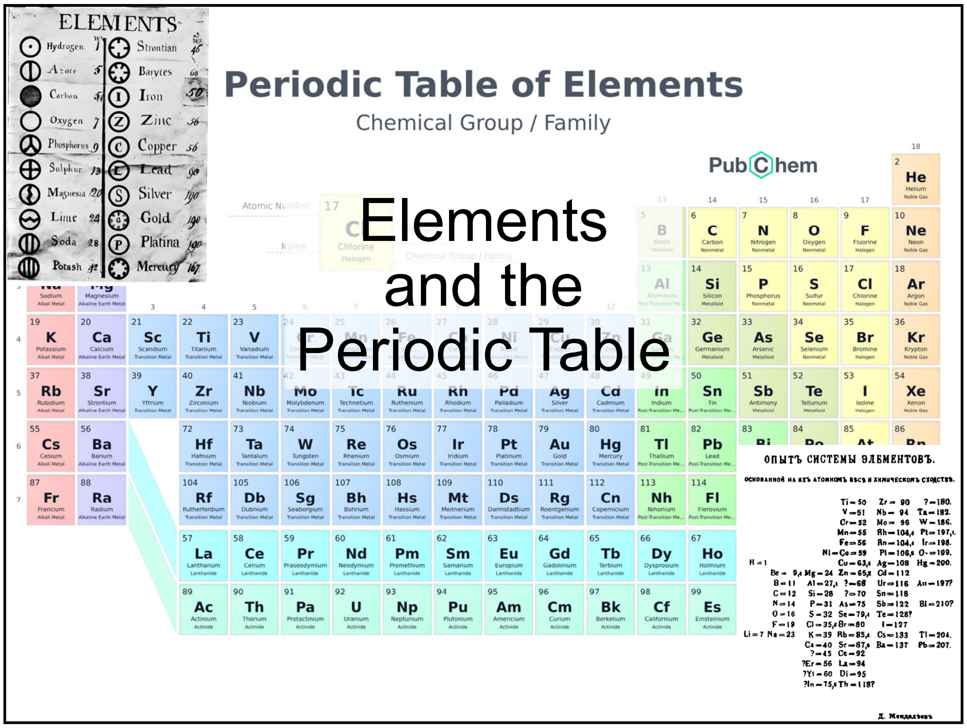
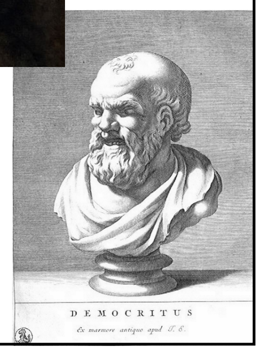
Story Time



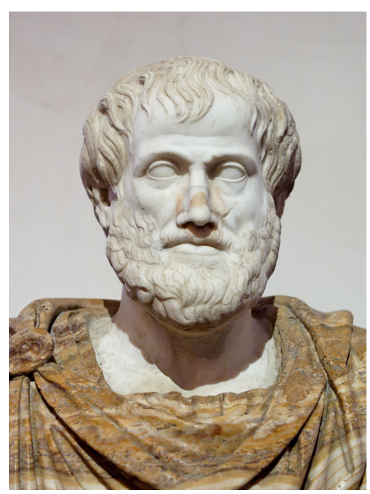
Elements and the Periodic Table

- The history of the periodic table reflects over two centuries of growth in the understanding of the chemical and physical properties of the elements.
  - The history of the periodic table is linked to the discovery of elements.
  - As more elements were discovered, there was a need to provide a convenient way to list them and show their properties.

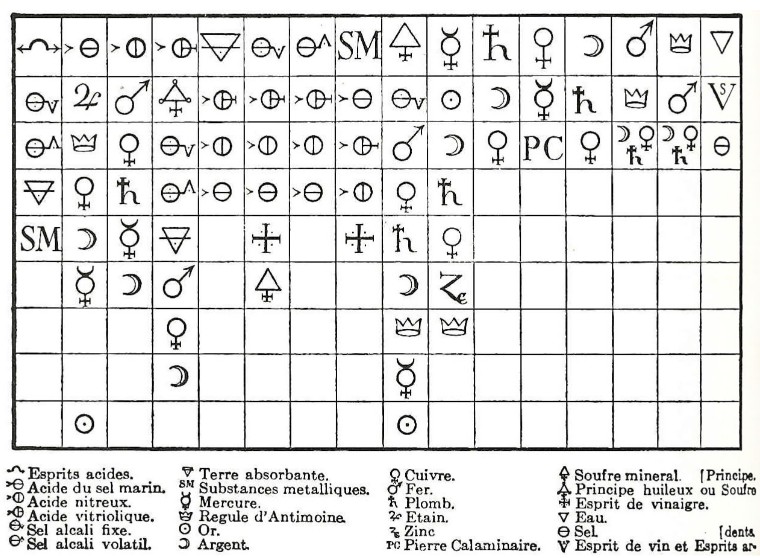
- Leucippus and Democritus (Greek)
  - c. 5th Century BCE
  - Proposed that all matter was composed of small indivisible particles which they called "atoms."



- Aristotle (Greek)
  - c. 330 BCE
  - Proposed that everything is made up of a mixture of one or more roots.
  - The four roots, which the Athenian philosopher Plato called elements, were earth, water, air and fire.



- Étienne François Geoffroy (French)
  - 1817
  - Prepared tables of "affinities."
  - These were lists, showing how different compounds and elements reacted with each other.

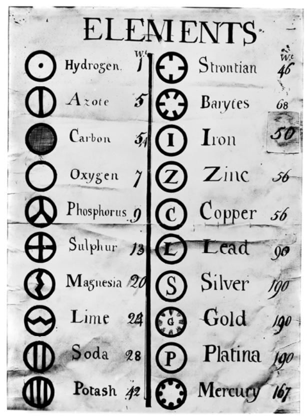


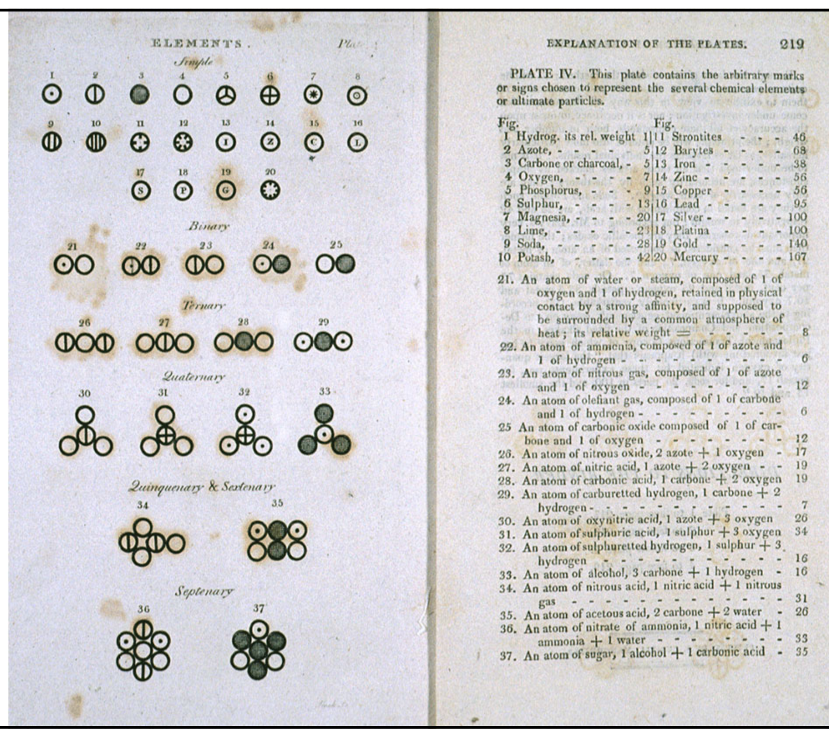
Geoffroy, Étienne-François, l'Aîné (1718). "Table des differents rapports observés en chimie entre differentes substances". Memoires de l'Academie Royale des Sciences: pp.202-212. Paris: Imprimerie royale. Scan from the original work

- Antoine Lavoisier (French)
  - 1789
  - Defined an element as a substance whose smallest units cannot be broken down into a simpler substance.
  - Lavoisier grouped the known elements based on their properties into gases, non-metals, metals and earths.

- John Dalton (English)
  - 1803
  - Proposed the atomic theory.
    - All matter was composed of small indivisible particles termed atoms.
    - Atoms of a given element possess unique characteristics and weight.
    - Three types of atoms exist: simple, compound, and complex.

- Dalton proposed a new set of standard symbols (to replace the symbols that most alchemists used) for the chemical elements in his book *A New System of Chemical Philosophy*.





EXPLANATION OF THE PLATES. 219

PLATE IV. This plate contains the arbitrary marks or signs chosen to represent the several chemical elements or ultimate particles.

Fig.			Fig.		
1	Hydrog. its rel. weight	1	11	Strontites	46
2	Azote,	5	12	Barytes	68
3	Carbone or charcoal,	5	13	Iron	38
4	Oxygen,	7	14	Zinc	56
5	Phosphorus,	9	15	Copper	56
6	Sulphur,	13	16	Lead	95
7	Magnesia,	20	17	Silver	100
8	Lime,	23	18	Platina	100
9	Soda,	28	19	Gold	140
10	Potash,	42	20	Mercury	167

21. An atom of water or steam, composed of 1 of oxygen and 1 of hydrogen, retained in physical contact by a strong affinity, and supposed to be surrounded by a common atmosphere of heat; its relative weight = - - - - - - 8
22. An atom of ammonia, composed of 1 of azote and 1 of hydrogen - - - - - - 6
23. An atom of nitrous gas, composed of 1 of azote and 1 of oxygen - - - - - - 12
24. An atom of olefiant gas, composed of 1 of carbone and 1 of hydrogen - - - - - - 6
25 An atom of carbonic oxide composed of 1 of carbone and 1 of oxygen - - - - - - 12
26. An atom of nitrous oxide, 2 azote + 1 oxygen - 17
27. An atom of nitric acid, 1 azote + 2 oxygen - - 19
28. An atom of carbonic acid, 1 carbone + 2 oxygen 19
29. An atom of carburetted hydrogen, 1 carbone + 2 hydrogen - - - - - - 7
30. An atom of oxynitric acid, 1 azote + 3 oxygen 26
31. An atom of sulphuric acid, 1 sulphur + 3 oxygen 34
32. An atom of sulphuretted hydrogen, 1 sulphur + 3 hydrogen - - - - - - 16
33. An atom of alcohol, 3 carbone + 1 hydrogen - 16
34. An atom of nitrous acid, 1 nitric acid + 1 nitrous gas - - - - - - 31
35. An atom of acetous acid, 2 carbone + 2 water - 26
36. An atom of nitrate of ammonia, 1 nitric acid + 1 ammonia + 1 water - - - - - - 33
37. An atom of sugar, 1 alcohol + 1 carbonic acid - 35

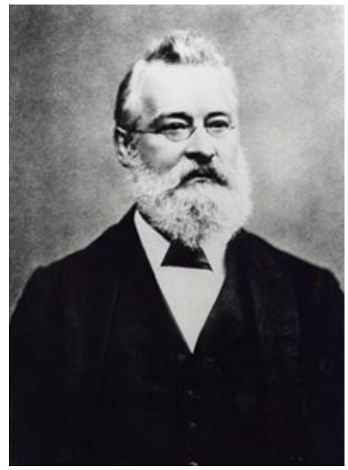
- Jöns Jacob Berzelius (Swedish)
  - 1813
  - Proposed a standard naming system for elements.
  - Berzelius' system proved efficient and eventually replaced all earlier symbolic systems. IUPAC later formalized and standardized the process.

The chemical signs ought to be letters, for the greater facility of writing, and not to disfigure a printed book. Though this last circumstance may not appear of any great importance, it ought to be avoided whenever it can be done. I shall take, therefore, for the chemical sign, the *initial letter of the Latin name of each elementary substance*: but as several have the same initial letter, I shall distinguish them in the following manner: –1. In the class which I call metalloids, I shall employ the initial letter only, even when this letter is common to the metalloid and to some metal. 2. In the class of metals, I shall distinguish those that have the same initials with another metal, or a metalloid, by writing the first two letters of the word. 3. If the first two letters be common to two metals, I shall, in that case, add to the initial letter the first consonant which they have not in common: for example, S = sulphur, Si = silicium, St = stibium (antimony) , Sn = stannum (tin), C = carbonicum , Co = cobaltum (cobalt), Cu = cuprum (copper) , O = oxygen , Os = osmium, &c.

- Johann Döbereiner (German)
  - 1829
  - Recognized triads of elements with chemically similar properties.

- Alexandre-Émile Béguyer de Chancourtois (French)
  - 1862
  - First to arrange the chemical elements in order of atomic weights.
    - Published his paper but did not publish his actual graph with the irregular arrangement.
    - The paper was ignored by chemists as it was written in terms of geology.

- John Newlands (British)
  - 1865
  - Noticed that there were similarities between elements with atomic weights that differed by seven.
    - “Law of Octaves”

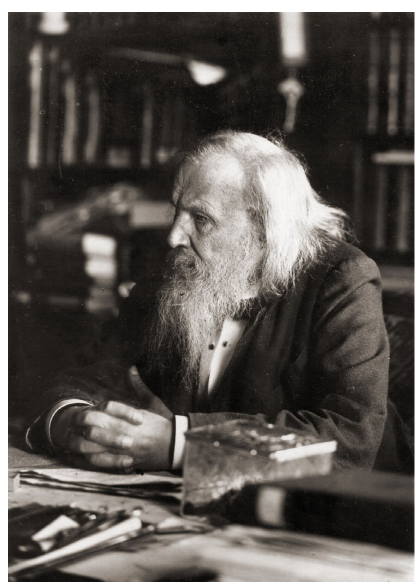


- The Law of Octaves was ridiculed by some of Newlands' contemporaries, and the Society of Chemists did not accept his work for publication.

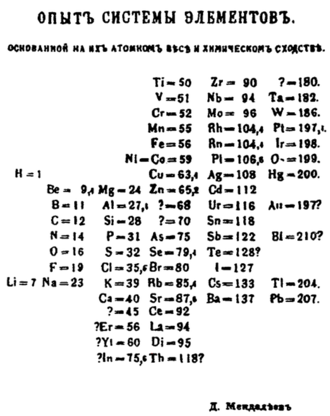
	No.		No.		No.		No.		No.		No.		No.		No.
H	1	F	8	Cl	15	Co & Ni	22	Br	29	Pd	36	I	42	Pt & Ir	50
Li	2	Na	9	K	16	Cu	23	Rb	30	Ag	37	Cs	44	Os	51
G	3	Mg	10	Ca	17	Zn	24	Sr	31	Cd	38	Ba & V	45	Hg	52
Bo	4	Al	11	Cr	19	Y	25	Ce & La	33	U	40	Ta	46	Tl	53
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Pb	54
N	6	P	13	Mn	20	As	27	Di & Mo	34	Sb	41	Nb	48	Bi	55
O	7	S	14	Fe	21	Se	28	Ro & Ru	35	Te	43	Au	49	Th	56

- Lothar Meyer (German)
  - 1868
  - Listed the elements in order of atomic weight, with elements with the same valency arranged in vertical lines.
    - Unfortunately for Meyer, his work wasn't published until 1870.

- Dmitri Mendeleev (Russian)
  - 1869
  - Notice that when the elements were arranged in order of increasing atomic weight, certain types of element regularly occurred.



- Mendeleev left gaps in his table for undiscovered elements.
- He even predicted the properties of five of these elements and their compounds.

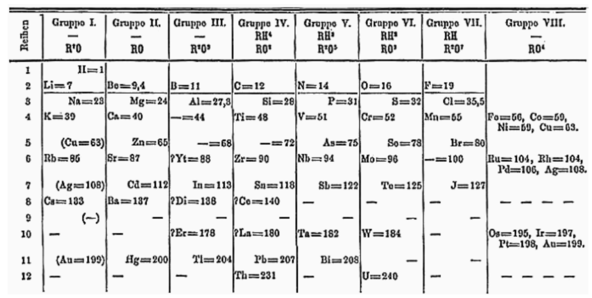


ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

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	Rn=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?		

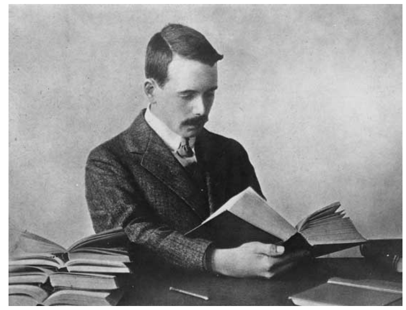
Д. Менделѣевъ



Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

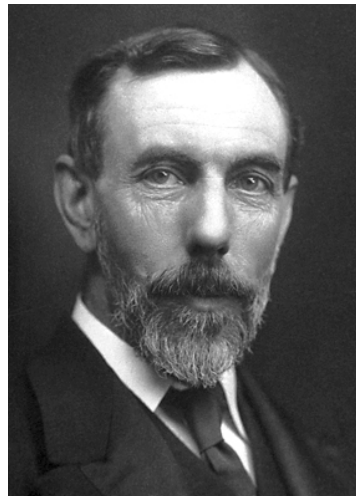
- Antonius van den Broek (Dutch)
  - 1913
  - Proposed that the positive nuclear charge of an atom was exactly equal to the element's position in the periodic table, rather than its atomic weight. He linked chemical and physical properties to this "atomic number."

- Henry Moseley (British)
  - 1913
  - Discovered a systematic mathematical relationship between the wavelengths of the X-rays produced and the atomic numbers of the metals that were used as the targets in X-ray tubes.

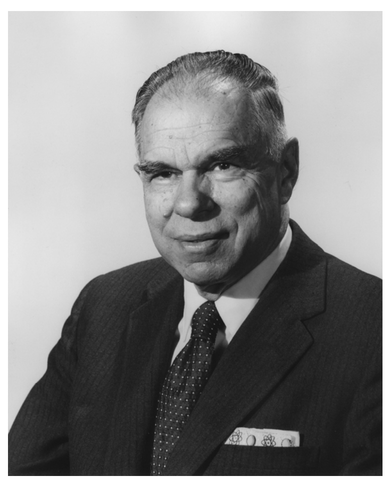


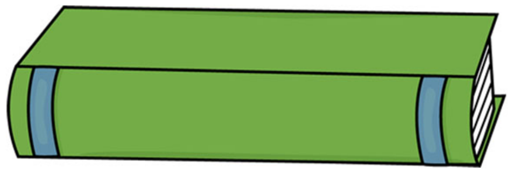
- Before Moseley's discovery, the atomic numbers of an element had been thought of as a semi-arbitrary sequential number, based on the sequence of atomic masses, but modified somewhat where chemists found this modification to be desirable.
- Moseley's discovery demonstrated that the atomic numbers of elements are not just rather arbitrary numbers based on chemistry and the intuition of chemists, but rather, they have a firm experimental basis from the physics of their X-ray spectra.

- Sir William Ramsay (Scottish)
  - 1894 – 1910
  - Discovered the noble gasses.
  - This demonstrated that the periodicity of the elements was 8 and not 7.



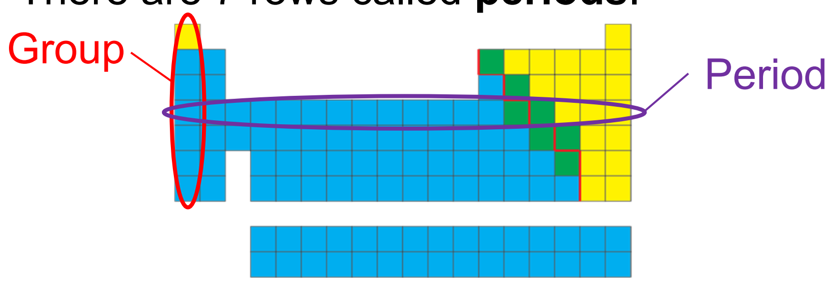
- Glenn T. Seaborg (American)
  - 1945
  - Suggested the classification of Lanthanides and Actinides (atomic numbers > 92), which are usually placed below the periodic table.
    - They are place below the table so that it fits on a piece of paper.



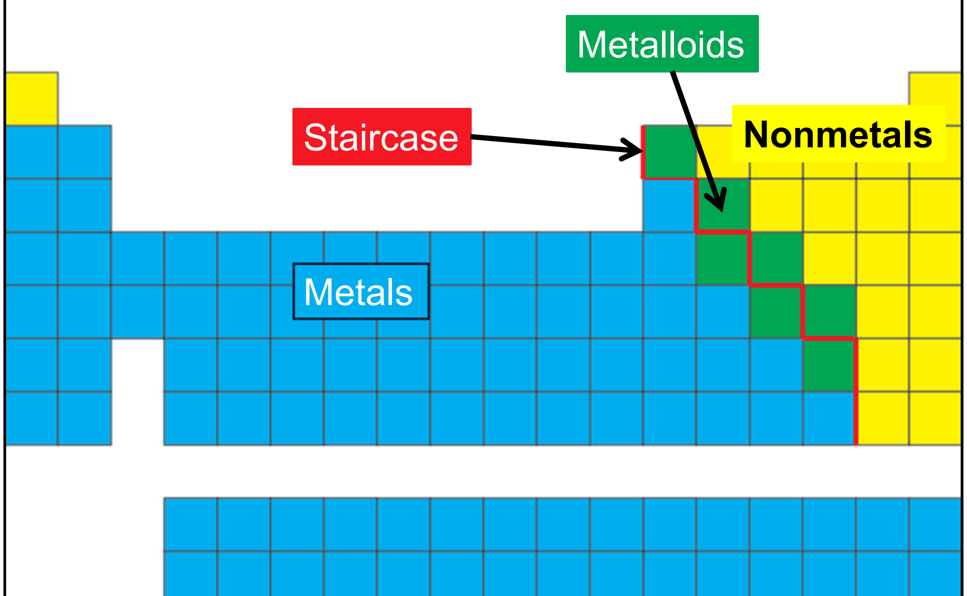


The Periodic Table

- The modern periodic table is arranged by atomic number.
- There are 18 columns called **groups**.
  - Elements in a group have similar chemical and physical properties.
- There are 7 rows called **periods**.



- The periodic table is split into two main categories: **metals** and **nonmetals**.
  - These categories are separated by a "staircase."
    - Metals are to the left of the staircase and nonmetals are to the right.
- Some elements along the staircase have properties of both metals and nonmetals. These elements are called **metalloids**.
  - Boron, Silicon, Germanium, Arsenic, Antimony, Tellurium, and Polonium



- Elements are classified as metals or nonmetals due to their properties.
  - Metals are shiny, malleable, ductile, and good conductors of heat and electricity.
  - Nonmetals are dull, brittle, and poor conductors of heat and electricity.
  - Metalloids tend to be shiny, brittle, and semiconductors.

Lithium

Sulfur

Silicon

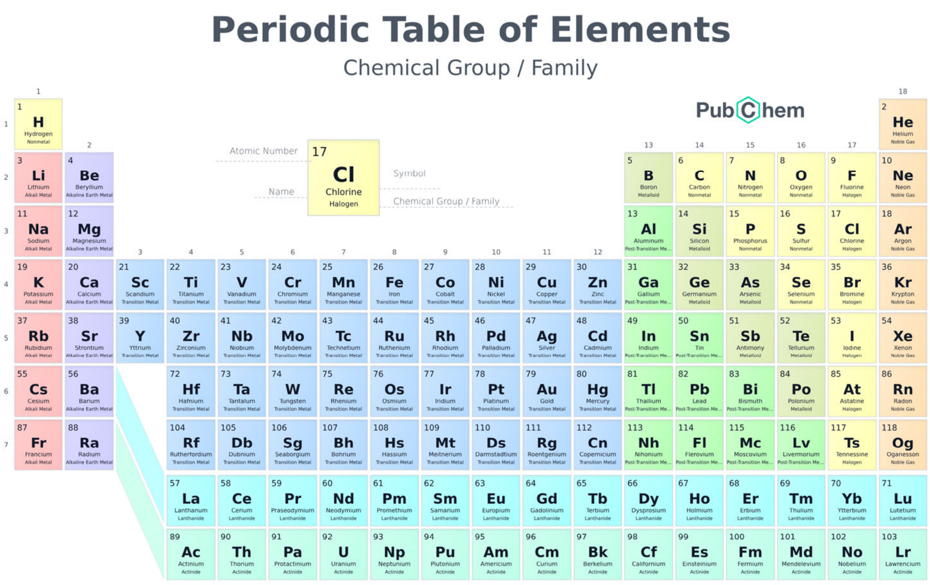
- The groups in the periodic table are often referred to by name.

Group	Name
1	**Alkali metals**
2	**Alkaline earth metals**
3-12	**Transition metals**
13	Boron group or earth metals
14	Carbon group or tetrels
15	Nitrogen group or pnictogens
16	Oxygen group or chalcogens
17	**Halogens**
18	**Noble gasses**

Chemical Symbols

- A chemical symbol is an abbreviation that we use to indicate an element or an atom of an element.
  - The symbols for the elements follow rules outlined by IUPAC (International Union of Pure and Applied Chemistry).
  - The first letter of each symbol is always capitalized.
    - If the symbol has a second letter, it is always lower case.

Element	Symbol	Element	Symbol
Aluminum	Al	Iron	Fe (*ferrum*)
Calcium	Ca	Lead	Pb (*plumbum*)
Carbon	C	Sodium	Na (*natrium*)
Chlorine	Cl	Potassium	K (*kalium*)
Oxygen	O	Gold	Au (*aurum*)
Helium	He	Silver	Ag (*argentum*)
Hydrogen	H	Tin	Sn (*stannum*)
Iodine	I	Mercury	Hg (*hydrargyrum*)



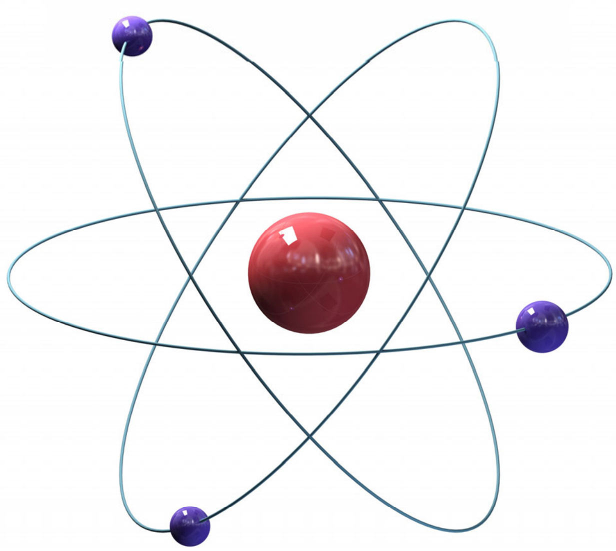
- The beauty of the periodic table is revealed in the patterns and trends in its rows and columns.
  - Going up or down a column, elements are organized into groups which have similar chemical properties.
  - Moving left or right within a row, the atoms trend smaller or larger in size, and their reactivities go up and down.

The Periodic Table: Crash Course Chemistry #4

https://youtu.be/0RRVV4Diomg

Story Time

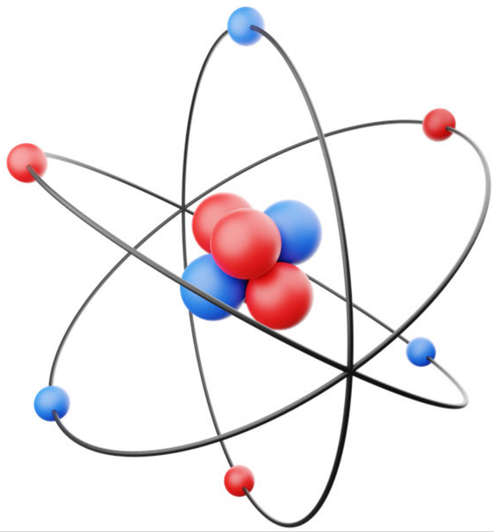
Atomic History



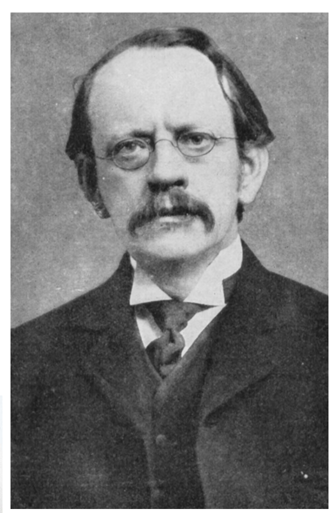
- John Dalton (English)
  - 1803
  - Helped to revolutionize chemistry with his hypothesis that the behavior of matter could be explained using an atomic theory.

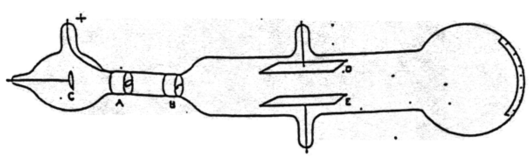
- Matter is composed of exceedingly small particles called atoms. An atom is the smallest unit of an element that can participate in a chemical change.
- An element consists of only one type of atom, which has a mass that is characteristic of the element and is the same for all atoms of that element. A macroscopic sample of an element contains an incredibly large number of atoms, all of which have identical chemical properties.

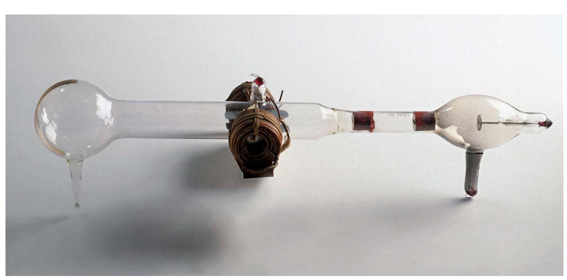
- If all matter is made of atoms, and the atoms of each element are different, then, what are atoms made of?



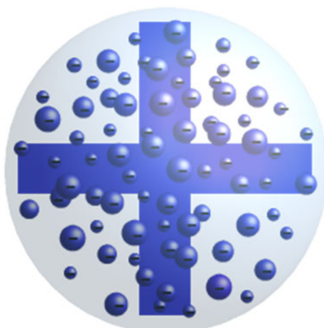
- J. J. Thomson (British)
  - 1897
  - Discovered the electron.



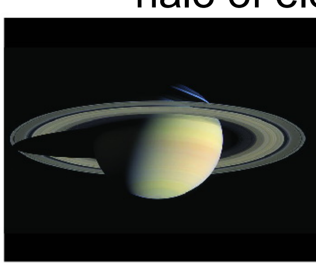


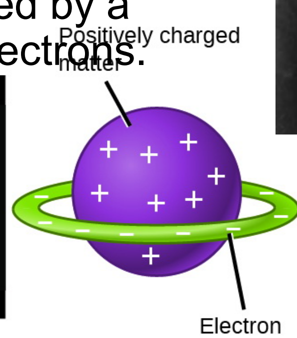


- In 1904, Thomson proposed the “plum pudding” model of the atom. (Based on the new evidence)
  - A positively charged mass with an equal amount of negatively charged electrons embedded in it.

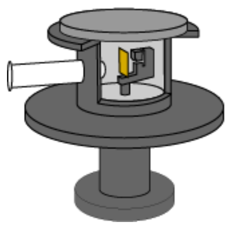


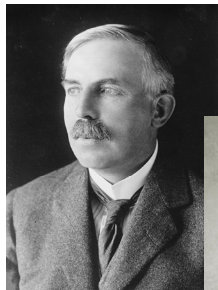
- Hantaro Nagaoka (Japanese)
  - 1903
  - Postulated a Saturn-like atom
    - A positively charged sphere surrounded by a halo of electrons.

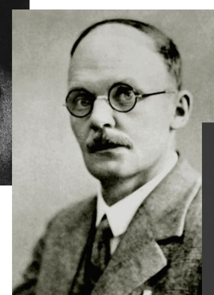


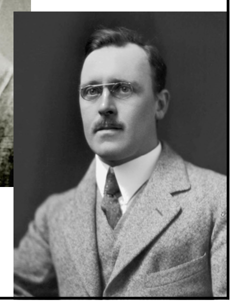


- Ernest Rutherford (English-New Zealand)
- Hans Geiger (German)
- Ernest Marsden (English-New Zealand)
  - 1909
  - Showed that atoms were mostly empty space.

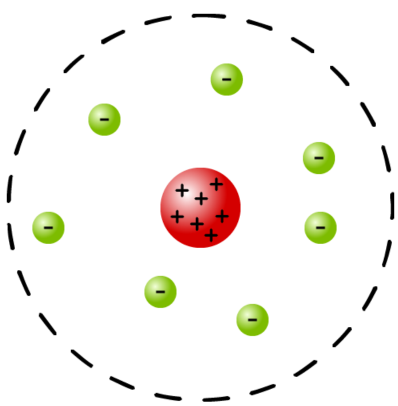




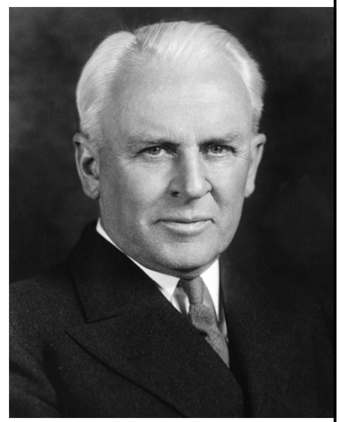




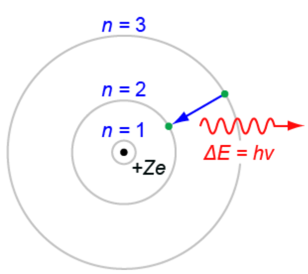
- From this result, Rutherford proposed that an atom had a very small positively charged nucleus, in which most of the mass is concentrated, surrounded by negatively charged electrons.



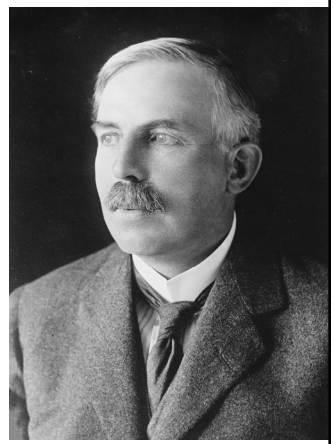
- Robert A. Millikan (American)
  - 1909
  - Experimentally determined the charge on an electron



- Niels Bohr (Danish)
  - 1913
  - Built on Rutherford's model and proposed that the electrons were in specific orbits (energy levels) around the nucleus.



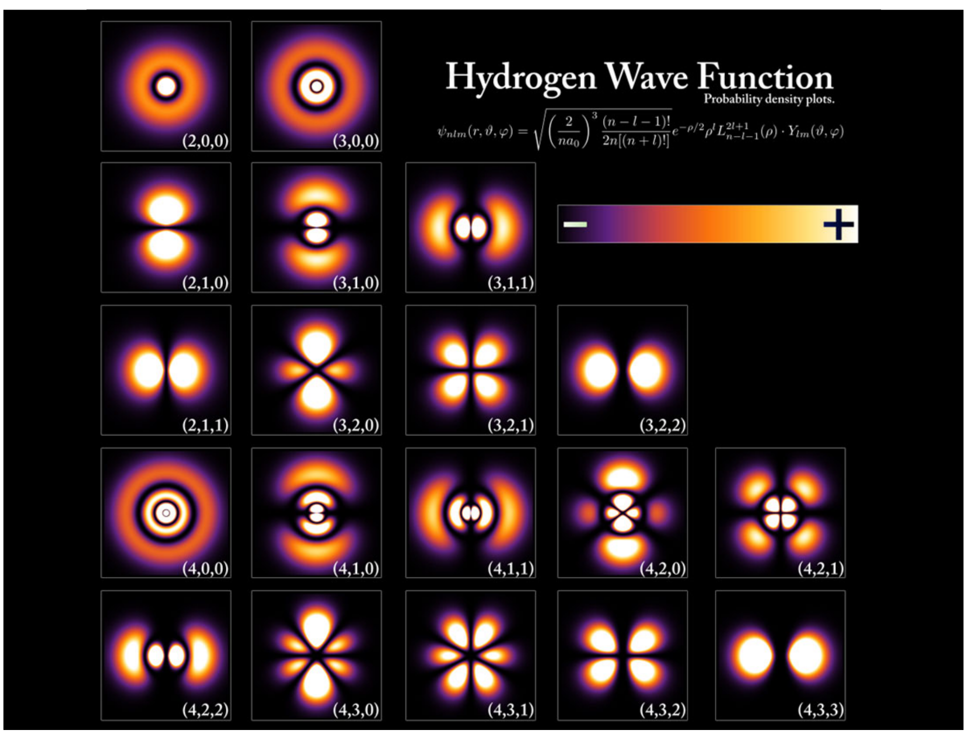
- Ernest Rutherford (English-New Zealand)
  - 1917
  - Performed an experiment that led him to conclude that the nucleus of an atom was made of positively charged particles.
  - The name "proton" was suggested by Rutherford at an informal meeting of fellow physicists in Cardiff in 1920.



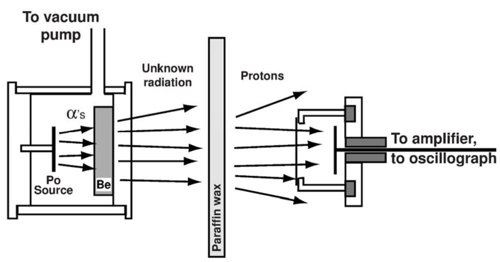
- Louis de Broglie (French)
  - 1924
  - Postulated the wave nature of electrons and suggested that all matter has wave properties.
    - This was experimentally confirmed in 1927.

- Erwin Schrödinger (Austrian)
  - 1926
  - Developed an equation that describes an electron as a wave function instead of a point
  - Schrödinger's wave model for hydrogen replaced Bohr's circular orbits with atomic orbitals giving only the probability of finding an electron at positions around the nucleus.

$$E\psi = \frac{-\hbar^2}{2\mu}\psi - \frac{q^2}{4\pi\varepsilon_0 r}\psi$$

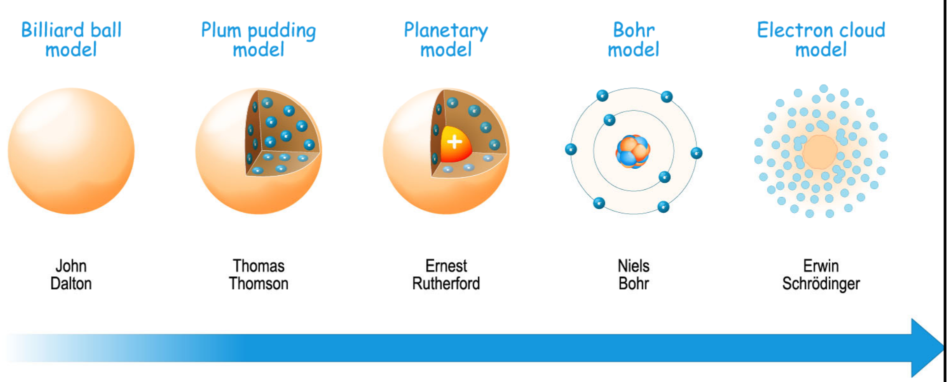


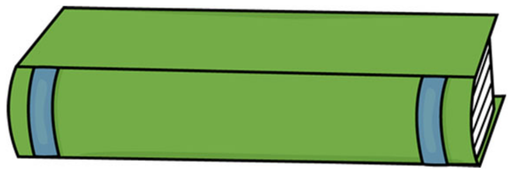
- James Chadwick (British)
  - 1932
  - Discovered the neutron.



These results, and others I have obtained in the course of the work, are very difficult to explain on the assumption that the radiation from beryllium is a quantum radiation, if energy and momentum are to be conserved in the collisions. The difficulties disappear, however, if it be assumed that the radiation consists of particles of mass 1 and charge 0, or neutrons. (Chadwick, J. Nature. Feb 27, 1932. p 312)

Timeline of atomic models





Atomic Structure

- Atoms have a very small nucleus composed of positively charged protons and uncharged (neutral) neutrons surrounded by a much larger space containing negatively charged electrons.

- If the nucleus were the size of a blueberry, then the atom would be the size of a football field.

- Protons, neutrons, and electrons are extremely small.
  - For example, a carbon atom weighs less than 2×10^{-23} g, and an electron has a charge of less than 2×10^{-19} C (coulomb).

- When describing the properties of tiny objects such as atoms, we use appropriately small units of measure, such as the **unified atomic mass unit** (u) and the **fundamental unit of charge** (e).
  - The unified atomic mass unit is defined as exactly $\frac{1}{12}$ of the mass of a single atom of the carbon-12 isotope.

Properties of Subatomic Particles

Particle	Location	Symbol	Charge (e)	Mass (u)
proton	nucleus	p^+	$+1$	1
neutron	nucleus	n^0	0	1
electron	outside the nucleus	e^-	-1	0.00055

- The number of protons in the nucleus of an atom is the **atomic number (Z)**.
  - The number of protons determines what element the atom is.
    - If an atom has 6 protons it is a Carbon atom, if it has 12 protons it is a Magnesium atom.
- A neutral atom has the same number of protons (+) and electrons (-).
  - Therefore, atomic number also indicates the number of electrons in an atom.

- The total number of protons and neutrons in an atom is called its **mass number (A)**.
  - The number of neutrons is therefore the difference between the mass number and the atomic number.
    - A – Z = number of neutrons.

Example

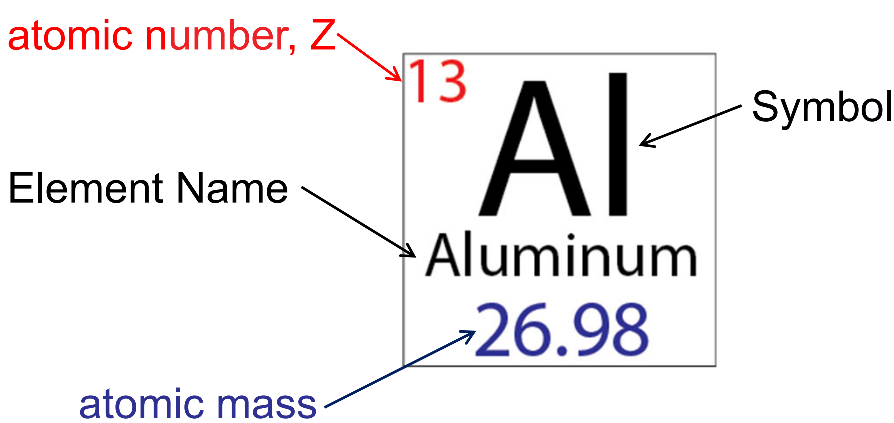
Titanium has an atomic number 22 and a mass number of 48. Determine the number of protons, neutrons, and electrons in one atom of titanium.

Number of protons: 22

Number of neutrons: 48 – 22 = 26

Number of electrons: 22

- The atomic number and mass number can be read from the periodic table.



The mass number, A, is the atomic mass rounded to nearest whole number (27 in this case).

Example

Determine the number of protons, neutrons, and electrons in an atom of sodium.

Atomic Number, Z: 11

Mass Number, A: 23

Number of protons: 11

Number of neutrons: 12

Number of electrons: 11

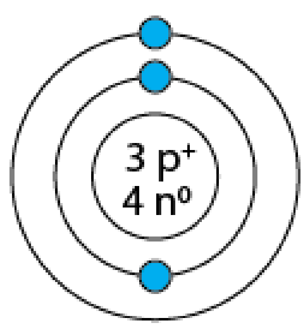
Electron Energy Levels

- Electrons occupy specific energy levels or shells.
  - Each energy level can hold a different number of electrons.
    - 1st shell (K): 2 electrons
    - 2nd shell (L): 8 electrons
    - 3rd shell (M): 18 electrons

- Electrons fill orbit shells in a consistent order.
- Under standard conditions, atoms fill the inner shells (closer to the nucleus) first, often resulting in a variable number of electrons in the outermost shell.
- Electrons follow the **octet rule.**
  - An atom is more stable energetically when it has 8 electrons in its most outer or **valence** shell.

Bohr Diagrams

- Bohr diagrams can be used to show the energy levels of the electrons in an atom.
  - The electrons are shown as dots in circular orbits about the nucleus.



Example

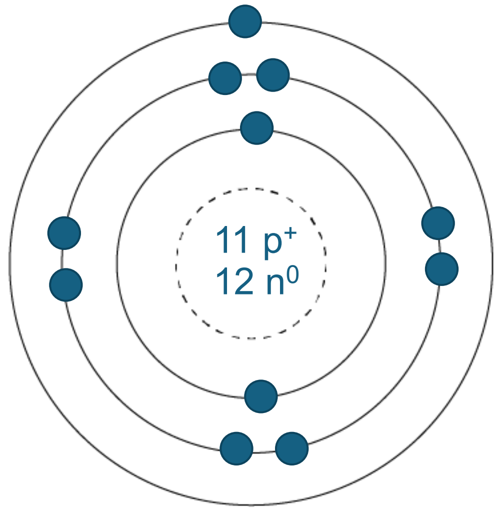
Sodium

Atomic number, Z=11

Mass number, A=23

Protons = 11
Neutrons = 12
Electrons = 11

1 shell (K) = 2
2 shell (L) = 8
3 shell (M) = 1



- Once we understood what atoms were made of, more patterns in the periodic table were revealed.
  - The group number represents the number of valence electrons.
  - The period number represents the number of energy levels present.
  - The table organizes elements into blocks: the s block, the p block, the d block, and the f block, which reveal more about how the electrons are arranged.