

Matter in Chemistry

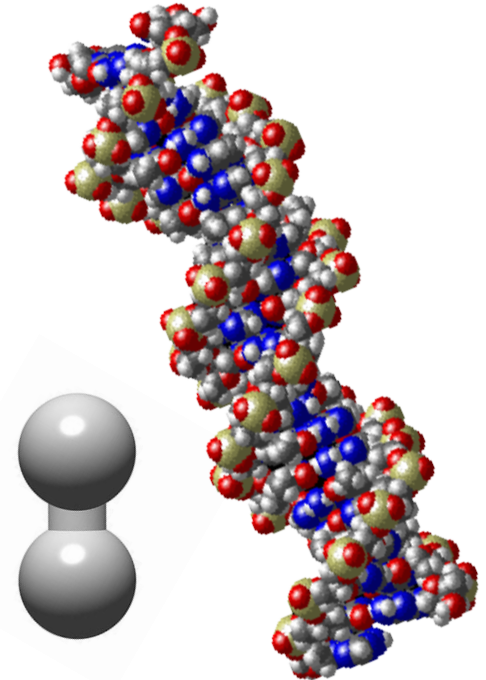
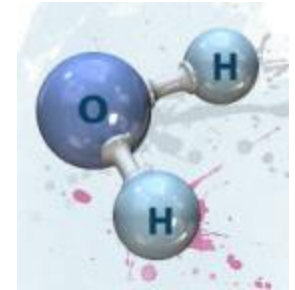
IA 1 H Hydrogen 1 1.01	IIA 2 Li Lithium 3 6.94	Be Beryllium 4 9.01	IIIB 3 B Boron 5 10.81	IVB 4 C Carbon 6 12.01	V 5 N Nitrogen 7 14.01	VIB 6 O Oxygen 8 16.00	VII 7 F Fluorine 9 19.00	VIII 8 Ne Neon 10 20.18	VIII 9 Na Sodium 11 22.99	VIII 10 Mg Magnesium 12 24.31	VIII 11 K Potassium 19 39.10	VIII 12 Ca Calcium 20 40.08	VIII 13 Sc Scandium 21 44.96	VIII 14 Ti Titanium 22 47.88	VIII 15 V Vanadium 23 50.94	VIII 16 Cr Chromium 24 52.00	VIII 17 Mn Manganese 25 54.94	VIII 18 Fe Iron 26 55.85	VIII 19 Co Cobalt 27 58.93	VIII 20 Ni Nickel 28 58.69	VIII 21 Cu Copper 29 63.55	VIII 22 Zn Zinc 30 65.39	VIII 23 Ga Gallium 31 69.72	VIII 24 Ge Germanium 32 72.61	VIII 25 As Arsenic 33 74.92	VIII 26 Se Selenium 34 78.96	VIII 27 Br Bromine 35 79.90	VIII 28 Kr Krypton 36 83.80	VIII 29 Rb Rubidium 37 85.47	VIII 30 Sr Strontium 38 87.62	VIII 31 Y Yttrium 39 88.91	VIII 32 Zr Zirconium 40 91.22	VIII 33 Nb Niobium 41 92.91	VIII 34 Mo Molybdenum 42 95.94	VIII 35 Tc Technetium 43 (98)	VIII 36 Ru Ruthenium 44 101.07	VIII 37 Rh Rhodium 45 102.91	VIII 38 Pd Palladium 46 106.42	VIII 39 Ag Silver 47 107.87	VIII 40 Cd Cadmium 48 112.41	VIII 41 In Indium 49 114.82	VIII 42 Sn Tin 50 118.71	VIII 43 Te Tellurium 52 127.60	VIII 44 I Iodine 53 126.90	VIII 45 Xe Xenon 54 131.29	VIII 46 Cs Caesium 55 132.91	VIII 47 Ba Barium 56 137.33	Lanthanide Series	VIII 48 Hf Hafnium 72 178.49	VIII 49 Ta Tantalum 73 180.95	VIII 50 W Tungsten 74 183.85	VIII 51 Re Rhenium 75 186.21	VIII 52 Os Osmium 76 190.23	VIII 53 Ir Iridium 77 192.22	VIII 54 Pt Platinum 78 195.08	VIII 55 Au Gold 79 196.97	VIII 56 Hg Mercury 80 200.59	VIII 57 Tl Thallium 81 204.38	VIII 58 Pb Lead 82 207.20	VIII 59 Bi Bismuth 83 208.98	VIII 60 Po Polonium 84 (209)	VIII 61 At Astatine 85 (210)	VIII 62 Rn Radon 86 (222)	VIII 63 Fr Francium 87 (223)	VIII 64 Ra Radium 88 (226)	Actinide Series	VIII 65 Rf Rutherfordium 104 (261)	VIII 66 Db Dubnium 105 (262)	VIII 67 Sg Seaborgium 106 (263)	VIII 68 Bh Bohrium 107 (262)	VIII 69 Hs Hassium 108 (265)	VIII 70 Mt Meitnerium 109 (266)	VIII 71 La Lanthanum 57 138.91	VIII 72 Ce Cerium 58 140.12	VIII 73 Pr Praseodymium 59 140.90	VIII 74 Nd Neodymium 60 144.24	VIII 75 Pm Promethium 61 (145)	VIII 76 Sm Samarium 62 150.36	VIII 77 Eu Europium 63 151.96	VIII 78 Gd Gadolinium 64 157.25	VIII 79 Tb Terbium 65 158.92	VIII 80 Dy Dysprosium 66 162.50	VIII 81 Ho Holmium 67 164.93	VIII 82 Er Erbium 68 167.26	VIII 83 Tm Thulium 69 168.93	VIII 84 Yb Ytterbium 70 173.04	VIII 85 Lu Lutetium 71 174.96	VIII 86 Ac Actinium 89 227.02	VIII 87 Th Thorium 90 232.03	VIII 88 Pa Protactinium 91 231.03	VIII 89 U Uranium 92 238.02	VIII 90 Np Neptunium 93 (237)	VIII 91 Pu Plutonium 94 (244)	VIII 92 Am Americium 95 (243)	VIII 93 Cm Curium 96 (247)	VIII 94 Bk Berkelium 97 (247)	VIII 95 Cf Californium 98 (251)	VIII 96 Es Einsteinium 99 (252)	VIII 97 Fm Fermium 100 (257)	VIII 98 Md Mendelevium 101 (258)	VIII 99 No Nobelium 102 (259)	VIII 100 Lr Lawrencium 103 (260)
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Matter in Chemistry

Ordinary matter is composed of atoms and groups of atoms *bonded* together, called molecules.

- There are **many different types of atoms**, and consequently, there are **many possible combinations of two or more atoms** that can chemically bond.
- Molecules as components of matter are common in organic substances. They also make up most of the oceans and atmosphere.
- However, the **majority of familiar solid substances on Earth**, including most of the minerals that make up the crust, mantle, and core of the Earth, contain many chemical bonds, but **are not made of identifiable molecules**.



Chemical Substance

A chemical *substance* is a form of matter that has a definite chemical composition throughout and distinct characteristic properties.



liquid nitrogen



gold ingots

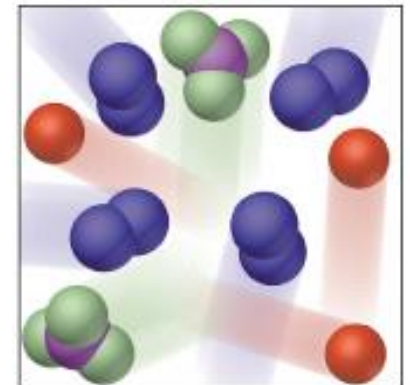
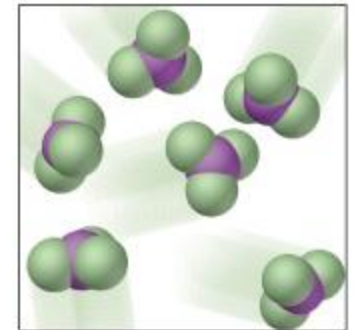
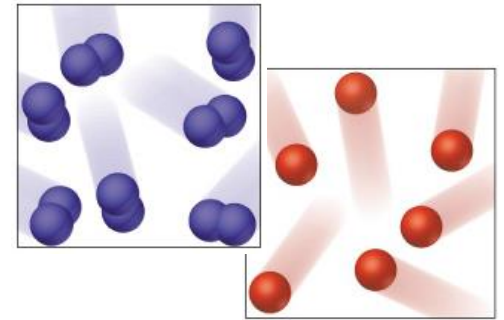


silicon crystals

All ordinary matter can be classified as either a *pure substance* or a *mixture*.

Classification of Substances

- **Elements**: substances that are made from **one type of atom** only.
- **Compounds**: substances that are made from **more than one** type of atom **chemically bonded** together.
- **Mixtures**: substances that are made from **more than one** type of atom **combined physically**, but not chemically.

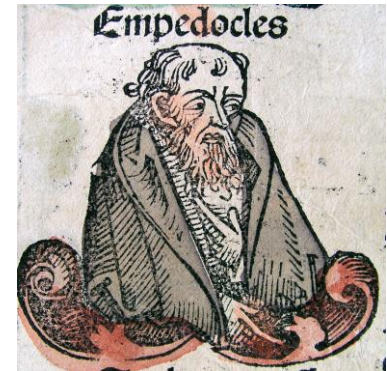


Elements: History

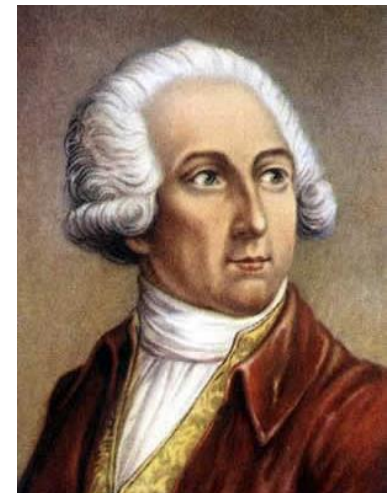
The Big Idea: “everything” is made of a limited number of “elements” in a great variety of combinations.

- Ancient philosophy:

- Empedocles’ (5th century BC) **earth, water, air, fire**.
- The term “**elements**” (*stoicheia*) was first used by the Greek philosopher **Plato** (4th century BC).
- Aristotle (350 BC) - a fifth element called “**aether**”.



- Robert Boyle, 1661: **corpuscularism** theory - analysis of matter as constituted by indecomposable *chemical elements*.

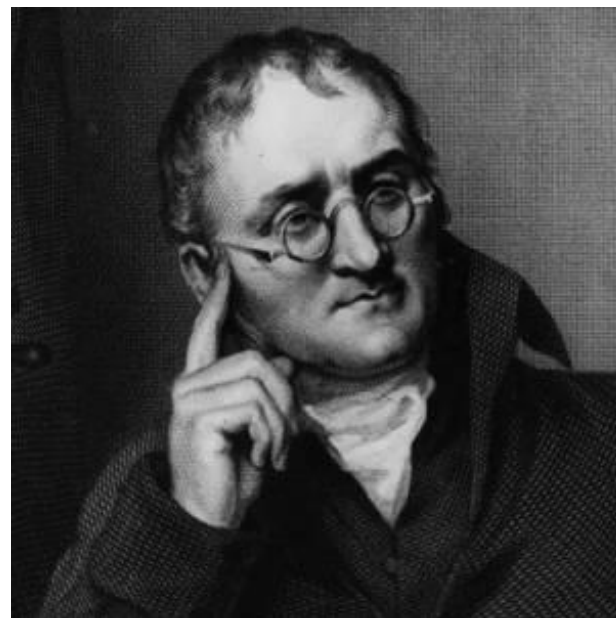


- Antoine Lavoisier, 1789: the **first modern list of chemical elements** (contained **33 elements** including *light* and *caloric*, “element” of heat).

Atomic Weight

John Dalton (1766–1844):

- Atoms of a given element are identical in size, mass, and other properties; atoms of different elements differ in size, mass, and other properties.
- Atoms of different elements combine in simple whole-number ratios to form chemical compounds.
- Chemical analysis of simple compounds like water, ammonia, carbon dioxide, etc. allows to determine relative atomic weights of the constituent elements.
- **1803-1805:** Dalton published his **first table of relative atomic weights** containing **six elements**:
hydrogen (conventionally assumed to weigh 1), *oxygen*, *nitrogen*, *carbon*, *sulfur*, and *phosphorus*.



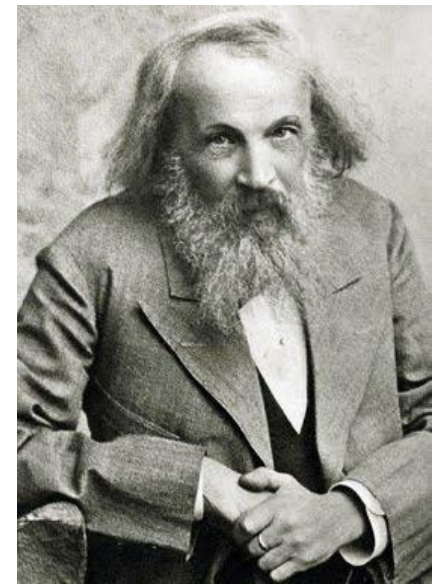
Systematization of Elements

By 1818, atomic weights were determined for **45** out of **49 known elements** by careful studies of chemical reactions.

- **First attempts to organize elements:**
 - **1829**, Johann Wolfgang Döbereiner, *Law of Triades* (“3-in-a-row”)
 - **1862**, Alexandre-Emile de Chancourtois, the first notion of periodicity by increasing atomic weight, “screw” periodic table
 - **1864**, Julius Lothar Meyer, table based on *valency*
 - **1863-1866**, John Newlands, *Law of Octaves* (“8-in-a-row”)
 - **1867**, Gustavus Hinrichs, “spiral” periodic system based on atomic spectra and weight
 - **1870**, Meyer expanded his periodic table
- **Dmitri Mendeleev, 1869**: **periodic table** of **66 elements**.
- **Horace Deming, 1923**: the popular periodic table layout, also known as the **common** or **standard form**.

Mendeleev's Table

- 1869, Dmitri Mendeléev: the **first accepted version** of the periodic table.
- Elements were **grouped according to their atomic weight**.



ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.
ОСНОВАННОЙ НА ВѢСЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

		Ti = 50	Zr = 90	? = 180.
		V = 51	Nb = 94	Ta = 182.
		Cr = 52	Mo = 96	W = 186.
		Mn = 55	Rh = 104,4	Pt = 197,4
		Fe = 56	Ru = 104,4	Ir = 198.
		Ni = Co = 59	Pd = 106,4	Os = 199.
H = 1		Cu = 63,4	Ag = 108	Hg = 200.
Be = 9,4	Mg = 24	Zn = 65,4	Cd = 112	
B = 11	Al = 27,1	? = 68	Ur = 116	Au = 197?
C = 12	Si = 28	? = 70	Sn = 118	
N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
O = 16	S = 32	Se = 79,4	Te = 128?	
F = 19	Cl = 35,4	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133
		Ca = 40	Sr = 87,4	Ba = 137
		? = 45	Ce = 92	Pb = 207.
		?Er = 86	La = 94	
		?Yt = 80	Di = 95	
		?In = 75,4	Th = 118?	

Д. Менделѣевъ

- Gaps were left in the table when it seemed that the corresponding element had not yet been discovered (*predicted* elements).
- The order suggested by the atomic weights was occasionally ignored to *better classify* elements into chemical families (having similar physical/chemical characteristics and properties).
- With the development of theories of atomic structure, it became apparent that Mendeleev had *unintentionally* listed the elements in order of increasing atomic number or nuclear charge.

Elements Discovery Timeline from Antiquity to 2012

1 H																	2 He
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	-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

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
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

Known in antiquity

also known when (akw) Levoisier published his list of elements (1789)

akw Mendeleev published his periodic table (1869)

akw Deming published his periodic table (1923)

akw Seaborg published his periodic table (1945)

also known (ak) up to 2000

ak to 2012

Chemical Element

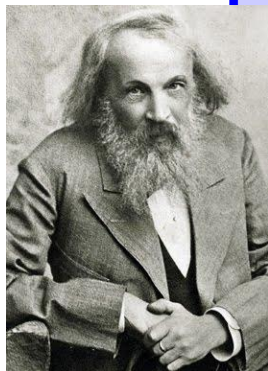
A **chemical element** consists of a **single type of atom** distinguished by its atomic number.

- Some elements can occur as more than a single chemical substance (*allotropes*): oxygen exists as both *diatomic oxygen* (O_2) and *ozone* (O_3).
- Native elements copper and gold were known in primitive human societies; iron was being extracted (smelted) as early as 1500 BC.
- Nearly all of the naturally-occurring elements were discovered by 1900.
- There are **118 known elements**, about 80 of which are stable (they do not change by radioactive decay into other elements). There are **94 naturally occurring** elements and **24 synthetic (man-made)** elements.
- The number of possible elements is not known.



Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18														
1 H Hydrogen 1.00794	<div style="display: flex; justify-content: space-between;"> <div style="width: 15%;"> <p>Atomic # Symbol Name Atomic Mass</p> </div> <div style="width: 15%;"> <p>C Solid Hg Liquid H Gas Rf Unknown</p> </div> <div style="width: 40%; text-align: center;"> <p>Metals</p> <table border="1" style="margin: auto;"> <tr> <td style="background-color: yellow;">Alkali metals</td> <td style="background-color: orange;">Alkaline earth metals</td> <td style="background-color: lightblue;">Lanthanoids</td> <td style="background-color: lightgreen;">Transition metals</td> <td style="background-color: lightpurple;">Poor metals</td> <td style="background-color: lightyellow;">Other nonmetals</td> <td style="background-color: lightblue;">Noble gases</td> </tr> <tr> <td></td> <td></td> <td style="background-color: lightblue;">Actinoids</td> <td></td> <td></td> <td></td> <td></td> </tr> </table> </div> <div style="width: 15%;"> <p>Nonmetals</p> </div> </div>																Alkali metals	Alkaline earth metals	Lanthanoids	Transition metals	Poor metals	Other nonmetals	Noble gases			Actinoids					2 He Helium 4.002602
Alkali metals	Alkaline earth metals	Lanthanoids	Transition metals	Poor metals	Other nonmetals	Noble gases																									
		Actinoids																													
3 Li Lithium 6.941	4 Be Beryllium 9.012182																	5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797								
11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050																	13 Al Aluminum 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948								
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.887	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798														
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293														
55 Cs Caesium 132.9054519	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (209.9824)	85 At Astatine (209.9871)	86 Rn Radon (222.0176)														
87 Fr Francium (223)	88 Ra Radium (226)	89-103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium	118 Uuo Ununoctium (294)														



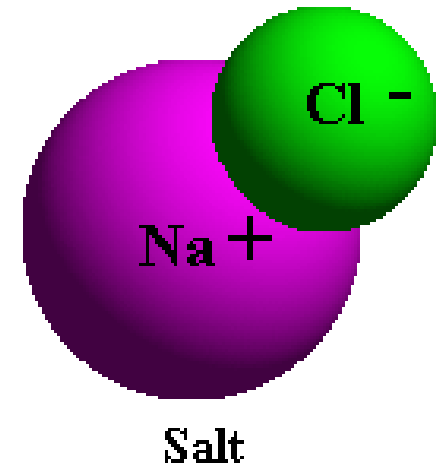
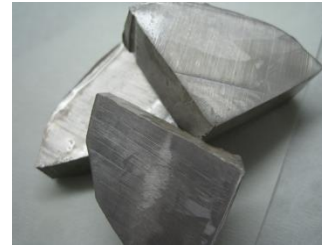
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90768	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	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 (262)

Elements and Compounds

- Sodium is an **element**.
- Chlorine is an **element**.
- When **sodium** and **chlorine** **bond** they make up the **compound sodium chloride**, commonly known as **table salt**.



Compounds have *different properties than the elements that make them up:*

for example, table salt has different properties than **sodium**, an **explosive metal**, and **chlorine**, a **poisonous gas**.

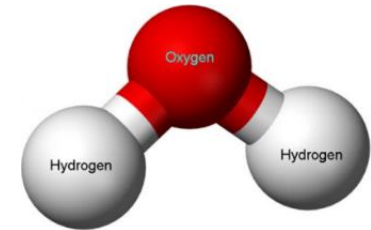
Elements, Compounds, Mixtures

- **Hydrogen** is an **element**.
- **Oxygen** is an **element**.
- When **hydrogen** and **oxygen** **bond** they make the **compound** **water**.
- When **salt** and **water** are **combined**, a **mixture** is created.

Components in mixtures
retain their individual
properties.



Water is a
compound



Ocean water
is a **mixture**

Types of Mixtures

A *mixture* is a combination of two or more substances in which the substances retain their distinct identities.

- **Homogenous** – composition of the mixture is the same throughout; only one phase of matter is present (ex: air, steel, solder).
- **Heterogeneous** – composition is not uniform throughout (ex: cement, sand, cereal).

