

## Lecture 1: Atoms, Chemical bonds

### 1.1 Composition of the Atom

- The basic structural unit of an element is the atom.
- The nucleus is the very small and very dense core at the center of the atom containing:

1. Protons: positively charged particles.

The number of protons is indicated by the atomic number,  $Z$ .

2. Neutrons: neutral particles.

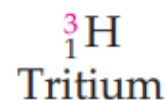
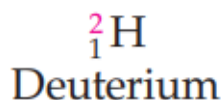
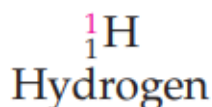
The number of neutrons is calculated from the mass number minus the atomic number,  $A-Z$ .

3. Electrons are negatively charged particles that are located in a diffuse region. For a neutral atom,

The number of electrons equals the number of protons.

- Isotopes are atoms of the same element that have a different number of neutrons. Isotopes of the same element have the same chemical properties.

For example, all of the following are isotopes of hydrogen:



- The atomic mass is the weighted average of the masses of the isotopes of an element in atomic mass units;  
 $1 \text{ amu} = 1.66 * 10^{-24} \text{ grams (g)}$ .

### 1.2 The Periodic Law and the Periodic Table

- The periodic law relates the structure of elements to their chemical and physical properties. The modern periodic table groups the elements according to these properties.
- **Periods** are horizontal rows, numbered 1 through 7 from top to bottom. The lanthanide series is part of period 6; the actinide series is part of period 7.
- Vertical columns are referred to as **groups** or families.

REPRESENTATIVE ELEMENTS

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Metals (main group)  
Metals (transition)  
Metals (inner transition)  
Metalloids  
Nonmetals  
Unknown

1 Atomic number  
H Symbol  
1.008 Atomic mass

1	2	TRANSITION ELEMENTS										13	14	15	16	17	18								
IA (1)	IIA (2)	IIIB (3)	IVB (4)	VB (5)	VIB (6)	VII B (7)	VIII B (8)	VIII B (9)	VIII B (10)	IB (11)	IIB (12)	IIIA (13)	IVA (14)	VA (15)	VIA (16)	VIIA (17)	VIIIA (18)								
1 H Hydrogen 1.008	3 Li Lithium 6.941	4 Be Beryllium 9.012	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95							
2	3 Li Lithium 6.941	4 Be Beryllium 9.012	19 K Potassium 39.10	20 Ca Calcium 40.08	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3			
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3	85 At Astatine (210)	86 Rn Radon (222)			
4	19 K Potassium 39.10	20 Ca Calcium 40.08	55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)	117 Uus Unseptium (294)	118 Uuo Unoctium (294)			
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)	117 Uus Unseptium (294)	118 Uuo Unoctium (294)			
6	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (272)	112 Cn Copernicium (277)	113 Uut Ununtrium (284)	114 Fl Flerovium (285)	115 Uup Ununpentium (288)	116 Lv Livermorium (289)	117 Uus Unseptium (294)	118 Uuo Unoctium (294)	119 Uuq Ununquadium (294)	120 Uuq Ununquadium (294)	119 Uuq Ununquadium (294)	120 Uuq Ununquadium (294)			
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (272)	112 Cn Copernicium (277)	113 Uut Ununtrium (284)	114 Fl Flerovium (285)	115 Uup Ununpentium (288)	116 Lv Livermorium (289)	117 Uus Unseptium (294)	118 Uuo Unoctium (294)	119 Uuq Ununquadium (294)	120 Uuq Ununquadium (294)	119 Uuq Ununquadium (294)	120 Uuq Ununquadium (294)			
INNER TRANSITION ELEMENTS																									
6	Lanthanides	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (147)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0										
7	Actinides	90 Th Thorium 232.0	91 Pa Protactinium (231)	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (242)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)										

Figure (1.1): The periodic table (الجدول الدوري للأطلاع فقط)

### 1.3 Chemical Bonding

Chemical bonding: is the attractive force between atoms in a compound can be classified as

- Covalent, atoms sharing electrons
- Polar covalent and nonpolar covalent
- Ionic, consisting of cations and anions

**Electronegativity** is a measure of the ability of an atom to attract electrons in a chemical bond, and the difference in electronegativity is used in classifying chemical bonds.

- Difference of 0.5 and less—nonpolar covalent
- Difference between 0.5 and 2.0—polar covalent
- Difference of 2.0 or larger—ionic

### 1.4 Naming Compounds and Writing Formulas of Compounds

The system for naming compounds (nomenclature) is different for ionic and covalent compounds

### 1. Ionic compounds: name cation followed by the anion.

Some examples follow:

Formula	Cation	and	Anion Stem	+ ide	=	Compound Name
NaCl	sodium		chlor	+ ide		sodium chloride
Na <sub>2</sub> O	sodium		ox	+ ide		sodium oxide
Li <sub>2</sub> S	lithium		sulf	+ ide		lithium sulfide
AlBr <sub>3</sub>	aluminum		brom	+ ide		aluminum bromide
CaO	calcium		ox	+ ide		calcium oxide

With many elements, such as transition metals, several ions of different charge may exist. Fe<sup>2+</sup>, Fe<sup>3+</sup> and Cu<sup>+</sup>, Cu<sup>2+</sup> are two common examples. Clearly, an ambiguity exists if we use the name iron for both Fe<sup>2+</sup> and Fe<sup>3+</sup> or copper for both Cu<sup>+</sup> and Cu<sup>2+</sup>. Two systems have been developed to avoid this problem: the Stock system and the common nomenclature system.

For systematic name:			
Formula	Cation Charge	Cation Name	Systematic Name
FeCl <sub>2</sub>	2 +	Iron(II)	Iron(II) chloride
FeCl <sub>3</sub>	3 +	Iron(III)	Iron(III) chloride
Cu <sub>2</sub> O	1 +	Copper(I)	Copper(I) oxide
CuO	2 +	Copper(II)	Copper(II) oxide
For common nomenclature:			
Formula	Cation Charge	Cation Name	Common -ous/ic Name
FeCl <sub>2</sub>	2 +	Ferrous	Ferrous chloride
FeCl <sub>3</sub>	3 +	Ferric	Ferric chloride
Cu <sub>2</sub> O	1 +	Cuprous	Cuprous oxide
CuO	2 +	Cupric	Cupric oxide

**Monatomic ions** are ions consisting of a single atom. The ions that are particularly important in biological systems are highlighted in red. **Polyatomic ions**, such as the hydroxide ion, OH<sup>-</sup>, are composed of two or more atoms bonded together. These ions, although bonded to other ions with ionic bonds, are themselves held together by covalent bonds.

**TABLE 3.2** Common Monatomic Cations and Anions

Cation	Name	Anion	Name
H <sup>+</sup>	Hydrogen ion	H <sup>-</sup>	Hydride ion
Li <sup>+</sup>	Lithium ion	F <sup>-</sup>	Fluoride ion
Na <sup>+</sup>	Sodium ion	Cl <sup>-</sup>	Chloride ion
K <sup>+</sup>	Potassium ion	Br <sup>-</sup>	Bromide ion
Cs <sup>+</sup>	Cesium ion	I <sup>-</sup>	Iodide ion
Be <sup>2+</sup>	Beryllium ion	O <sup>2-</sup>	Oxide ion
Mg <sup>2+</sup>	Magnesium ion	S <sup>2-</sup>	Sulfide ion
Ca <sup>2+</sup>	Calcium ion	N <sup>3-</sup>	Nitride ion
Ba <sup>2+</sup>	Barium ion	P <sup>3-</sup>	Phosphide ion
Al <sup>3+</sup>	Aluminum ion		
Ag <sup>+</sup>	Silver ion		

Note: The ions of principal biological importance are highlighted in red.

**TABLE 3.3** Common Polyatomic Cations and Anions

Ion	Name
H <sub>3</sub> O <sup>+</sup>	Hydronium
NH <sub>4</sub> <sup>+</sup>	Ammonium
NO <sub>2</sub> <sup>-</sup>	Nitrite
NO <sub>3</sub> <sup>-</sup>	Nitrate
SO <sub>3</sub> <sup>2-</sup>	Sulfite
SO <sub>4</sub> <sup>2-</sup>	Sulfate
HSO <sub>4</sub> <sup>-</sup>	Hydrogen sulfate
OH <sup>-</sup>	Hydroxide
CN <sup>-</sup>	Cyanide
PO <sub>4</sub> <sup>3-</sup>	Phosphate
HPO <sub>4</sub> <sup>2-</sup>	Hydrogen phosphate
H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	Dihydrogen phosphate
CO <sub>3</sub> <sup>2-</sup>	Carbonate
HCO <sub>3</sub> <sup>-</sup>	Bicarbonate
ClO <sup>-</sup>	Hypochlorite
ClO <sub>2</sub> <sup>-</sup>	Chlorite
ClO <sub>3</sub> <sup>-</sup>	Chlorate
ClO <sub>4</sub> <sup>-</sup>	Perchlorate
CH <sub>3</sub> COO <sup>-</sup> (or C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup> )	Acetate
MnO <sub>4</sub> <sup>-</sup>	Permanganate
Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup>	Dichromate
CrO <sub>4</sub> <sup>2-</sup>	Chromate
O <sub>2</sub> <sup>2-</sup>	Peroxide

Note: The most commonly encountered ions are highlighted in red.

2. Covalent compounds: name first element first and then second element (with -ide ending). Use prefixes of di-, tri-, etc., to denote the number of atoms of each element in the compound

Example: **Name the covalent compound  $N_2O_4$**

The name is dinitrogen tetroxide.

**A Medical Perspective:** Kidney stones most often result from the combination of calcium cations ( $Ca^{2+}$ ) with anions such as oxalate ( $C_2O_4^{2-}$ ) and phosphate ( $PO_4^{3-}$ ). Calcium oxalate and calcium phosphate are ionic compounds that are only sparingly soluble in water. They grow in a three-dimensional crystal lattice. When the crystals become large enough to inhibit the flow of urine in the kidney or bladder, painful symptoms necessitate some strategy to remove the stones.

### 1.5 Properties of Ionic and Covalent Compounds

Properties	Ionic compound	Covalent compound
<b>Physical State</b>	All ionic compounds (for example, NaCl, KCl, and $NaNO_3$ ) are solids at room	Covalent compounds may be solids (glucose), liquids (water, ethanol), or gases (carbon dioxide, methane).
<b>Melting and Boiling Points</b>	Ionic compounds have higher melting points and boiling points than covalent compounds.	
<b>Structure of Compounds in the Solid State</b>	Ionic solids are crystalline, characterized by a regular structure,	Covalent solids may either be crystalline or have no regular structure. In the latter case, they are said to be amorphous
<b>Solutions of Ionic and Covalent Compounds</b>	When ionic compounds dissolve in water, the ions dissociate and the solution conducts electricity. These compounds are electrolytes.	When covalent compounds dissolve in water, the compound does not dissociate. They are nonelectrolytes.