



# Development of the Periodic Table

A brief history

Carbon 14 <b>Si</b> 282000 Silicon	Phosphorus 15 <b>P</b> 1050	Sulfur 16 <b>S</b> 350	Chlorine 17 <b>Cl</b> 35	Krypton 36 <b>Kr</b> $1 \times 10^4$
Germanium 32 <b>Ge</b> 1.5	Arsenic 33 <b>As</b> 1.8	Selenium 34 <b>Se</b> $5 \times 10^{-2}$	Bromine 35 <b>Br</b> 2.4	Xenon 54 <b>Xe</b> $3 \times 10^{-3}$
Tin 50 <b>Sn</b> 2.3	Antimony 51 <b>Sb</b> $2 \times 10^{-1}$	Tellurium 52 <b>Te</b> $1 \times 10^{-3}$	Iodine 53 <b>I</b> $4.5 \times 10^{-1}$	Radon 86 <b>Rn</b> $4 \times 10^{-13}$
Thallium 81 <b>Tl</b> $3.5 \times 10^{-4}$	Lead 82 <b>Pb</b> 14	Bismuth 83 <b>Bi</b> $8.5 \times 10^{-3}$	Polonium 84 <b>Po</b> $2 \times 10^{-10}$	Astatine 85 <b>At</b>

Potassium 19 <b>K</b> 20900	Calcium 20 <b>Ca</b> 41500	Scandium 21 <b>Sc</b> 22
Rubidium 37 <b>Rb</b> 90	Strontium 38 <b>Sr</b> 370	Yttrium 39 <b>Y</b>
Cesium 55 <b>Cs</b> 3	Barium 56 <b>Ba</b> 425	
Francium 87 <b>Fr</b>	Radium 88 <b>Ra</b> $9 \times 10^4$	

# THE PERIODIC TABLE

- Is an arrangement of elements in which the elements are separated into **groups** based on a set of **repeating properties**

**Periodic Table of the Elements**

The periodic table is organized into groups and periods. The groups are labeled at the top and bottom of the table, and the elements are color-coded according to their properties.

1 1IA 11A		2 IIA 2A												13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.0079																			2 He Helium 4.0026
3 Li Lithium 6.941	4 Be Beryllium 9.01218												5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797	
11 Na Sodium 22.989768	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.4527	18 Ar Argon 39.948		
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.921595	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80		
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 95.94	43 Tc Technetium 98.9062	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29		
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [209]	85 At Astatine 209	86 Rn Radon 222.0176		
87 Fr Francium 223	88 Ra Radium 226.0254	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [271]	111 Rg Roentgenium [272]	112 Cn Copernicium [285]	113 Uut Ununtrium [288]	114 Uuq Ununquadium [289]	115 Uup Ununpentium [288]	116 Uuh Ununhexium [288]	117 Uus Ununseptium [293]	118 Uuo Ununoctium [294]		
		57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967			
		89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03688	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0798	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]			

Alkali Metal
Alkaline Earth
Transition Metal
Basic Metal
Semimetals
Nonmetals
Halogens
Noble Gas
Lanthanides
Actinides

# EXPANSION OF THE ELEMENTS

- French scientist **Lavoisier** compiled a list of all the known elements
  - Contained **33** elements **organized into four categories**
- The advent of **electricity and the Industrial revolution** played a large role in the discovery of new elements.
- By **1870**, there were approximately **70 known elements**.

## Table of the Elements (33)

Antimony  
Arsenic  
Bismuth  
Cobalt  
Copper  
Gold  
Iron  
Lead  
Manganese  
Mercury  
Molybdena  
Nickel  
Platina  
Silver  
Tin  
Tungstein  
Zinc

Oxygen  
Azote  
Hydrogen  
Sulphur  
Phosphorus  
Charcoal  
Muriatic radical  
Fluoric radical  
Boracic radical

Lime  
Magnesia  
Barytes  
Argill  
Silex

Argill (alum=potassium aluminum sulfate)

Silex (silicon dioxide = quartz)

Magnesia (Epsom salts=magnesium sulfate)

Lime = calcium oxide

# MENDELEEV'S TABLE

- Russian chemist, **Dmitri Mendeleev**, demonstrated a connection between **atomic mass and elemental properties**
- When elements were **ordered by increasing atomic mass**, there was a periodic **pattern in their properties**
- **Mendeleev** arranged the **elements in order of increasing atomic mass** into columns
  - Similar properties appeared at regular intervals
- Noting the similar properties and trends, he was able to **predict the properties of the yet-to-be-discovered** elements scandium, gallium, and germanium

			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 = 106,6	Os = 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	Sc = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	J = 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?		

# MOSELEY'S CORRECTIONS

- Mendeleev's table wasn't completely correct
  - Arranging elements by mass resulted in several elements being placed in groups of elements with different properties
- **Moseley** - 1913:
  - Arranged the elements according to:
    1. Increasing **atomic number**
    2. Elements with **similar properties** were put in the **same column**



# PERIODIC LAW

- After 1913 scientists were able to organize the **table based on atomic number** (# of protons)
- Periodic Law:
  - When elements are arranged in order of **increasing** atomic number, there is a periodic **repetition of their physical and chemical properties**
- This law produced the modern periodic table.

# Periodic Table of the Elements

1 1IA 11A																	18 VIIIA 8A
1 <b>H</b> Hydrogen 1.0079	2 IIA 2A											13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	2 <b>He</b> Helium 4.00260
3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.01218											5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.00574	8 <b>O</b> Oxygen 15.9994	9 <b>F</b> Fluorine 18.998403	10 <b>Ne</b> Neon 20.1797
11 <b>Na</b> Sodium 22.989768	12 <b>Mg</b> Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 <b>Al</b> Aluminum 26.981539	14 <b>Si</b> Silicon 28.0855	15 <b>P</b> Phosphorus 30.973762	16 <b>S</b> Sulfur 32.066	17 <b>Cl</b> Chlorine 35.4527	18 <b>Ar</b> Argon 39.948
19 <b>K</b> Potassium 39.0983	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.95591	22 <b>Ti</b> Titanium 47.88	23 <b>V</b> Vanadium 50.9415	24 <b>Cr</b> Chromium 51.9961	25 <b>Mn</b> Manganese 54.938	26 <b>Fe</b> Iron 55.847	27 <b>Co</b> Cobalt 58.9332	28 <b>Ni</b> Nickel 58.6934	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.39	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.64	33 <b>As</b> Arsenic 74.92159	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.80
37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.90585	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.90638	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium 98.9072	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.9055	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.8682	48 <b>Cd</b> Cadmium 112.411	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.90447	54 <b>Xe</b> Xenon 131.29
55 <b>Cs</b> Cesium 132.90543	56 <b>Ba</b> Barium 137.327	57-71	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.9479	74 <b>W</b> Tungsten 183.85	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.22	78 <b>Pt</b> Platinum 195.08	79 <b>Au</b> Gold 196.9665	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.3833	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98037	84 <b>Po</b> Polonium [209.9824]	85 <b>At</b> Astatine 209.9871	86 <b>Rn</b> Radon 222.0176
87 <b>Fr</b> Francium 223.0197	88 <b>Ra</b> Radium 226.0254	89-103	104 <b>Rf</b> Rutherfordium [261]	105 <b>Db</b> Dubnium [262]	106 <b>Sg</b> Seaborgium [266]	107 <b>Bh</b> Bohrium [264]	108 <b>Hs</b> Hassium [269]	109 <b>Mt</b> Meitnerium [268]	110 <b>Ds</b> Darmstadtium [269]	111 <b>Rg</b> Roentgenium [272]	112 <b>Cn</b> Copernicium [277]	113 <b>Uut</b> Ununtrium [289]	114 <b>Uuq</b> Ununquadium [289]	115 <b>Uup</b> Ununpentium [289]	116 <b>Uuh</b> Ununhexium [289]	117 <b>Uus</b> Ununseptium [289]	118 <b>Uuo</b> Ununoctium [289]
Lanthanide Series	57 <b>La</b> Lanthanum 138.9055	58 <b>Ce</b> Cerium 140.115	59 <b>Pr</b> Praseodymium 140.90765	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium 144.9127	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.9655	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.92534	66 <b>Dy</b> Dysprosium 162.50	67 <b>Ho</b> Holmium 164.93032	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93421	70 <b>Yb</b> Ytterbium 173.04	71 <b>Lu</b> Lutetium 174.967		
Actinide Series	89 <b>Ac</b> Actinium 227.0278	90 <b>Th</b> Thorium 232.0381	91 <b>Pa</b> Protactinium 231.03688	92 <b>U</b> Uranium 238.0289	93 <b>Np</b> Neptunium 237.0482	94 <b>Pu</b> Plutonium 244.0642	95 <b>Am</b> Americium 243.0614	96 <b>Cm</b> Curium 247.0703	97 <b>Bk</b> Berkelium 247.0703	98 <b>Cf</b> Californium 251.0796	99 <b>Es</b> Einsteinium [254]	100 <b>Fm</b> Fermium 257.0951	101 <b>Md</b> Mendelevium 258.1	102 <b>No</b> Nobelium 259.1009	103 <b>Lr</b> Lawrencium [262]		
Alkali Metal	Alkaline Earth	Transition Metal	Basic Metal	Semimetals	Nonmetals	Halogens	Noble Gas	Lanthanides	Actinides								





# PERIODIC TABLE MAP

- The table is a map to ANY element
- You can find an element if you know:
  1. **Atomic number**
  2. **Period** and **group** number
    - **Period**: horizontal rows (left to right)
    - **Group**: vertical columns (top to bottom)
      - Also called “Families”
- Beginning with hydrogen in period 1, there are a total of **7 periods**
  - During electron configuration we called the periods the “principle energy level”!
- Each group is numbered **1 - 18**
  - Elements in groups 1, 2, and 13-18 possess a wide range of chemical and physical properties
    - These are known as the “**main group**” or “**representative**” elements
  - Elements in groups 3 - 12 are referred to as **transition** elements
    - Classified as metals, non-metals, and metalloids

# PERIODS AND GROUPS

## ■ Periods:

- Beginning with hydrogen in period 1, there are a total of **7 periods**
- Properties of the elements within a period change as you move across a period from **left to right**

## ■ Groups:

- Each group is numbered **1 - 18**
- Elements in groups 1, 2, and 13-18 possess a wide range of chemical and physical properties
  - These are known as the “main group” or “representative” elements
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# PROPERTIES OF METALS

- **Generally shiny** when smooth and clean
- **Solid at room temperature**
- Good conductors of **heat and electricity**
- Most are **malleable** and ductile
- **~80%** of the periodic table is metallic
  
- **Alkali Metals:**
  - Except for hydrogen, Group 1 elements
  - Highly reactive and usually exist as compounds with other elements
  
- **Alkaline Earth Metals:**
  - Group 2
  - Highly reactive

# NONMETALS AND METALLOIDS

## ■ Nonmetals:

- Poor conductors of **heat and electric current**
- Most are **gaseous** at room temperature

## ■ Metalloids:

- Properties exist between **metal and nonmetal**
- Highly **dependent on conditions** of the environment
  - i.e. temperature, state of matter, etc.

1 IA 1A																	18 VIIIB 8A						
1 H	2 IIA 2A	Metals										Metalloids			Nonmetals				2 He				
3 Li	4 Be																	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	3 IIIA 3B	4 IVA 4B	5 VA 5B	6 VIA 6B	7 VIIA 7B	8	9 VIII 8B	10	11 IB 1B	12 IIB 2B	13 IIIB 3A	14 IVB 4A	15 VB 5A	16 VIB 6A	17 VIIB 7A	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 Lu	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 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	114 Uuq											
		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								
		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								

- What trends do you see?
- Are there any exceptions to the trends?
- What divides metals from nonmetals?

# GROUP NAMES

- Recall that columns are called “**groups**” or “**families**”
- Common names have been assigned to these groups as well
- Group 1:
  - **Alkali Metals**
  - Reactive with water (Li, Na, K, Rb, Cs, Fr)
- Group 2:
  - **Alkaline Earth Metals**
  - Abundant in Earth’s crust (Be, Mg, Ca, Sr, Ba, Ra)

# GROUP NAMES CONTINUED

- Groups 3 – 12
  - **Transition metals**
    - They transition from metals to nonmetals
- There is a special class within the transition metals called **Inner transition metals**
  - Include **Lanthanides and Actinides**
  - Sometimes called the **rare earth elements**
  - Located on the bottom of the periodic table



# MORE GROUP NAMES

- There are two special group names in the nonmetal section of the table
  - **Halogens**
    - **Group 17**
    - Include F, Cl, Br, I, At
    - **Most reactive nonmetals**
  - **Noble Gases**
    - **Group 18**
    - Include He, Ne, Ar, Kr, Xe, Rn
    - **Uniquely unreactive (“inert”)**
- Groups 1, 2, 13 – 17 are called the **representative elements** because they show a wide range of chemical and physical properties

# HOW DOES ELEMENT LOCATION HELP DETERMINE ATOMIC STRUCTURE?

- Element location tells us about how the atom is structured
- Group number tells us the number of valence electrons
  - Outermost electrons in the atom
- Period tells us the number of energy levels in the atom
  - Refers to the size of the atom and how many electrons can be accommodated