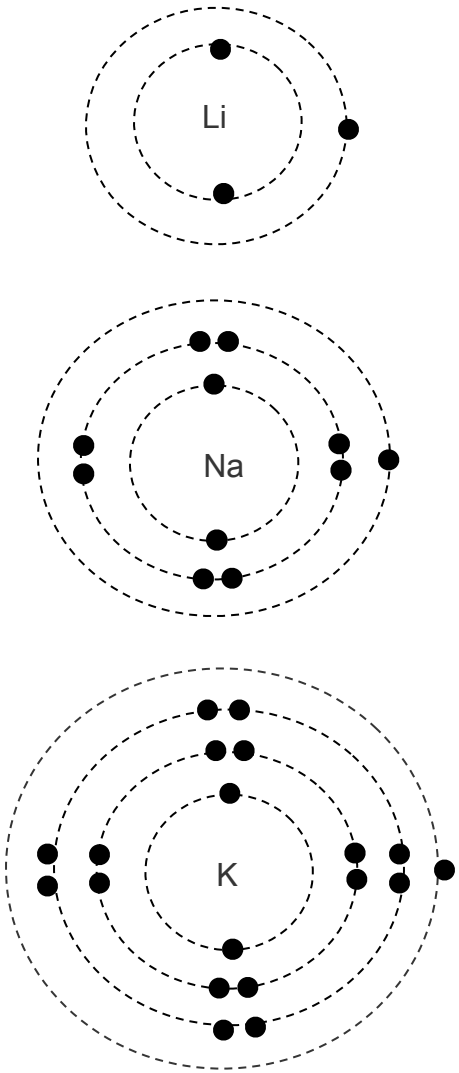
Cesium

Cation Reactivity



reactivity increases

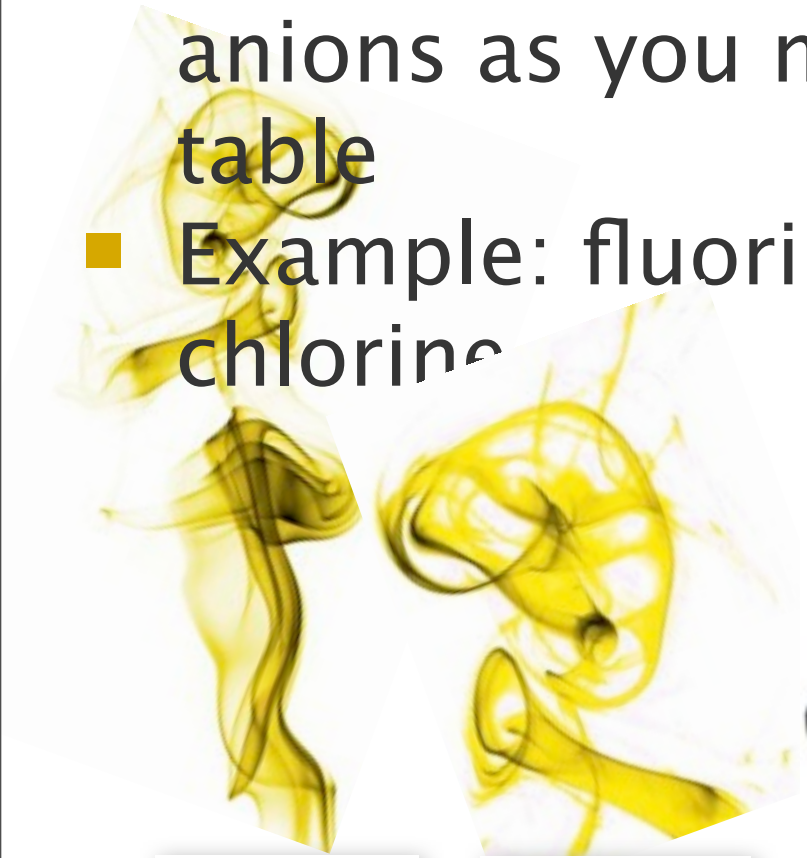
Cation Reactivity



- Why does cation reactivity increase as you move down the periodic table?
- Answer:
  - Electrons that are further away from the nucleus are more easily lost.
  - Thus atoms with more orbitals will be more reactive.

Anion Reactivity

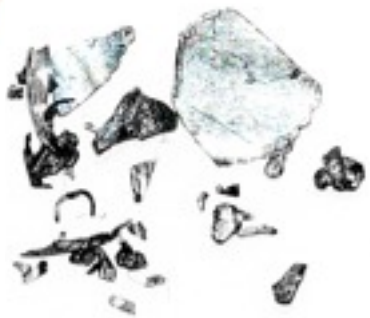
- Reactivity generally decreases for anions as you move down the periodic table
- Example: fluorine is more reactive than chlorine



Fluorine

Chlorine

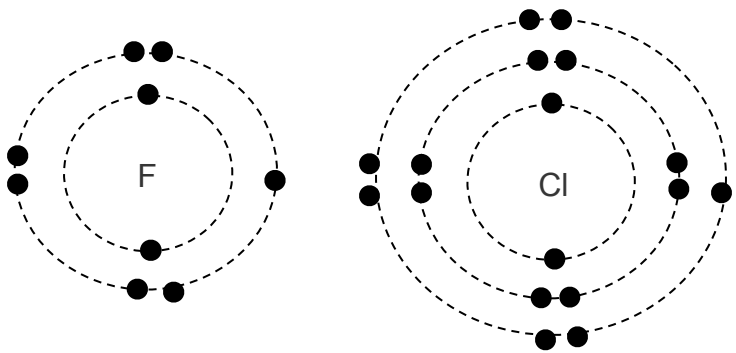
Bromine



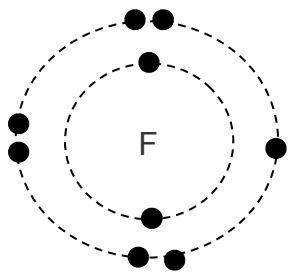
Iodine

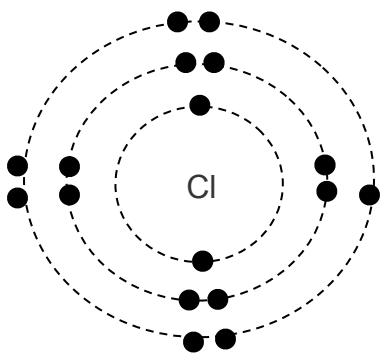
Astatine

Anion Reactivity



Anion Reactivity





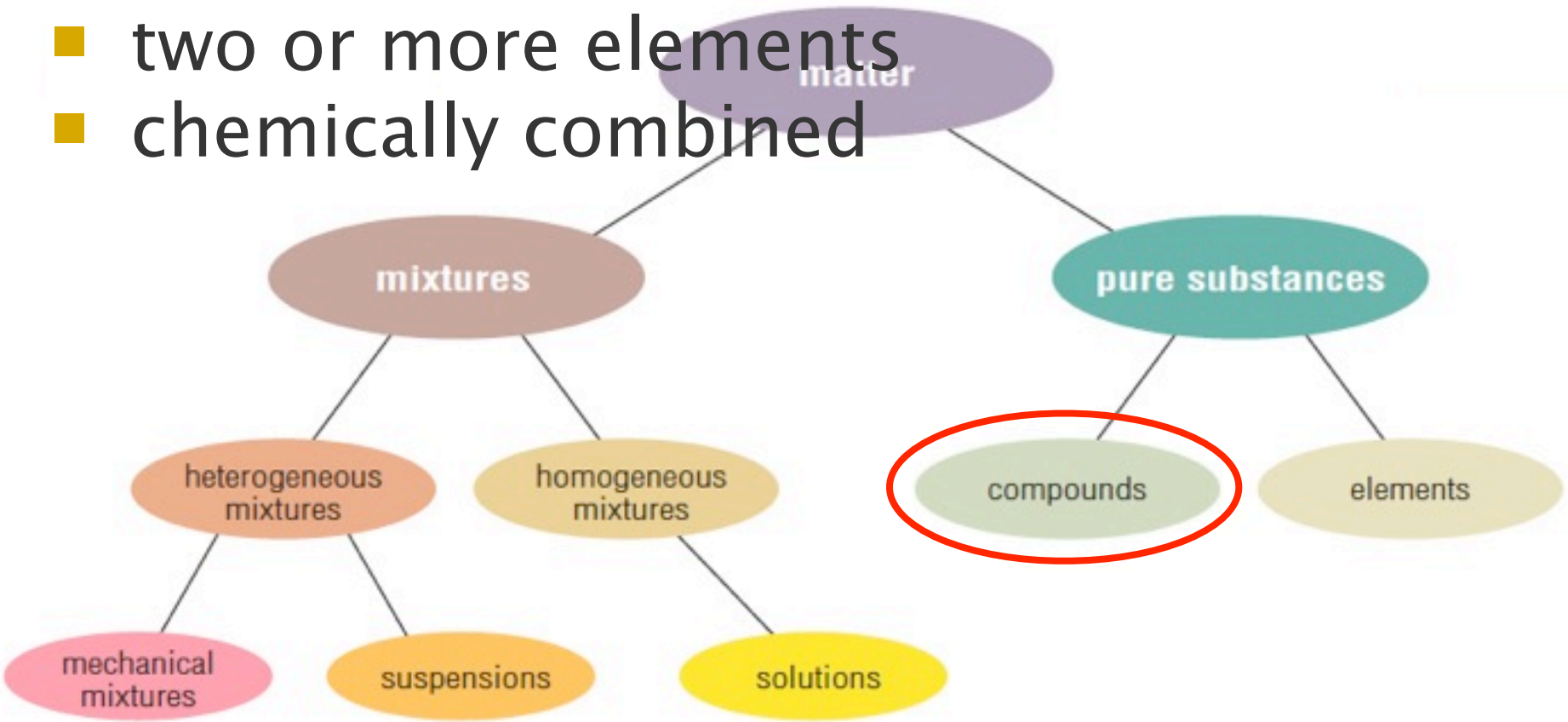
- Why does anion reactivity decrease as you move down the periodic table?
- Answer:
  - Elements whose valence shell is closer to the nucleus will gain electrons more readily because they are closer to the nucleus.
  - Negative electrons have a stronger attraction for the positive nucleus when the valence shell is closer to the

Video: Ferocious Elements (14:00)

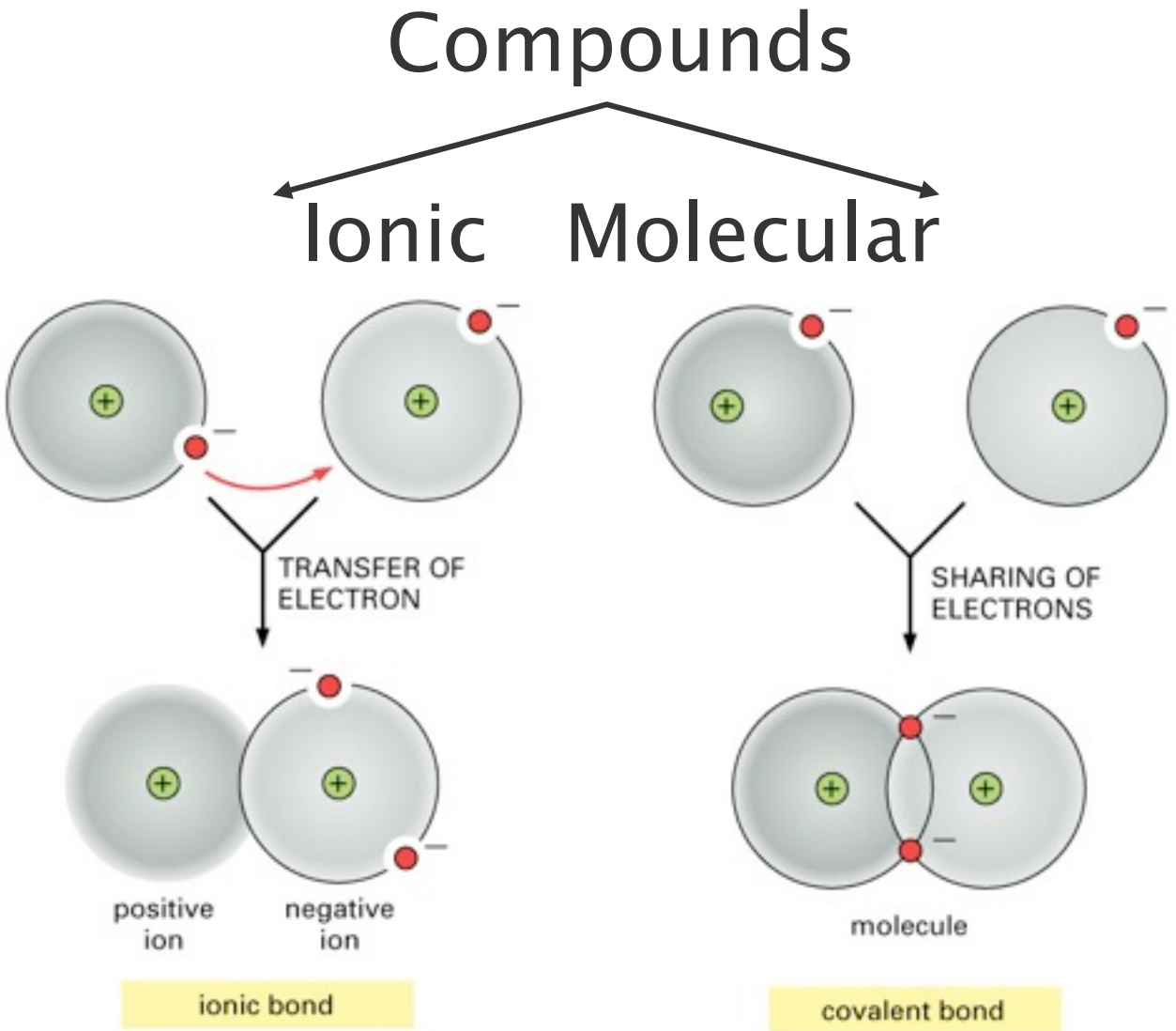
Review: Classification of Matter

Definition of compound:

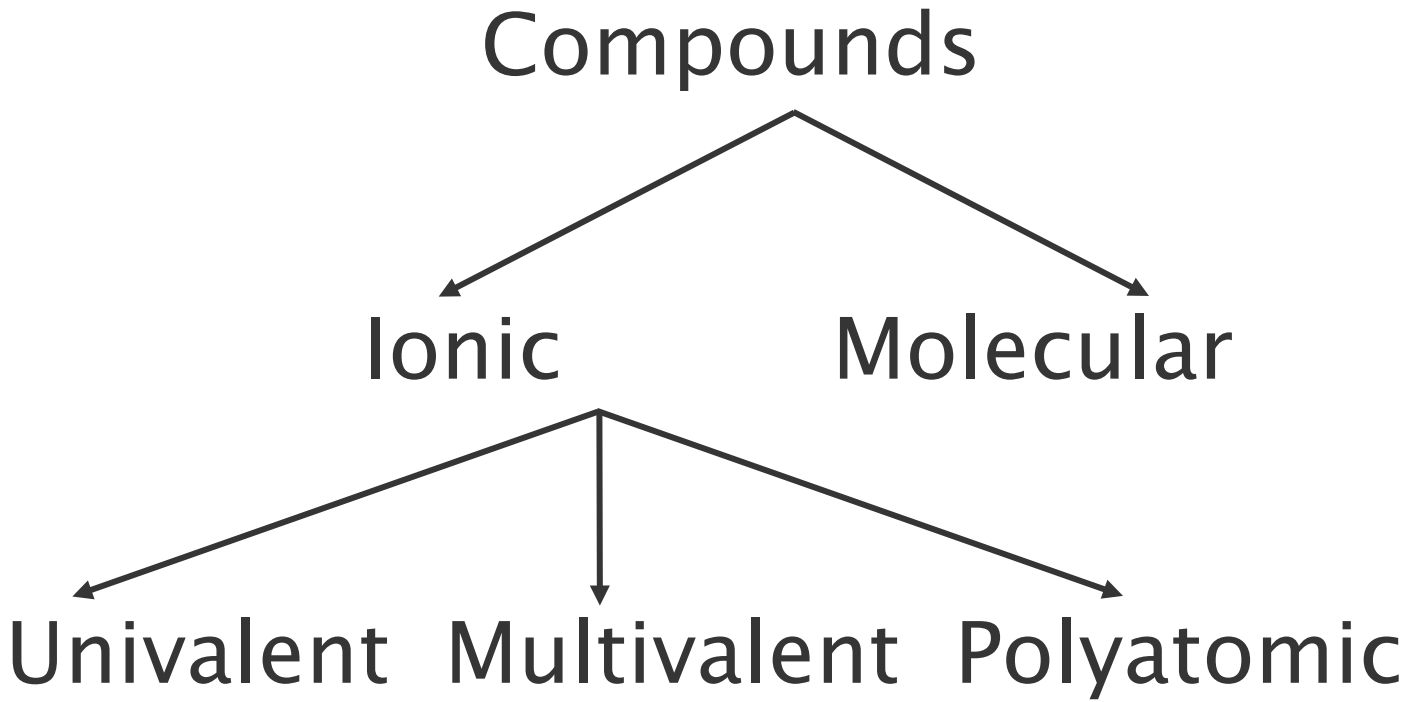
- pure substance
- two or more elements
- chemically combined



Types of Compounds



Types of Compounds

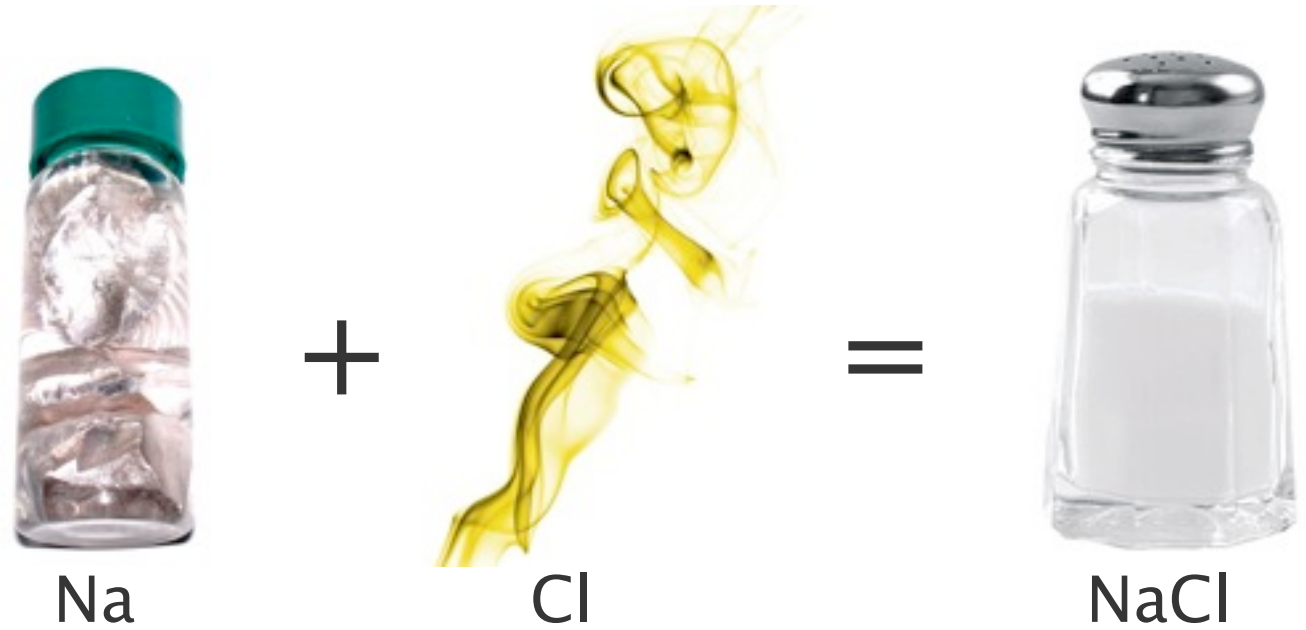


Ionic Compounds

- Ionic compounds form when atoms transfer electrons
- Ionic compounds consists of:
  - ions of opposite charges
  - cation and anion
  - an electron donor and acceptor

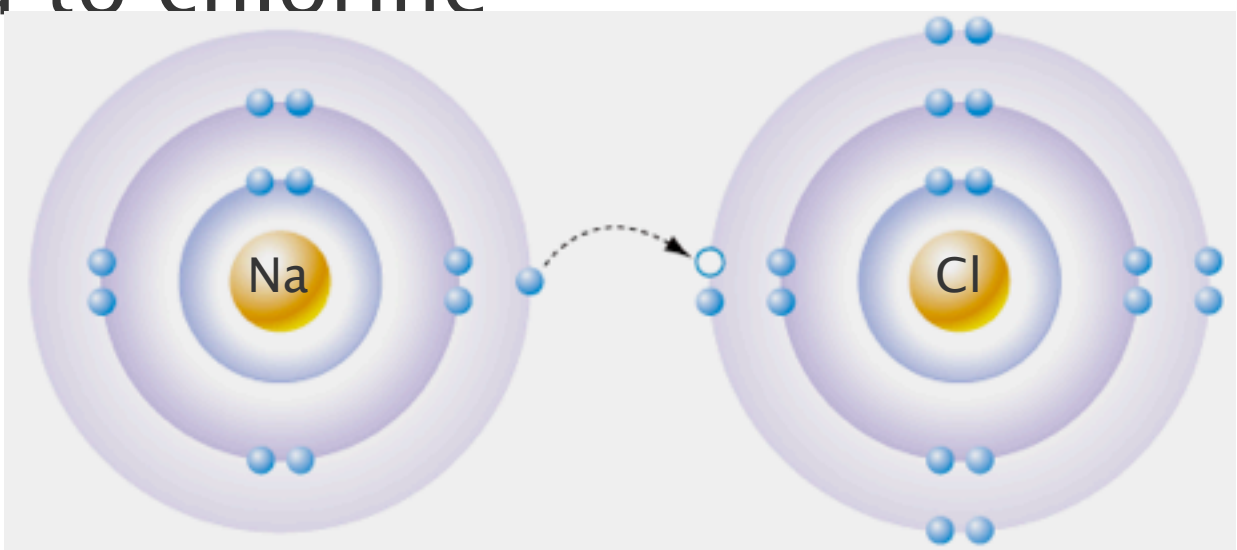
Example of Ionic Compound

- Formation of NaCl, or table salt



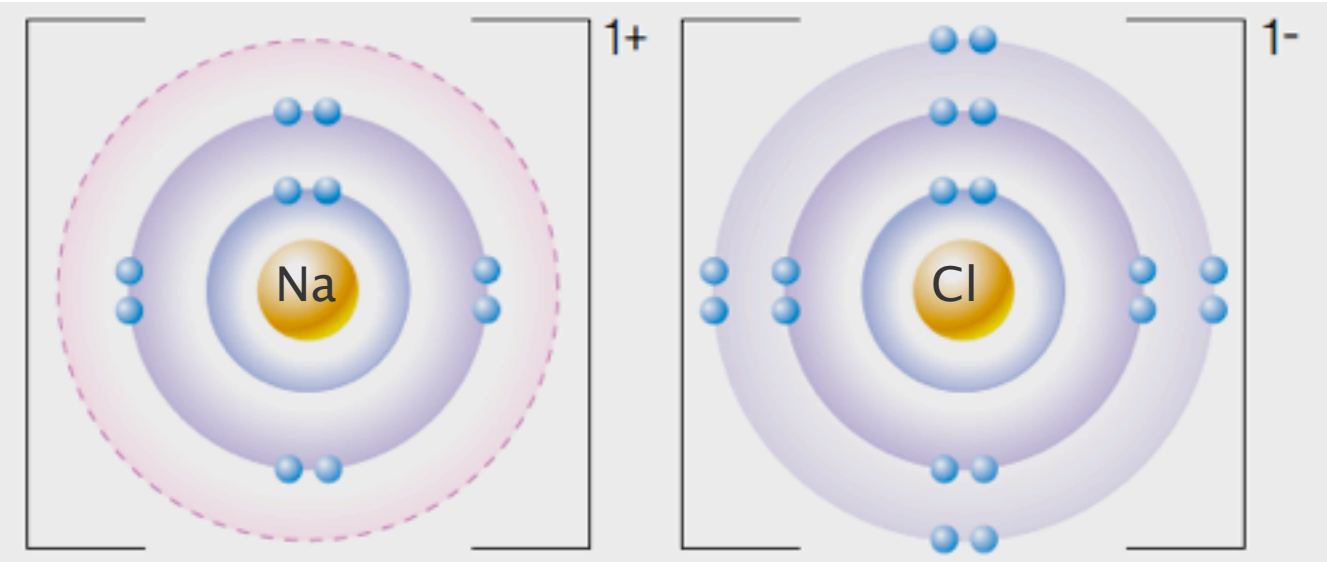
Example of Ionic Compound

- Sodium has 1 valence electron and wants to remove it to be stable
- Chlorine has 7 valence electrons and wants to gain one to be stable
- Thus, one electron from sodium is transferred to chlorine



Ionic Bond

- A cation will react with an anion to acquire a **full valence shell**
- The attraction between the cation and the anion is known as an **ionic bond**

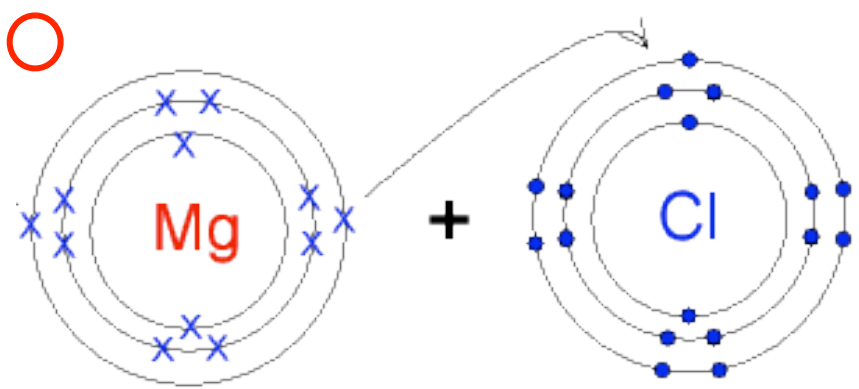


Forming Ionic Compounds

- Transfer of electrons until both elements in the compound have a full valence shell
- If the number of electrons that an atom wants to give away does not equal the number of electrons that the receiving atom wants, then more atoms of either element can be added until both elements are full

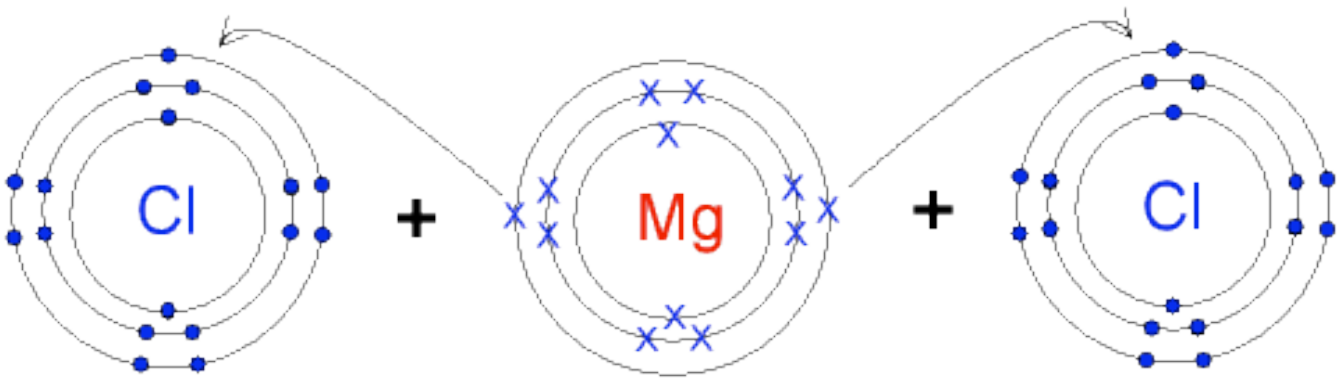
Forming Ionic Compounds

- Example: Form an ionic compound between magnesium and oxygen
  - Draw Bohr (or Lewis) diagram for each element
  - Use arrows to move electrons to fill valence shell



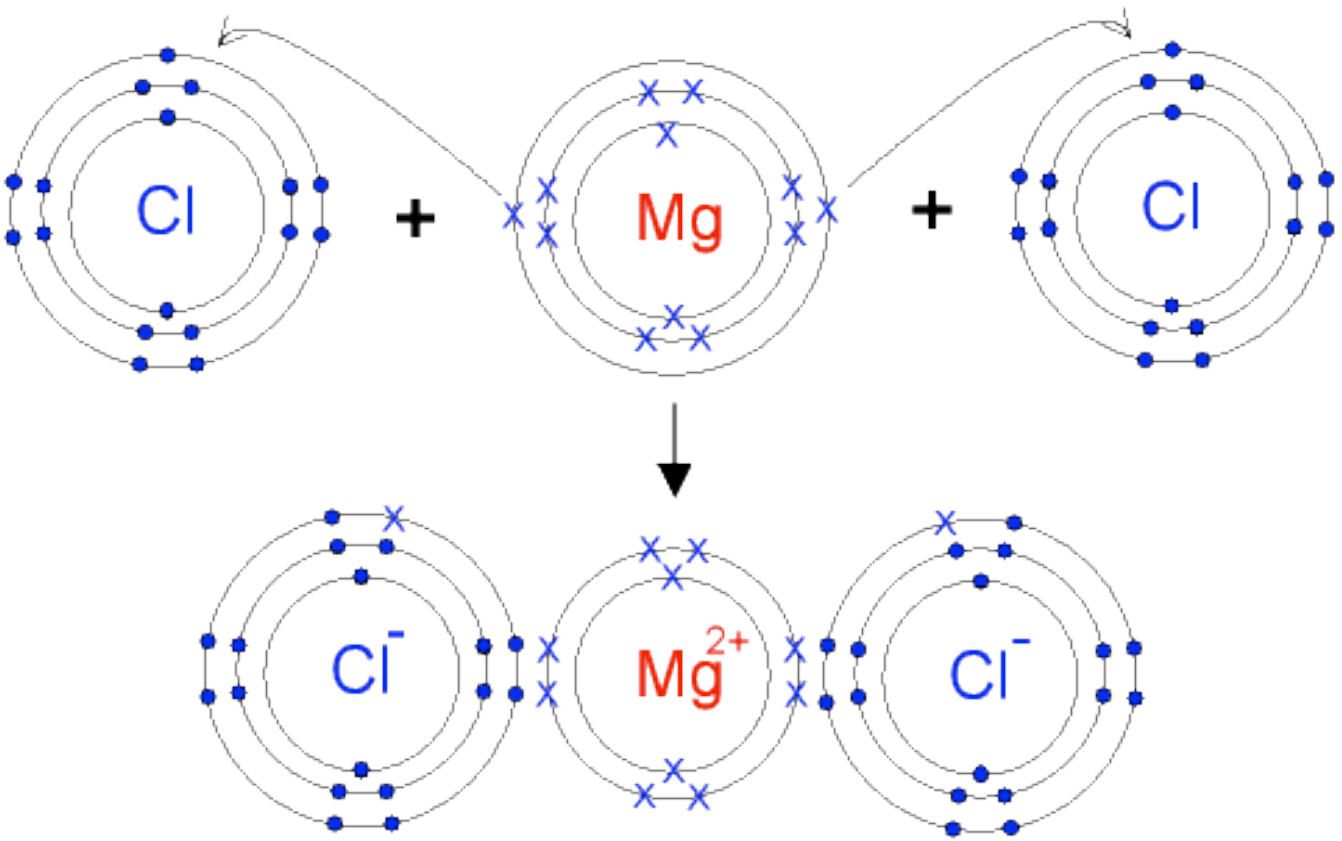
Forming Ionic Compounds

- Example: Form an ionic compound between magnesium and oxygen
  - If the valence shells are not full after moving as many of the electrons as possible, add more atoms as needed



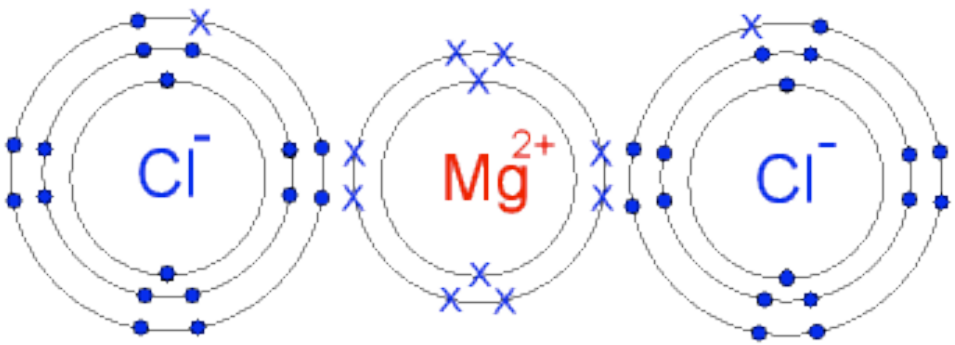
Forming Ionic Compounds

- Example: Form an ionic compound between magnesium and oxygen



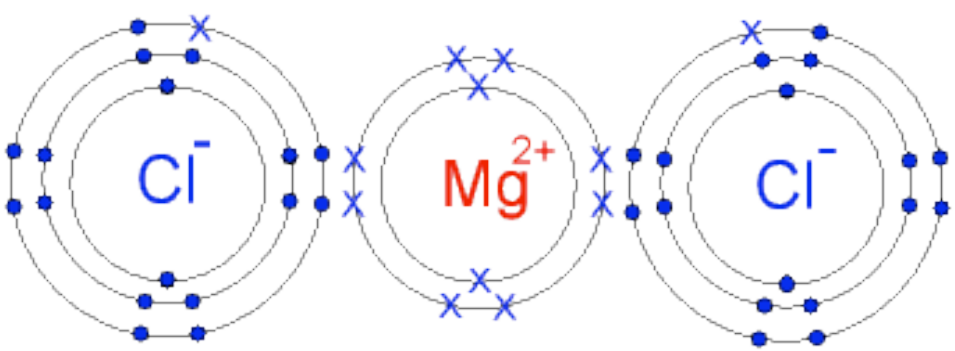
Forming Ionic Compounds

- Example: Form an ionic compound between magnesium and oxygen
- Final composition this ionic compound is:
  - 1 magnesium atom
  - 2 chlorine atoms
  - Chemical formula: $MgCl_2$



Ionic Compound Chemical Formula

- The cation is always written first
- The anion is always written second
- If there is more than 1 atom, it is indicated by a subscript following the element symbol (bottom-right)
- Example: MgCl2



Is there a faster way?

- Drawing the Bohr/Lewis diagram every time you want to determine the chemical formula of an ionic compound is tedious and takes a long time
- There is a faster way that requires knowing stable form of elements

No net charge rule

- All ionic compounds must have a net charge of zero

- Example: MgCl2

Atoms	# valence electron	Movement of electrons	Charge of ion	Number of atoms in the compound	Total charge
Mg	2	Lose 2	2+	1	+2
Cl	7	Gain 1	1–	2	–2
				Net charge	ZERO!

Rule for all compounds

- Although ionic compounds are made of charged particles, the compound itself has **no net charge**
- All ion charges must be equal and add up to **zero**

Writing Chemical Formula for Ionic

1. Identify the charge of the ions in the compound
   - Example: Calcium chloride
   - Ca^{2+} and Cl^{-}
2. Determine the number of positive and negative ions needed to make the compound neutral
   - Need 2 Cl^{-} to equal 1 Ca^{2+}
3. Write the cation first. Use subscript to indicate the number of ions if it is more than 1. Make sure to use on the lowest common multiple.
   - Calcium chloride = CaCl2
   - Wrong: Ca2Cl4

	C	Cl
Charge		
Number of		
Total charge		

Writing Chemical Formula for Ionic Compounds

- Example Problem 1: Write the chemical formula for Aluminum oxide.
- Write the element symbol and their charges.
- How many of each do we need to make the compound neutral?
- Write the chemical formula using subscripts as needed.

	Al	O
Charge		
Number of		
Total charge		

Nomenclature

- A system used to name things
- In this case, we will be naming a variety of different types of ionic compounds:
  - Univalent
  - Polyatomic

Univalent Ionic Compounds

- Compounds where the cation only has one possible charge.

Naming Univalent Ionic Compounds

1. Name the cation first
   - The name of the metal ion is the same as the element name
   - Example: in KBr, the name of the K+ ion is potassium
2. Name the anion second
   - When a non-metal becomes a negative ion, the ending of its name changes to “ide”
   - Example: a bromine atom become bromide ion (Br –)
3. Combine the names. The formulas of ionic compounds often contain numbers called subscripts which can be ignored when determining the name.
   - Example: Na3P is sodium phosphide

Naming Univalent Ionic Compounds

Example Problem 2: Write the name of the ionic compound ZnF2

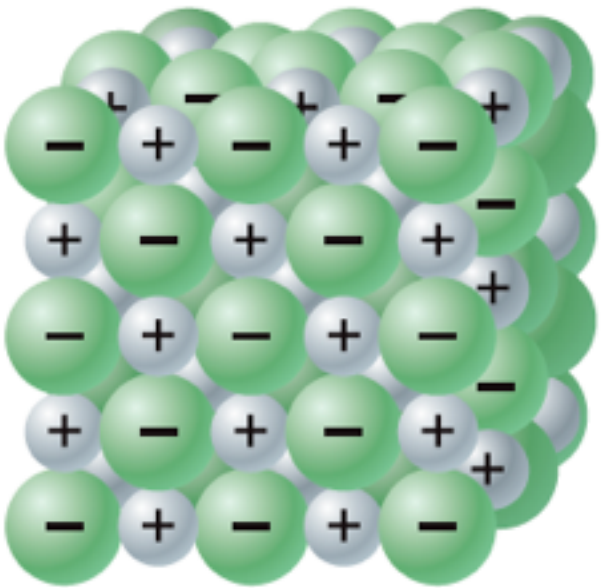
1. Name the metal ion:
   - Zn forms only one type of ion (Zn^{2+}), so the name is zinc
2. Name the non-metal ion:
   - The atom is fluorine so the ion is fluoride
3. Combine the names:
   - ZnF2 = zinc fluoride

Properties of Ionic Compounds

- At room temperature, most are hard, brittle solids that can be crushed

Properties of Ionic Compounds

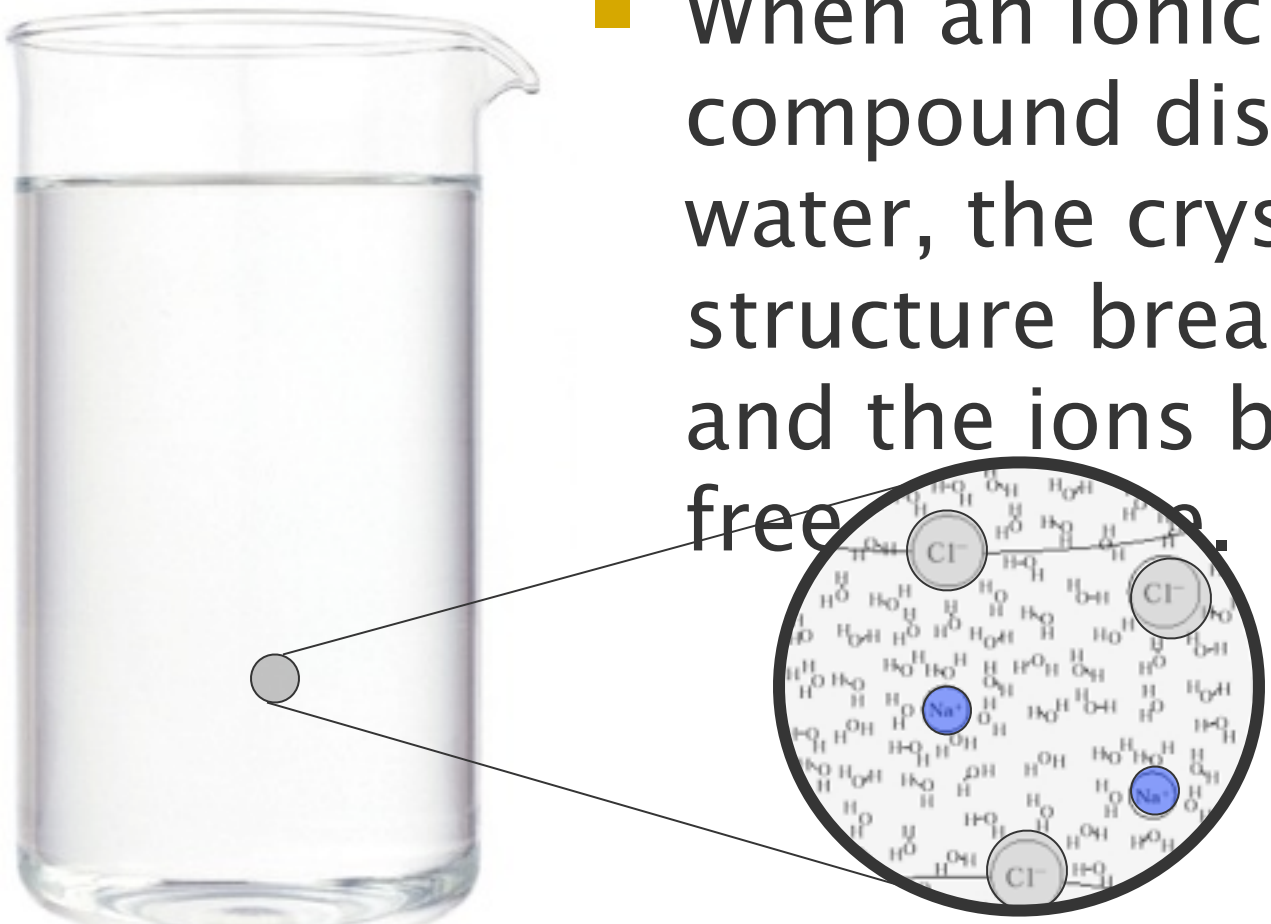
- Ionic compounds form crystals that have an alternating arrangement of positively charged ions and negatively charged ions
- When they break their edges are well-defined



Properties of Ionic Compounds

- In an ionic crystal, every ion is attracted to every other ion
- Thus, ionic crystals have very high **melting points**
- Eg. NaCl melts at 800°C

Properties of Ionic Compounds



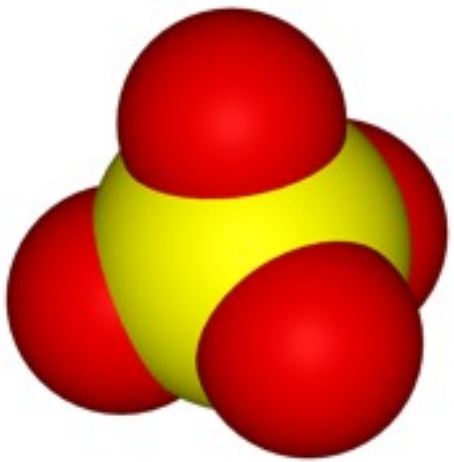
- When an ionic compound dissolves in water, the crystal structure breaks down and the ions become free to move.

Properties of Ionic Compounds

- Solutions of ionic compounds can conduct electricity

Polyatomic Ions

- Poly = 2 or more
- Atomic = atoms

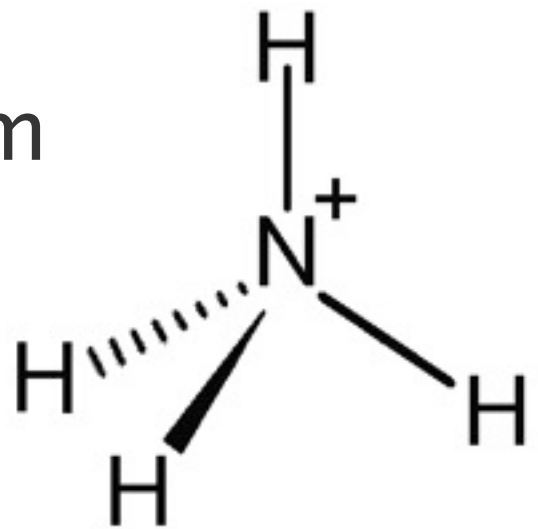


- A polyatomic ion is a group of atoms, usually of different elements, that act as a single ion

- Example: one atom of sulphur and four atoms of oxygen form the polyatomic ion called sulphate, or $SO4^{2-}$

Polyatomic Ions

- Similar polyatomic ions are named using the suffixes “-ate” or “-ite”
- Example: NO_3^- is nitrate; NO_2^- is nitrite
- Most common polyatomic ions have a negative charge
- However, the ammonium ion NH_4^+ has a positive charge



Examples of Polyatomic Ions

Name	Formul
ammonium	NH_4^+
carbonate	CO_3^{2-}
bicarbonate	HCO_3^-
hydroxide	OH^-
nitrate	NO_3^-
nitrite	NO_2^-
permanganate	MnO_4^-
phosphate	PO_4^{3-}
phosphite	PO_3^{3-}
sulphate	SO_4^{2-}
sulphite	SO_3^{2-}

Naming Polyatomic Ionic Compounds

Example Problem 3: Write the name of the ionic compound $LiHCO_3$

1. Name the cation:
   - Example: Li^+ = lithium
2. Identify the polyatomic ion (use table):
   - Example: HCO_3^- = bicarbonate
3. Combine the names. Do not change the polyatomic ending.
   - $LiHCO_3$ = lithium bicarbonate

Writing Chemical Formula for Polyatomic Ionic Compounds

1. Identify the charge of the ions in the compound
   - Example: Calcium chlorate
   - Ca^{2+} and $ClO4^{-}$
2. Determine the number of positive and negative ions needed to make the compound neutral
   - Need 2 $ClO4^{-}$ to equal 1 Ca^{2+}
3. Write the cation first. If subscripts are needed for the polyatomic ion, place a bracket around it first.
   - Calcium chlorate = $Ca(ClO4)_2$

	C	ClO
Charge		
Numbe r of		
Total charge		

Writing Chemical Formula for Polyatomic Ionic Compounds

- Example Problem 4: Write the chemical formula for calcium phosphate.
- Write the symbols of the cations and include their charges.
- How many of each do we need to make the compound neutral?
- Write the chemical formula using subscripts and brackets as needed.