

Ions

- Formed when the number of protons is not equal to the number of electrons in an atom
 - Ions with more protons than electrons are called **cations**
 - ✓ **Net positive charge**
 - Ions with more electrons than protons are called **anions**
 - ✓ **Net negative charge**
- Monatomic ion**: Derived from a single atom
- Polyatomic ion**: Derived from a group of atoms with an overall charge

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Table 2.3: Common Monatomic Ions

Cation Name	Symbol	Anion Name	Symbol
Sodium ion	Na ⁺	Fluoride ion	F ⁻
Lithium ion	Li ⁺	Chloride ion	Cl ⁻
Potassium ion	K ⁺	Bromide ion	Br ⁻
Magnesium ion	Mg ²⁺	Sulfide ion	S ²⁻
Aluminum ion	Al ³⁺	Nitride ion	N ³⁻

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Mathematical Description

- Coulombs' law** states that the **force between ions** is proportional to the product of the ion charges divided by distance squared

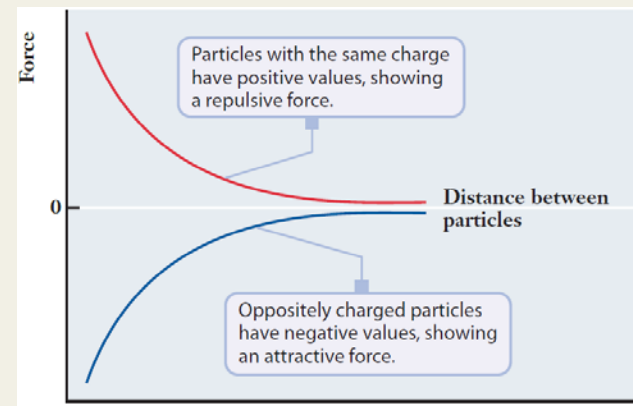
$$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$$

- Opposite charges attract and like charges repel
 - ✓ q_1 and q_2 are charges;
 - ✓ ϵ_0 is a constant called the permittivity of a vacuum;
 - ✓ r is the distance between the charges

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Mathematical Description (continued)



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Ions and Their Properties

- An element and its ion have the **same chemical symbol** but different properties
 - Sodium metal atoms lose an electron to form sodium cations
 - ✓ Sodium metal reacts violently with water
 - Chlorine gas molecules gain electrons to form chlorine anions (chloride)
 - ✓ Chlorine gas reacts violently with sodium metal
- Ionic compounds containing sodium ion and chloride ion dissolve in water without reacting

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(Q.6)

When news stories talk about sodium in the diet, to what form of sodium are they referring?

- Sodium metal
- Sodium atoms
- Sodium ions

Answer: Sodium ions

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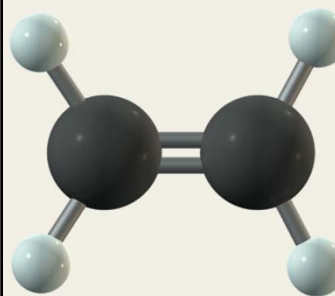
Chemical Formulas

- Types of chemical formulas
 - ✓ **Molecular formulas** indicate the elements and number of atoms of each element actually contained in a discrete unit of a compound
 - ✓ **Empirical formulas** tell the **relative ratio between the number of atoms of the different elements** present in a molecule

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Chemical Formulas (continued 1)



Ethylene, C_2H_4

- The molecular formula for ethylene is C_2H_4
- The empirical formula for ethylene is CH_2
- Polyethylene can be written as $-[CH_2CH_2]_n-$
 - ✓ Dashes are added to stress that these units are **attached end to end** to build up the long chain of the polymer

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Writing Chemical Formulas

- Indicate the types of atoms in the substance by their atomic symbols
- The number of atoms for each element is indicated by a subscript to the right of the chemical symbol. E.g. C_2H_4
- Groups of atoms can be designated using parentheses
 - Subscripts outside these parentheses mean that all atoms enclosed in the parentheses are multiplied by the value indicated in the subscript
- Water molecules associated with certain compounds called **hydrates** are indicated separately from the rest of the compound
e.g. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

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Chemical Formulas (continued 2)

- Compounds have different properties than their constituent atoms
- Ionic compounds contain **cations and anions**, usually arranged in a **lattice**

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Example Problem 2.2

- One polymerization catalyst is diethylaluminum chloride, $\text{Al}(\text{C}_2\text{H}_5)_2\text{Cl}$
 - How many of each type of atom are in a molecule of this compound?

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(Q.7)

How many atoms are there in $\text{Fe}(\text{NO}_3)_3$?

- 8
- 11
- 13
- 15

Answer: 13

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Chemical Bonding

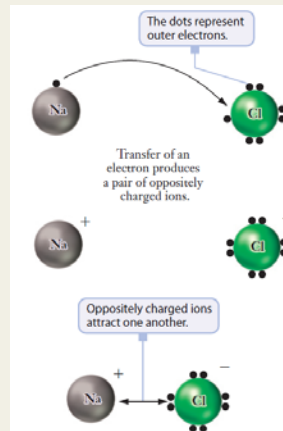
- Characteristics of chemical bonds
 - ✓ All bonds are created by the exchange or sharing of electrons

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Chemical Bonding Categories:

1) Ionic:



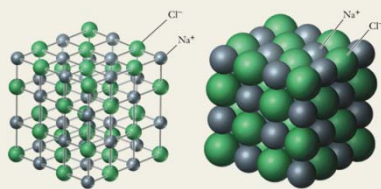
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Chemical Bonding Categories:

1) Ionic:

- Some compounds are composed of collections of oppositely charged ions that form an extended array called **a lattice**.
- The bonding in these compounds is called **ionic bonding**

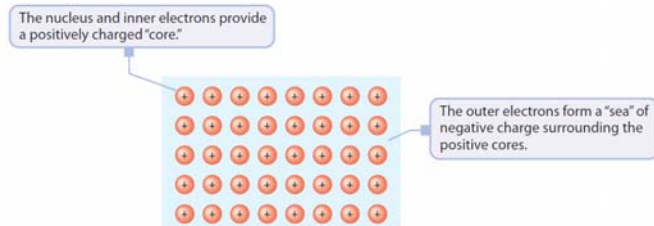


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Chemical Bonding Categories:

- 2) **Metallic:** Bonding in which the nuclei and some fraction of their electrons comprise a positively charged "core" localized at lattice points in an extended array, and other electrons move more or less freely throughout the whole array



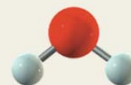
Ionic Bonding

- 3) **Covalent:** Bonding in which electrons are shared between pairs of atoms

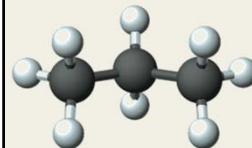
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Covalent Bonding



Water, H_2O



Propane, C_3H_8



Carbon dioxide, CO_2

- In covalent bonds, electrons are shared in pairs
 - ✓ One pair (single bond), two pairs (double bond), or three pairs of electrons (triple bond) can be shared between two nuclei
 - ✓ Results in double bonds or triple bonds
 - ✓ Enables formation of long chains in all polymers

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(Q.8)

Which type of bonding occurs when there are distinct molecules rather than extended systems?

- Covalent bonding
- Ionic bonding
- Metallic bonding

Answer: Covalent bonding

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(Q.9)

For which type of chemical bond are the bonding electrons not constrained to a localized region?

- Covalent
- Ionic
- Metallic

Answer: Metallic

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Periodic Table

Metals
Metalloids
Nonmetals

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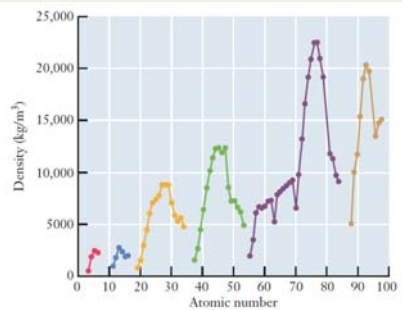
The Periodic Table

- **Periods**
 - Horizontal rows on the periodic table
- **Groups**
 - Vertical columns on the periodic table

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Periods and Groups



- Plot of density of elements as a function of atomic number
- Colors represent a period or row in the periodic table

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Periods and Groups (continued 1)

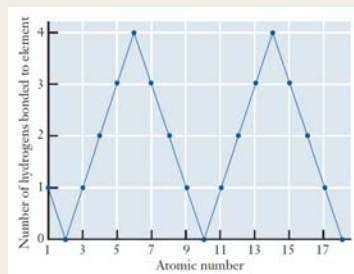
- Darker shading indicates higher density

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Periods and Groups (continued 2)

- Graph of the number of hydrogen atoms with which an individual atom of various elements will combine



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Periodic Table

1

H

2

17

H

18

3

Li

4

Be

5

B

6

C

7

N

8

O

9

F

10

Ne

11

Na

12

Mg

13

Al

14

Si

15

P

16

S

17

Cl

18

Ar

19

K

20

Ca

21

Sc

22

Ti

23

V

24

Cr

25

Mn

26

Fe

27

Co

28

Ni

29

Cu

30

Zn

31

Ga

32

Ge

33

As

34

Se

35

Br

36

Kr

37

Rb

38

Sr

39

Y

40

Zr

41

Nb

42

Mo

43

Tc

44

Ru

45

Rh

46

Pd

47

Ag

48

Cd

49

In

50

Sn

51

Sb

52

Te

53

I

54

Xe

55

Cs

56

Ba

57

La

58

Ce

59

Pr

60

Nd

61

Pm

62

Sm

63

Eu

64

Gd

65

Tb

66

Dy

67

Ho

68

Er

69

Tm

70

Yb

71

Lu

87

Fr

88

Ra

89

Ac

90

Th

91

Pa

92

U

93

Np

94

Pu

95

Am

96

Cm

97

Bk

98

Cf

99

Es

100

Fm

101

Md

102

No

103

Lr

Metals

Metalloids

Nonmetals

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Periods and Groups (continued 3)

- Common names of specific groups
 - Group 1 - **Alkali metals**
 - Group 2 - **Alkaline earth metals**
 - Group 17 - **Halogens**
 - Group 18 - **Noble gases/rare gases**
- Table regions
 - Groups 1 to 2 and 13 to 18 are **main group elements/representative elements**
 - Groups 3 to 12 are **transition metals**
 - Lanthanides** and **actinides** are the elements that appear below the rest of the table

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Metals, Nonmetals, and Metalloids

1																	17	18
H	2											B	C	N	O	F	Ne	
Li	Be											Al	Si	P	S	Cl	Ar	
Na	Mg	3	4	5	6	7	8	9	10	11	12	Ga	Ge	As	Se	Br	Kr	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	In	Sn	Sb	Te	I	Xe	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	
58	59	60	61	62	63	64	65	66	67	68	69	70	71					
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu					
90	91	92	93	94	95	96	97	98	99	100	101	102	103					
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr					

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Metals, Nonmetals, and Metalloids



- **Metals**

- Are generally located toward the left and bottom of the periodic table
- Are shiny, malleable, and ductile (can be pulled into wires)
- Conduct electricity
- tend to form cations

- **Nonmetals**

- Occupy the upper right-hand portion of the periodic table
- Are not shiny, malleable, or ductile
- Are predominant or exclusive constituents of most of the molecules that make up the human body (C, H, O, N, P, S)
- Do not conduct electricity
- tend to form anions

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Metals, Nonmetals, and Metalloids




- **Metalloids or semimetals**

- Have chemical properties intermediate of metals and nonmetals
- Are clustered along a diagonal path in the periodic table between the metals and nonmetals

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(Q. 10)



In the periodic table, what region is the home of the nonmetal elements?


- Lower left
- Upper left
- Lower right
- Upper right

Answer: Upper right

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(Q. 11)



Based on the periodic table, what element is most likely to form polymers like carbon?

- Boron
- Nitrogen
- Silicon

Answer: Silicon

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Inorganic and Organic Chemistry



- Organic chemistry
 - Study of the compounds of the element carbon
 - Includes naturally occurring biological molecules and nearly all synthetic polymers
- Inorganic chemistry
 - Study of all other elements other than carbon and their compounds

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