# Chemistry 104 Chapter Four PowerPoint Notes

## Chemical Bonding: The Ionic Bond Model
## Chapter 4

Chemistry 104
Professor Michael Russell

## Ions

Atoms are electrically neutral because

number of protons = number of electrons

By gaining or losing electrons an atom can be converted into a charged particle called an ***ion***.

Loss of one or more electrons gives positively charged ion called a ***cation***.

Gaining one or more electrons gives negatively charged ion called a ***anion***.

***MAR***

## IONS AND IONIC COMPOUNDS

**CATIONS have protons > electrons**

**ANIONS have electrons > protons**

***Remember:***

**CATS have PAWS**

**CATions are PAWSitive**

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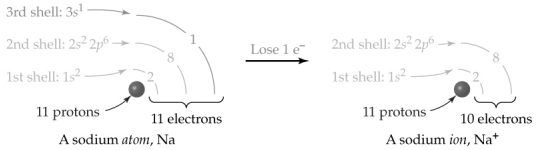
## Cations

The symbol for a cation is written by adding a positive charge as a superscript to the symbol for the element.

*For example*, Na loses an electron to make the sodium cation ($Na^+$).

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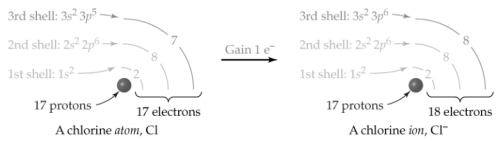
## Anions

The symbol for a anion is written by adding a negative charge as a superscript to the symbol for the element.

*For example*, Cl gains an electron to make the chloride anion ($Cl^-$).

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## Periodic Properties and Ion Formation

**Ionization energy**: Energy required to remove an electron from a single atom in the gaseous state

Ionization energy measures the ease in which atoms become ***cations***

**Electron affinity**: Energy released on adding an electron to a single atom in the gaseous state.

Electron affinity measures the ease in which atoms become ***anions***

Small ionization energy - electron easily lost, *cation formed*

Large electron affinity – electron easily gained, *anion formed*

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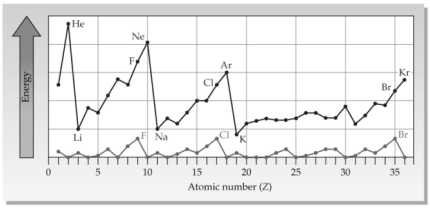
Halogens: *Large ionization energy* – electron not easily lost; *Large electron affinity* – electron easily gained – formation of anion is favored.




Graph shows relative ionization energies and electron affinities for elements in the first four rows of the periodic table.

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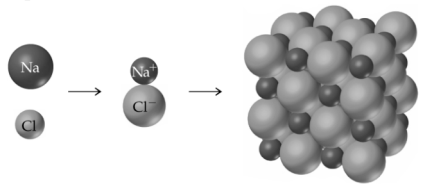
## Ionic Bonds

Opposite electrical charges *attract*

When sodium combines with chlorine, sodium transfers electron to chlorine forming $Na^+$ and $Cl^-$ ions.

The oppositely charged $Na^+$ and $Cl^-$ ions are held together by a *ionic bond*, making an *ionic compound*.

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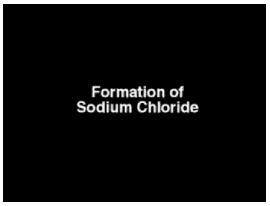
## Formation of NaCl

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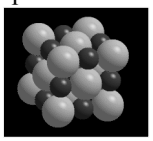
## Ionic Compounds

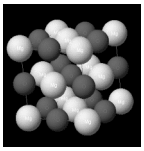
Ionic compounds *usually* crystalline solids

Ions vary in size and charge.

Ionic compounds have high melting and boiling points.



NaCl, $Na^+$ and $Cl^-$, m.p. 804 °C



MgO, $Mg^{2+}$ and $O^{2-}$ m.p. 2800 °C

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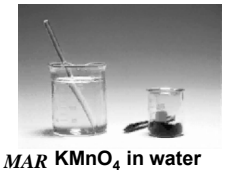
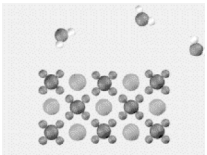
An ionic compound will *dissolve* in water if the *attraction* between water and the ions *overcomes* the attraction between the ions in an ionic compound.

An ionic compound will *not dissolve* in water if the *attraction* between water and the ions *cannot overcome* the attraction between the ions in an ionic compound.



*MAR* $KMnO_4$ in water



$K^+(aq) + MnO_4^-(aq)$

## Electron-Dot Symbols

*Electron-Dot Symbol*: Dots placed around atomic symbol to indicate the number of valence electrons

Group 1A atoms (Na, K, etc.) have a single dot

Group 2A atoms (Mg, Ca, etc.) have 2 dots, etc.

Helium is an exception

Li·
Na·
K·

Group 1A = one valence electron

Be:
Mg:
Ca:

Group 2A = two valence electrons

He:

Helium has two valence electrons

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## Ions of Some Common Elements

Metals of group 1A and 2A form only +1 and +2 ions. Ions of these elements all have a noble gas configuration through *electron loss* from their outermost shell.

Group 6A and 7A elements attain noble gas configuration by *gaining* 1 or 2 electrons.

**Group 6A:** $\cdot\ddot{O}\cdot + 2\,e^- \longrightarrow :\ddot{O}:^{2-}$

$\cdot\ddot{S}\cdot + 2\,e^- \longrightarrow :\ddot{S}:^{2-}$

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## Ions and the Octet Rule

***Octet Rule***: Main group elements undergo reactions that leave them with 8 valence electrons or a noble gas configuration - **isoelectronic** (same number of electrons) with noble gases.

All noble gases (except helium) have 8 electrons in their valence shell.

For example, in NaCl, $Na^+$ and $Cl^-$ have the following electron configurations:

$$\underset{1s^2\,2s^2\,2p^6\,3s^1}{Na} + \underset{1s^2\,2s^2\,2p^6\,3s^2\,3p^5}{Cl} \longrightarrow \underbrace{\underset{1s^2\,2s^2\,2p^6}{Na^+}}_{\text{Neon configuration}} + \underbrace{\underset{1s^2\,2s^2\,2p^6\,3s^2\,3p^6}{Cl^-}}_{\text{Argon configuration}}$$

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Common ions formed by elements in the first four periods

| 1A | 2A | | | | | | | | | | 3A | 4A | 5A | 6A | 7A | 8A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 $H^+$ | | | | | | | | | | | | | | | | 2 |
| 3 $Li^+$ | 4 $Be^{2+}$ | | | | | | | | | | 5 | 6 | 7 | 8 $O^{2-}$ | 9 $F^-$ | 10 |
| 11 $Na^+$ | 12 $Mg^{2+}$ | | | | Transition metals | | | | | | 13 $Al^{3+}$ | 14 | 15 | 16 $S^{2-}$ | 17 $Cl^-$ | 18 |
| 19 $K^+$ | 20 $Ca^{2+}$ | 21 $Sc^{3+}$ | 22 $Ti^{4+}$ | 23 $V^{2+}$ | 24 $Cr^{2+}$ $Cr^{3+}$ | 25 $Mn^{2+}$ | 26 $Fe^{2+}$ $Fe^{3+}$ | 27 $Co^{2+}$ | 28 $Ni^{2+}$ | 29 $Cu^{2+}$ | 30 $Zn^{2+}$ | 31 | 32 | 33 | 34 $Se^{2-}$ | 35 $Br^-$ | 36 |

**Groups IA - IIIA**: ion usually gets a positive charge equal to the group number

**Groups VA - VIIA:** ion usually gets a negative charge equal to the group number minus eight

*Ex:* Aluminum makes the $Al^{3+}$ ion

*Ex:* Nitrogen makes the $N^{3-}$ ion

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## Naming Cations

Main group metal cations (Groups 1A, 2A, and 3A) named by identifying the metal, followed by the word "ion":

$K^+$ Potassium ion

$Mg^{2+}$ Magnesium ion

$Al^{3+}$ Aluminum ion

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## Naming Anions

Main group nonmetal anions (Groups VA, VIA, and VIIA) named by identifying the nonmetal and *changing ending to "ide"* followed by the word "ion":

| | |
|---|---|
| $Cl^-$ | Chloride ion |
| $O^{2-}$ | Oxide ion |
| $P^{3-}$ | Phosphide ion |

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## Naming Ions

Transition metals can often form more than one type of cation. Two methods used:

| | $Cr^{2+}$ | $Cr^{3+}$ |
|---|---|---|
| Old name | Chromous ion | Chromic ion |
| New name | Chromium(II) ion | Chromium(III) ion |

Try to use the "new" method when possible

Roman numeral indicates charge on cation

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## Polyatomic Ions

*CATION: Positive Ion*

| | |
|---|---|
| $NH_4^+$ | ammonium ion |

*ANIONS: Negative Ions*

***Based on a Group 4A element***

| | |
|---|---|
| $CN^-$ | cyanide ion |
| $CH_3CO_2^-$ | acetate ion |
| $CO_3^{2-}$ | carbonate ion |
| $HCO_3^-$ | hydrogen carbonate ion (or bicarbonate ion) |

***Based on a Group 5A element***

| | |
|---|---|
| $NO_2^-$ | nitrite ion |
| $NO_3^-$ | nitrate ion |
| $PO_4^{3-}$ | phosphate ion |
| $HPO_4^{2-}$ | hydrogen phosphate ion |
| $H_2PO_4^-$ | dihydrogen phosphate ion |

***Based on a Group 6A element***

| | |
|---|---|
| $OH^-$ | hydroxide ion |
| $SO_3^{2-}$ | sulfite ion |
| $SO_4^{2-}$ | sulfate ion |
| $HSO_4^-$ | hydrogen sulfate ion (or bisulfate ion) |

***Based on a Group 7A element***

| | |
|---|---|
| $ClO^-$ | hypochlorite ion |
| $ClO_2^-$ | chlorite ion |
| $ClO_3^-$ | chlorate ion |
| $ClO_4^-$ | perchlorate ion |

***Based on a transition metal***

| | |
|---|---|
| $CrO_4^{2-}$ | chromate ion |
| $Cr_2O_7^{2-}$ | dichromate ion |
| $MnO_4^-$ | permanganate ion |

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## Naming Ionic Compounds

Ionic compounds are named by citing first the cation and then the anion with a space between the words. For example:

$NaBr$ – Sodium bromide

$MgSO_4$ – Magnesium sulfate

$SnCl_2$ – Tin(II) chloride

$SnCl_4$ – Tin(IV) chloride

$Al_2O_3$ – Aluminum oxide

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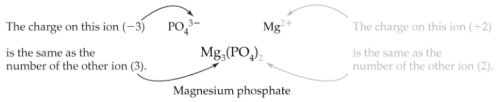
## Formulas of Ionic Compounds

Formula of an ionic compound shows the *lowest possible ratio* of atoms in the compound.




*Practice, practice, practice!!!*

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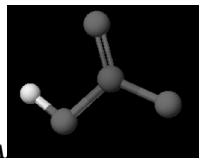
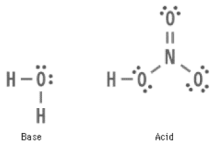
## $H^+$ and Acids

The *Hydrogen cation* ($H^+$) contains only a proton (no electrons or neutrons).

*Acids* are substances that provide $H^+$ ions in water; for example, HCl, $H_2SO_4$, $HNO_3$.

HCl dissolved in water → $H^+ + Cl^-$



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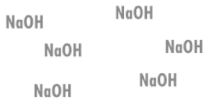
## $OH^-$ Ions and Bases

The *Hydroxide anion* ($OH^-$) is a polyatomic ion with a -1 charge.

*Bases* are substances that provide OH- ions in water; for example, NaOH, KOH, $Ba(OH)_2$.

NaOH dissolved in water → $Na^+ + OH^-$

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## *Test Yourself*

*Give the names for the following formulas:*

NaCl
$CaBr_2$
$MnF_2$
$Ga_2(SO_4)_3$
$Al(NO_3)_3$

*Give the formulas for the following names:*

hydrochloric acid
iron(III) oxide
potassium hydroxide
chromium(III) iodide

*Practice, practice, practice!*

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# Chemistry 104 Chapter Four PowerPoint Notes

## End of Chapter 4

**To review and study for Chapter 4, look at the "Concepts to Remember" at the end of Chapter Four**