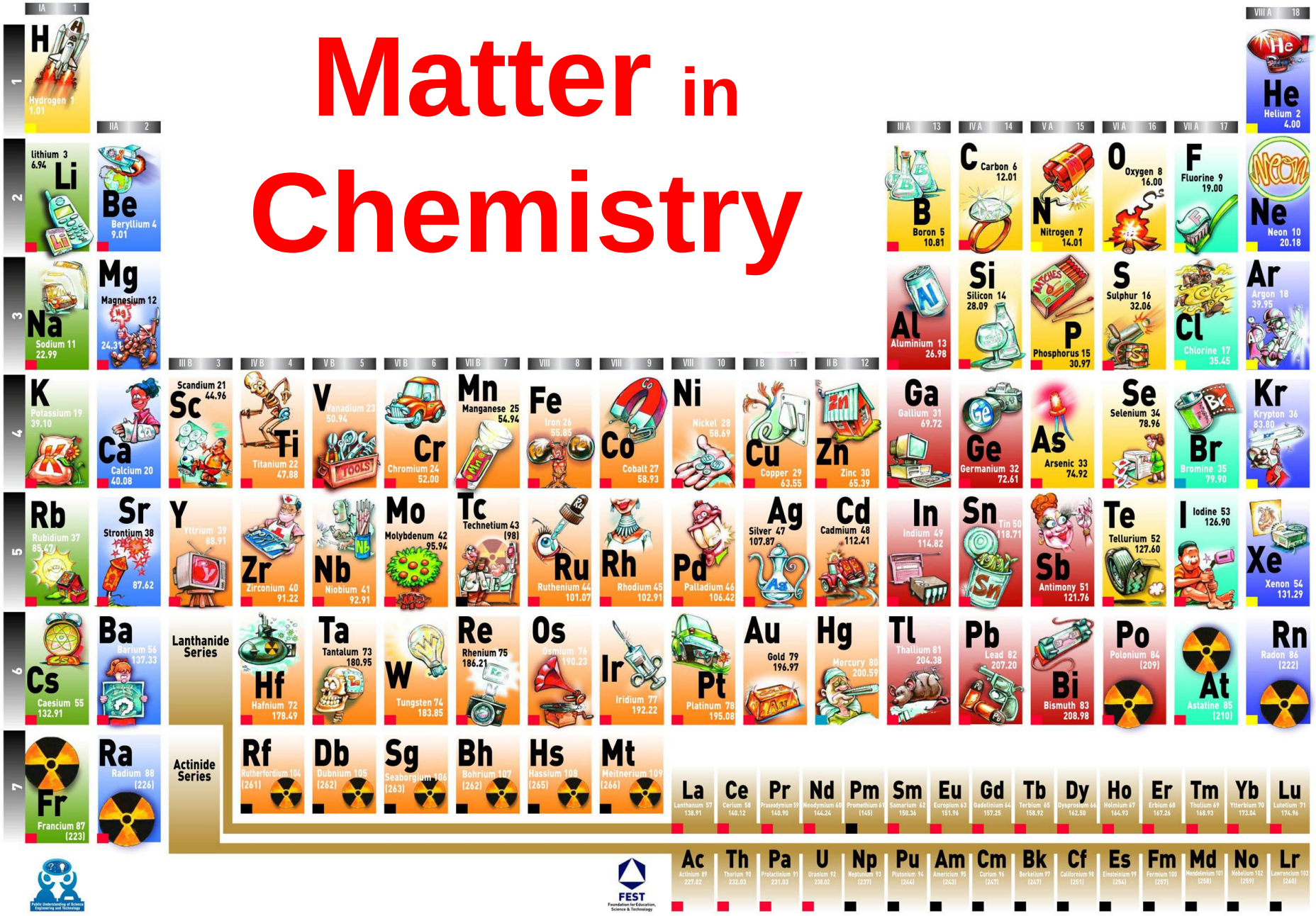
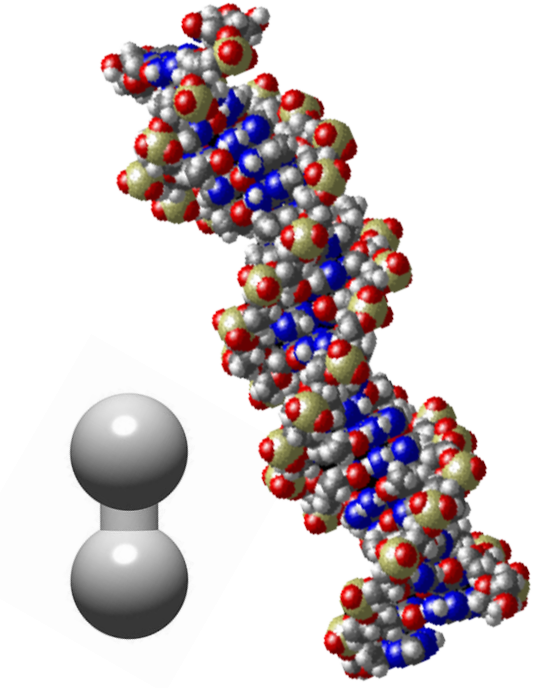
Matter in Chemistry



Matter in Chemistry

<u>Ordinary matter</u> is composed of <u>atoms</u> and groups of atoms *bonded* together, called <u>molecules</u>.

- **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.**

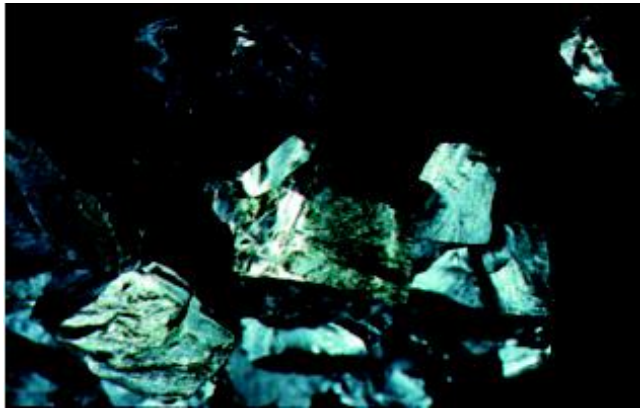


Chemical Substance

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

liquid nitrogen

gold ingots

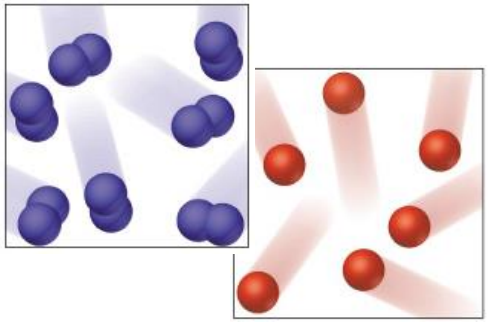


silicon crystals

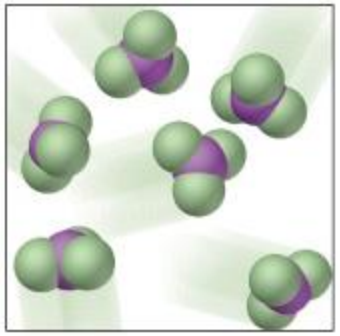
All ordinary matter can be classified as either a *pure substance* or a *mixture*.

Classification of Substances

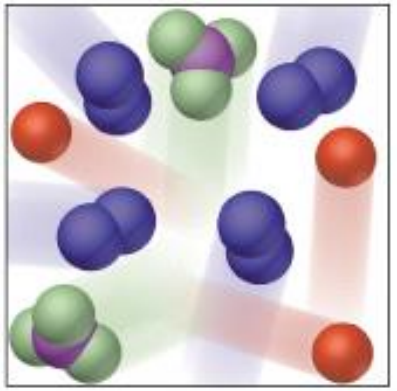
- **Elements: substances that are made from one type of atom only.**



- **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.

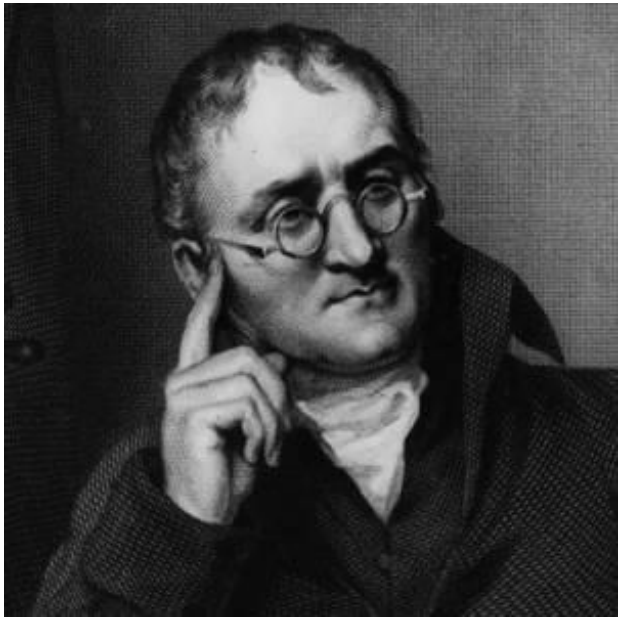
- **Ancient philosophy:**
  - Empedocles' (5th century BC) earth, water, air, fire.
  - The term "elements" (*stoicheia*) was first used by the Greek philosopher Plato (4th century BC).
  - Aristotle (350 BC) - a fifth element called "aether".

- **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:**

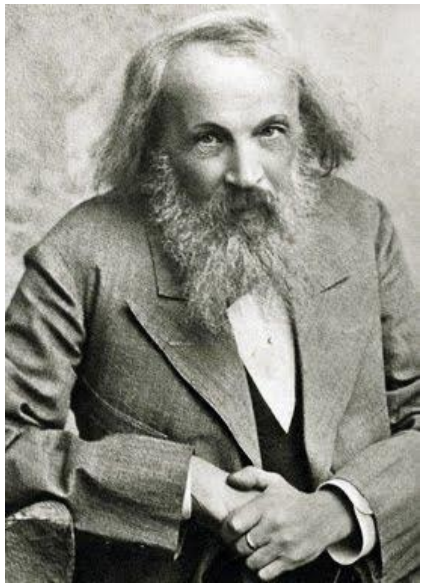
  hydrogen **(conventionally assumed to weigh 1),** ***oxygen, nitrogen, carbon, sulfur,*** **and** ***phosphorus*****.**

Systematization of Elements

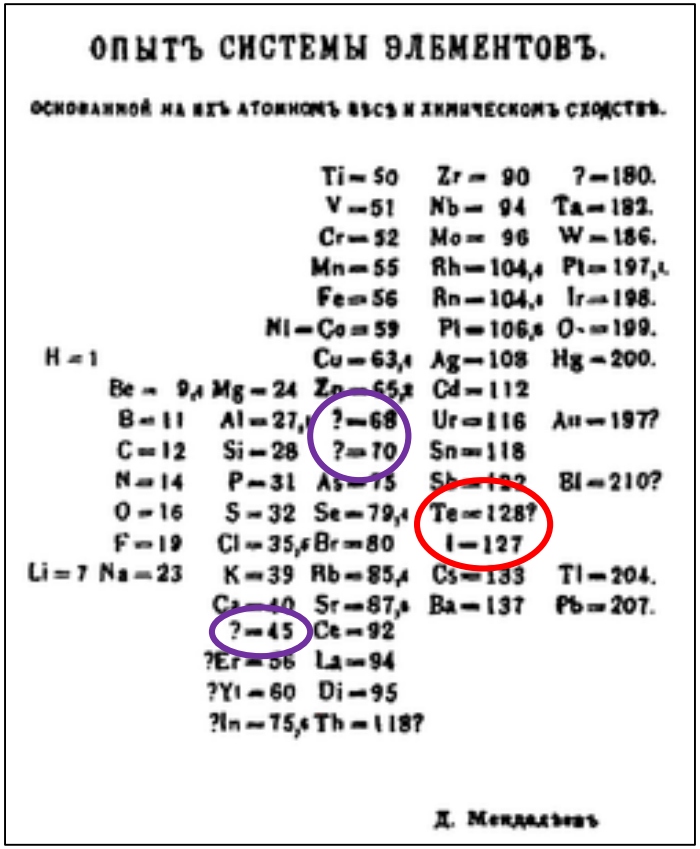
By 1818, atomic weights were determined for 45 out of 49 known elements by careful studies of chemical reactions.

- **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.

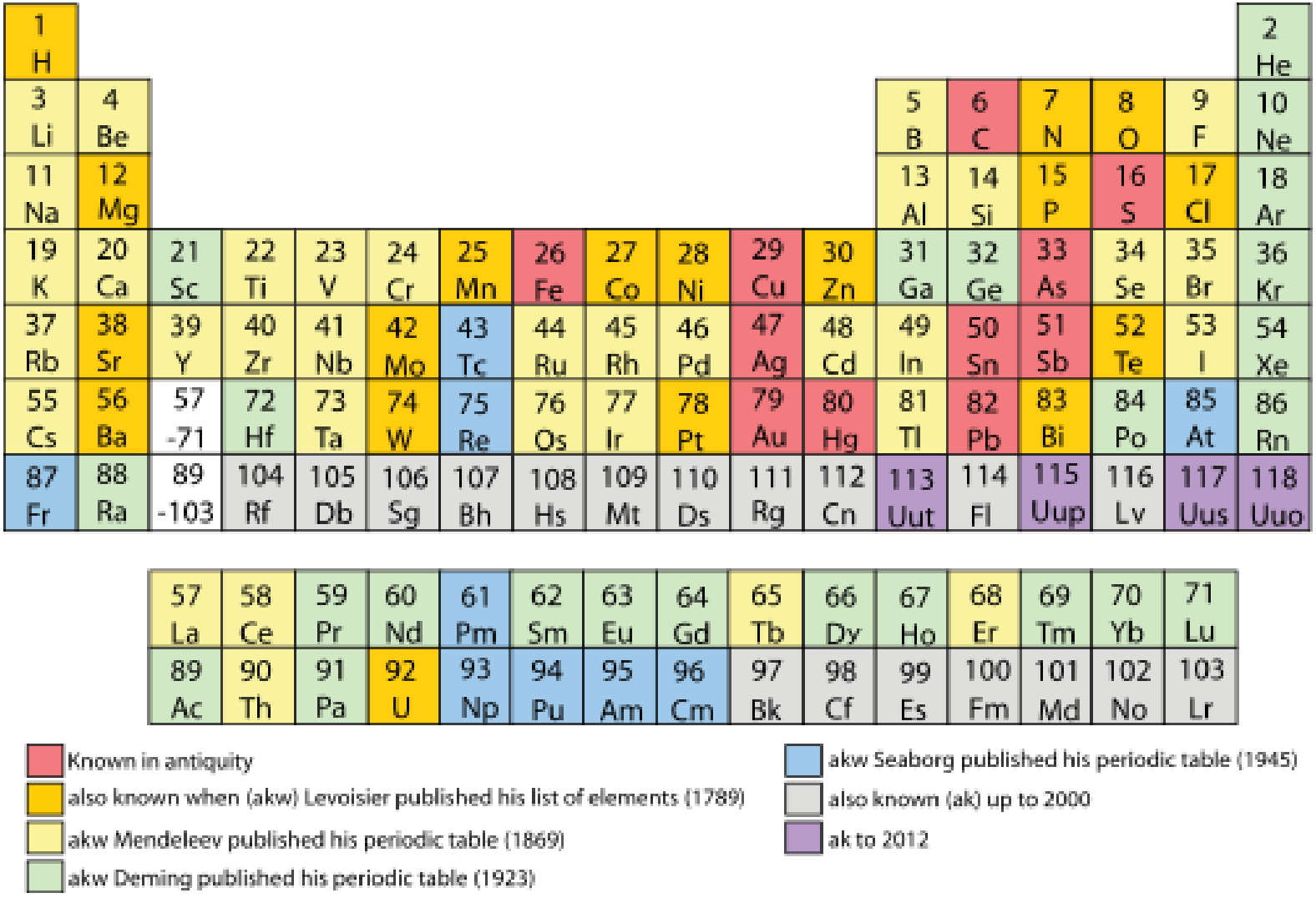
основанной на ихъ атомномъ вѣсѣ и химическомъ сходствѣ.

		Ti = 50	Zr = 90	? = 180.	
		V = 51	Nb = 94	Ta = 182.	
		Cr = 52	Mo = 96	W = 186.	
		Mn = 55	Rh = 104,4	Pt = 197,1	
		Fe = 56	Ru = 104,4	Ir = 198.	
		Ni = Co = 59	Pl = 106,6	O = 199.	
H = 1		Cu = 63,4	Ag = 108	Hg = 200.	
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 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 = 35,5	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204.
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207.
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	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



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																	2 **He** Helium 4.002602
2 **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
3 **Na** Sodium 22.98976928	12 **Mg** Magnesium 24.3050											13 **Al** Aluminium 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
4 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955912	22 **Ti** Titanium 47.867	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
5 **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
6 **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 (208.9824)	85 **At** Astatine (209.9871)	86 **Rn** Radon (222.0176)
7 **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)

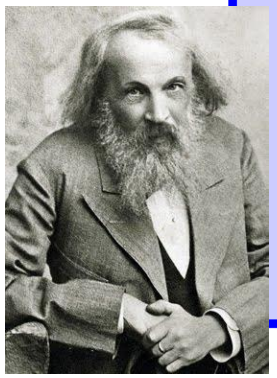
Atomic # Symbol Name Atomic Mass

C Solid
Hg Liquid
H Gas
Rf Unknown

Metals: Alkali metals; Alkaline earth metals; Lanthanoids; Actinoids; Transition metals; Poor metals
Nonmetals: Other nonmetals; Noble gases

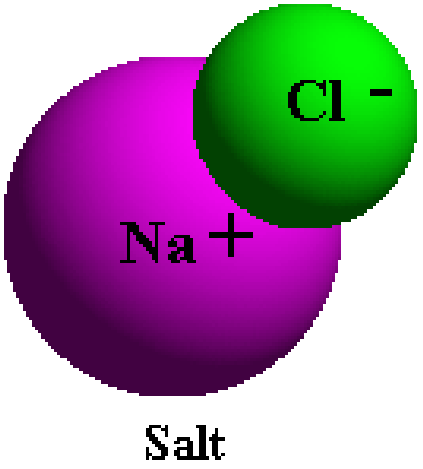
57 **La** Lanthanum 138.90547	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.242	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92535	66 **Dy** Dysprosium 162.500	67 **Ho** Holmium 164.93032	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)

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



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*:

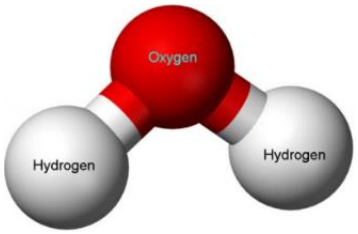
for example, table salt has different properties than **sodium**, an explosive metal, and **chlorine**, a poisonous gas.

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

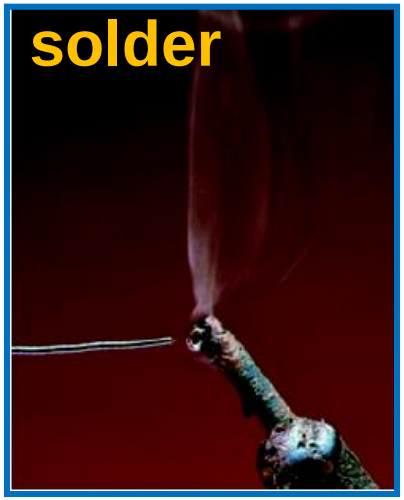


Ocean water is a mixture

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).**