

Ch 4. Atoms and Elements

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Early View of Atomic Structure

Early View of Atomic Structure

In the Beginning...

Greeks (~400 BC)

- Four elements – fire, earth, water, air
- Is matter continuous or made of discrete particles (atomos)?

Alchemists (next 2000 years)

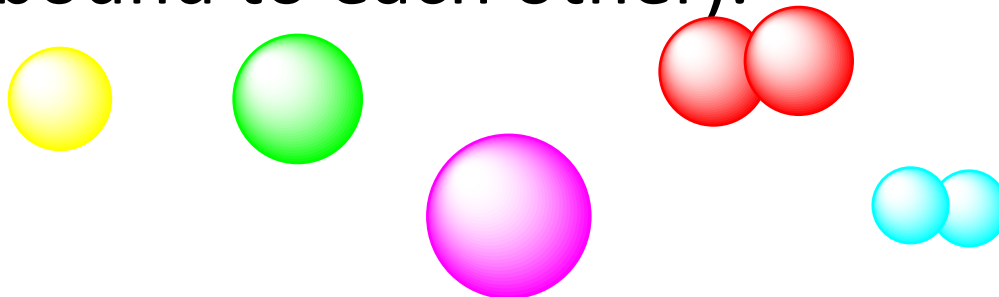
- First chemists
- Discovered elements; acid preparation

Robert Boyle (1627-1691)

- Science should be grounded in experiments.
- Elements are substances that cannot be broken down into simpler substances.

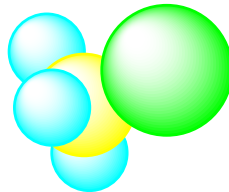
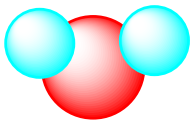
Dalton's Atomic Theory (1808)

1. Each element is made of tiny indivisible particles called **atoms** that cannot be created nor destroyed (law of conservation of matter).
2. Atoms of an element cannot be converted to atoms of another element. In chemical reactions, **atoms re-combine to form different substances** (change the way they are bound to each other).



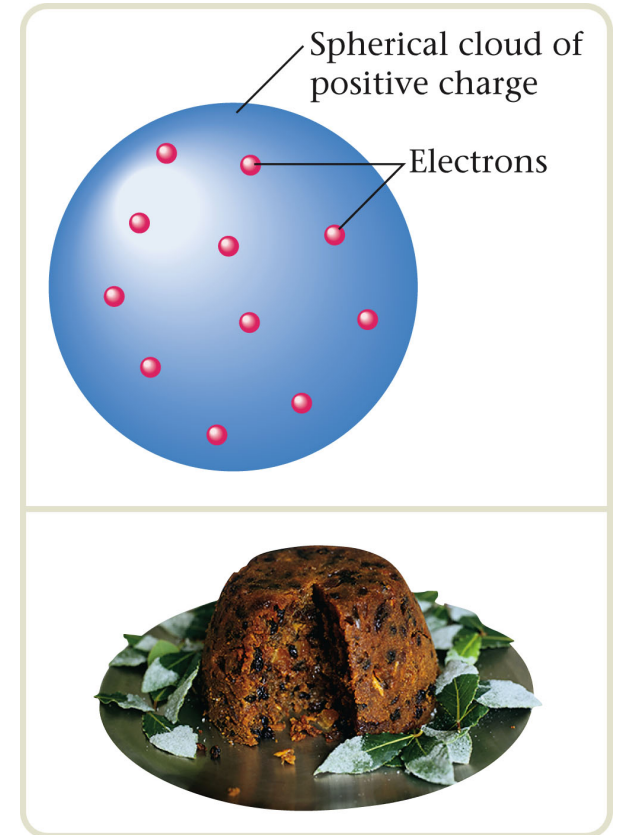
Dalton's Atomic Theory, continued

4. The **atoms of a given element are identical**, and different from those of any other element.
5. Atoms of one element can combine with atoms of other elements to form **compounds**. A given compound always has the same relative numbers and types of atoms.



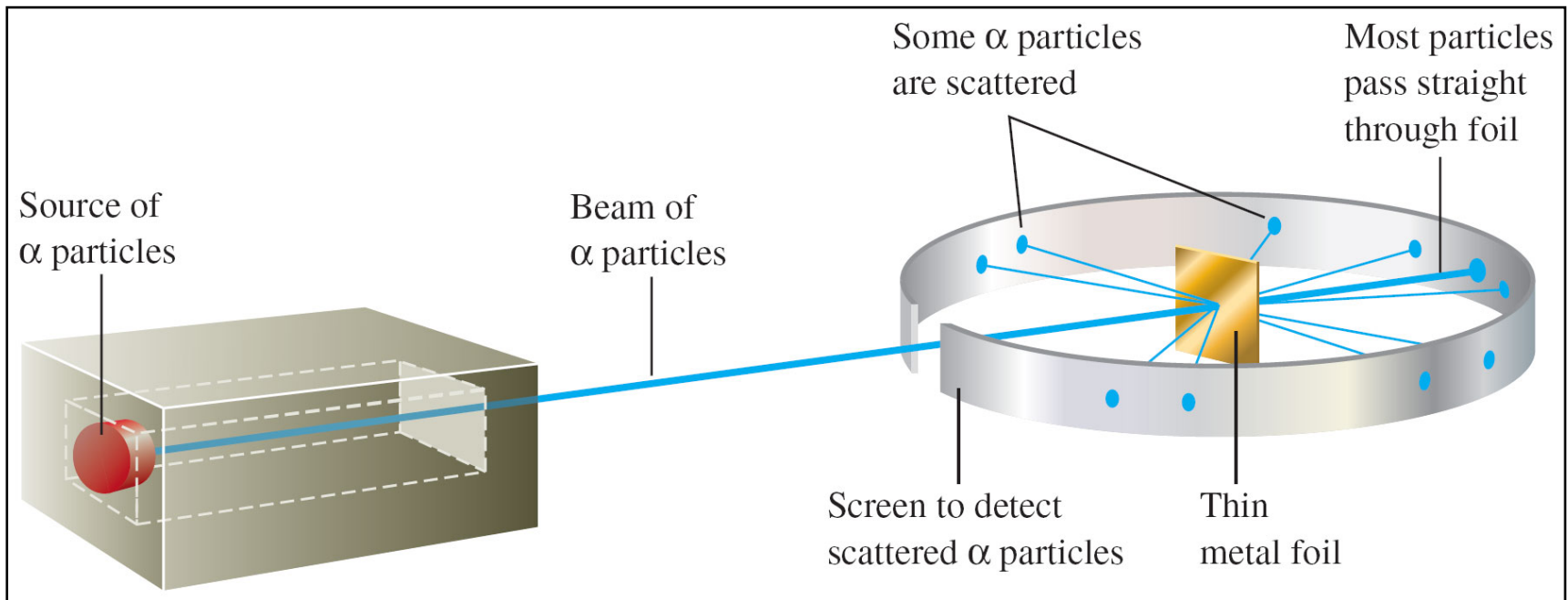
Hypothesized Atomic Structure, 1910

- Lord Kelvin, 1910
 - Plum pudding model

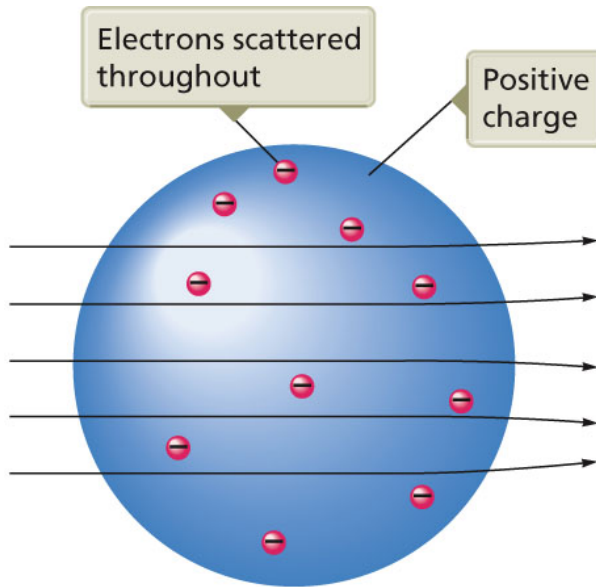


Rutherford's Gold Foil Experiment

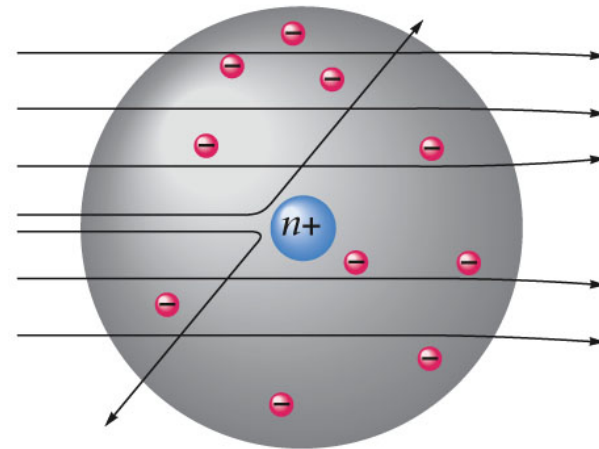
- 1911: Ernest Rutherford shot α -particles (positively charged particles with mass 7300x that of electron) through gold foil.



Rutherford's Gold Foil Experiment



Expected



Observed

The Nuclear Atom

Earnest Rutherford concluded the **nuclear atom:**
(1911-1919)

- An atom is mostly empty space that is occupied by electrons.
- Atom has a tiny, dense center of positive charge: **nucleus**.
- The nucleus contains particles called **protons**, which have charge of same magnitude as electrons but are positive.
- Most nuclei also contain a neutral particle: **neutron**. (with Chadwick, 1932)

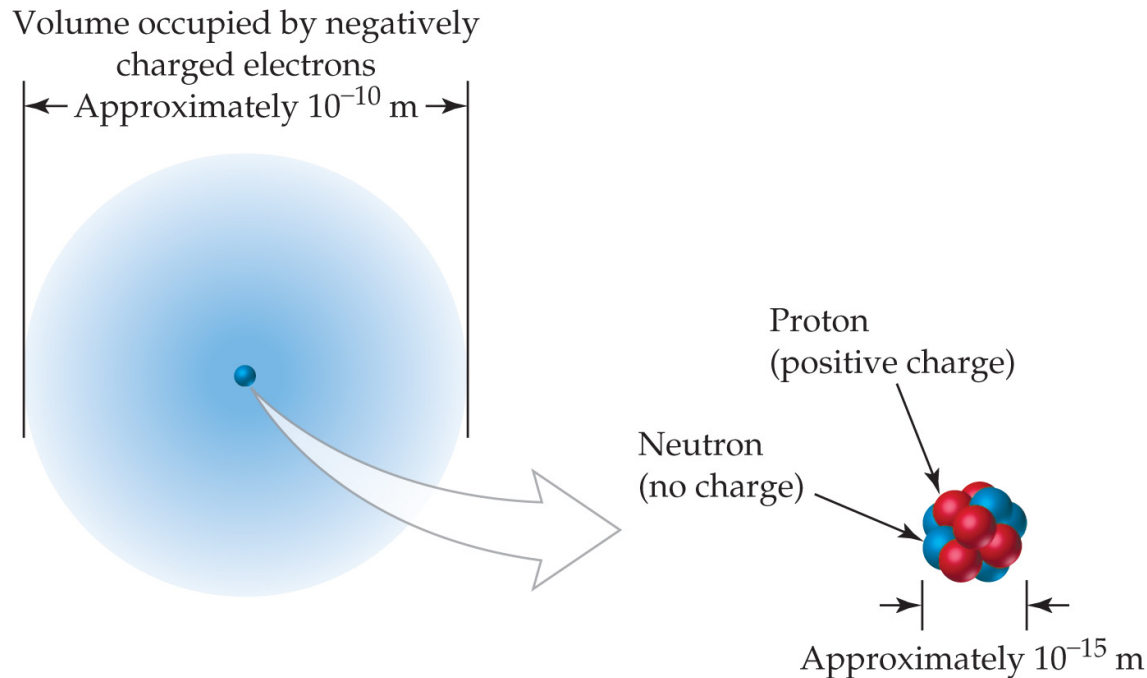
The Nuclear Atom

- *Protons*: Found in the nucleus; has positive charge equal in magnitude to the electron's negative charge.
- *Neutrons*: Found in the nucleus; no charge; virtually same mass as a proton.
- *Electrons*: Found outside the nucleus, relatively far from the nucleus; negatively charged.

Modern Atomic Theory

Modern Atomic Theory

Modern View of Atomic Structure



- Small, dense nucleus (nucleus diameter $\sim 10^{-15}$ m). **Nucleus accounts for almost all of atom's mass.**
- Electron moving far from nucleus (atom diameter $\sim 10^{-10}$ m). **Electron accounts for atom's size.**

Modern View of Atomic Structure

TABLE 4.1 Subatomic Particles

	Mass (kg)	Mass (amu)	Charge
proton	1.67262×10^{-27}	1.0073	1+
neutron	1.67493×10^{-27}	1.0087	0
electron	0.00091×10^{-27}	0.00055	1-

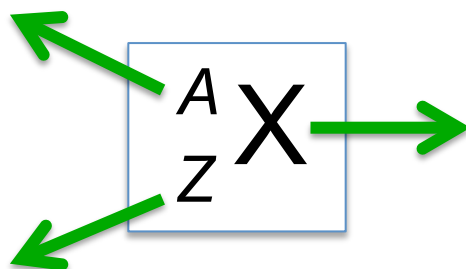
Symbols for Atoms (Isotope Symbols)

Mass Number

(number of protons +
neutrons)

Atomic Number

(number of protons)



Element Symbol

unique one- or
two-letter symbol

No. of protons = atomic number Z = IDENTIFIES

ELEMENT!

No. of neutrons = Mass number A – Atomic number Z

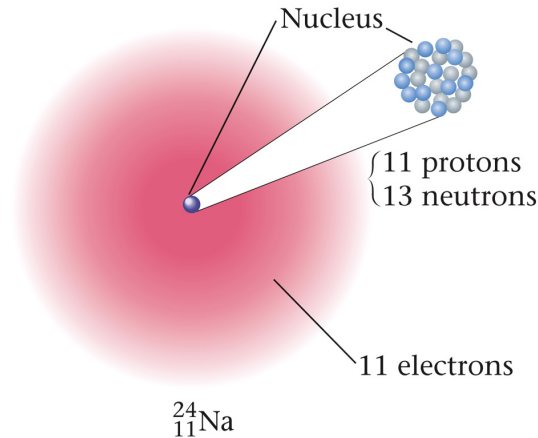
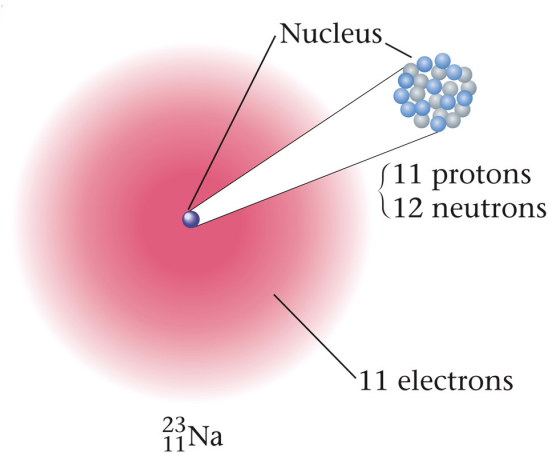
No. of electrons = No. of protons (since atoms are neutral)

Isotopes

Isotopes: Atoms with same number of protons, but different numbers of neutrons

→ So, isotopes have same atomic number (same element), but different mass numbers

Sodium Isotopes



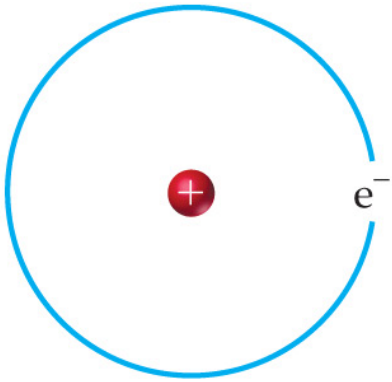
“Sodium-23” ${}^{23}_{11}\text{Na}$

- 11 = Atomic number Z (11 protons)
- 23 = Mass number A
- $A - Z = 12$ neutrons

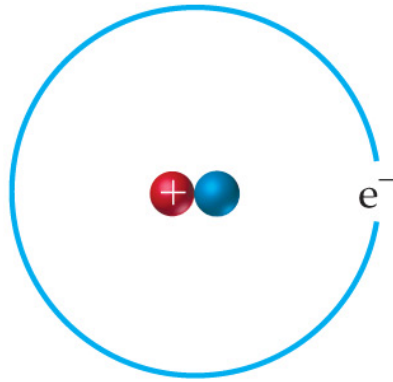
“Sodium-24” ${}^{24}_{11}\text{Na}$

- 11 = Atomic number Z (11 protons)
- 24 = Mass number A
- $A - Z = 13$ neutrons

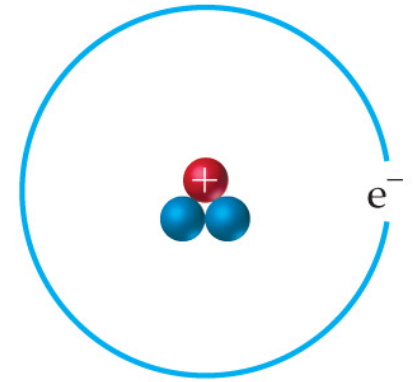
Hydrogen Isotopes



${}^1_1\text{H}$ Protium



${}^2_1\text{H}$ Deuterium



${}^3_1\text{H}$ Tritium

Isotopes

- Show almost identical chemical properties (The chemistry of atom is due to its electrons!).
- In nature, most elements contain mixture of isotopes.

Carbon Isotope	Natural Abundance
^{12}C	98.89%
^{13}C	1.11%

Atomic Mass

- Atoms have very tiny masses, so scientists made a unit for atomic mass to avoid using very small numbers.

$$1 \text{ atomic mass unit (amu)} = 1.660539 \times 10^{-24} \text{ g}$$

Atomic Mass Unit

- Definition of atomic mass unit is based on ^{12}C :

One atom of ^{12}C has a mass of exactly 12 amu.

So, 1 amu = $1/12$ the mass of ^{12}C atom

$$= 1.660539 \times 10^{-24} \text{ g}$$

- Masses of all other atoms are relative to this ^{12}C standard.

Atomic Mass

- On the periodic table, why does C have a mass of 12.01 amu, NOT 12 amu?

The atomic mass on the periodic table is an average atomic mass— weighted average of masses of all the isotopes of an element.

Finding Atomic Mass of an Element

Carbon Isotope	Natural Abundance
^{12}C	98.89%
^{13}C	1.11%

Atomic weight of element =
 $\Sigma[\text{fractional abundance}_i \times \text{isotopic mass}_i]$

For C: $(0.9889)(12\text{amu}) + (0.01110)(13.0034 \text{ amu}) =$
12.01 amu

(*No carbon atom actually has a mass of 12.01 amu– it's an average mass.)

Ex probs

ions

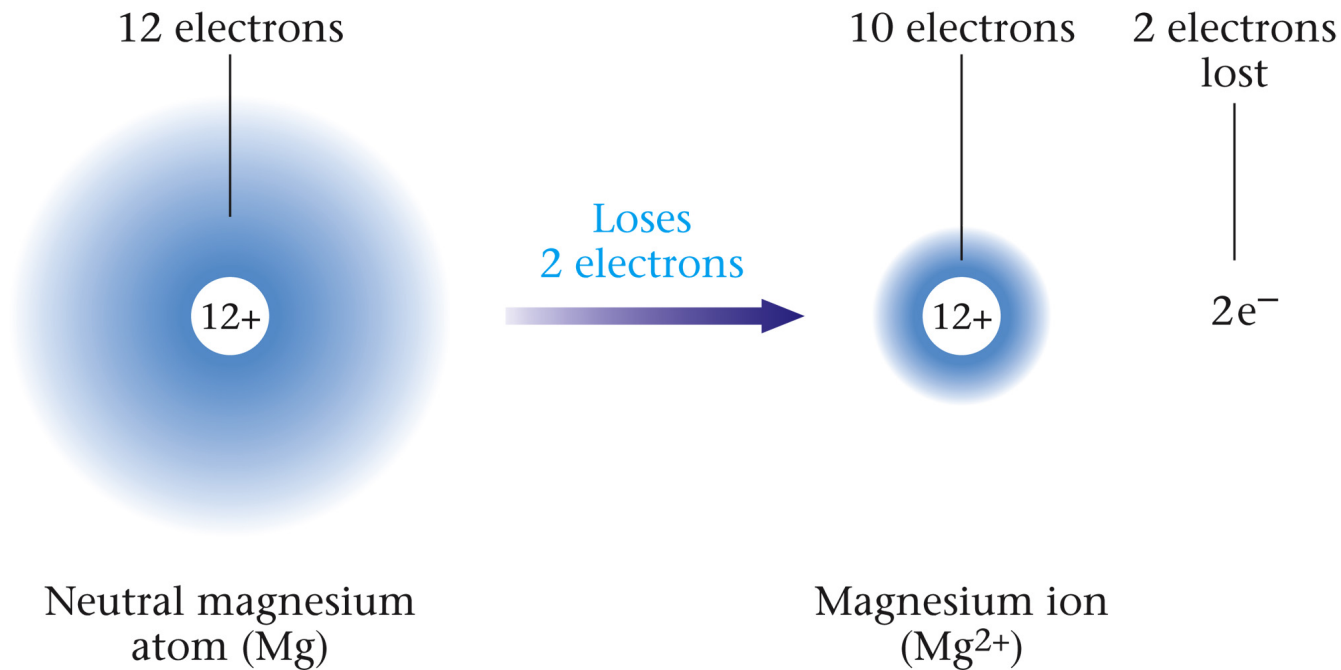
ions

Ions

- Atoms are neutral, having a net charge of zero.
- When electrons are removed from or added to a neutral atom, a charged particle called **ion** is formed.

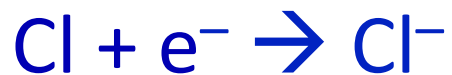
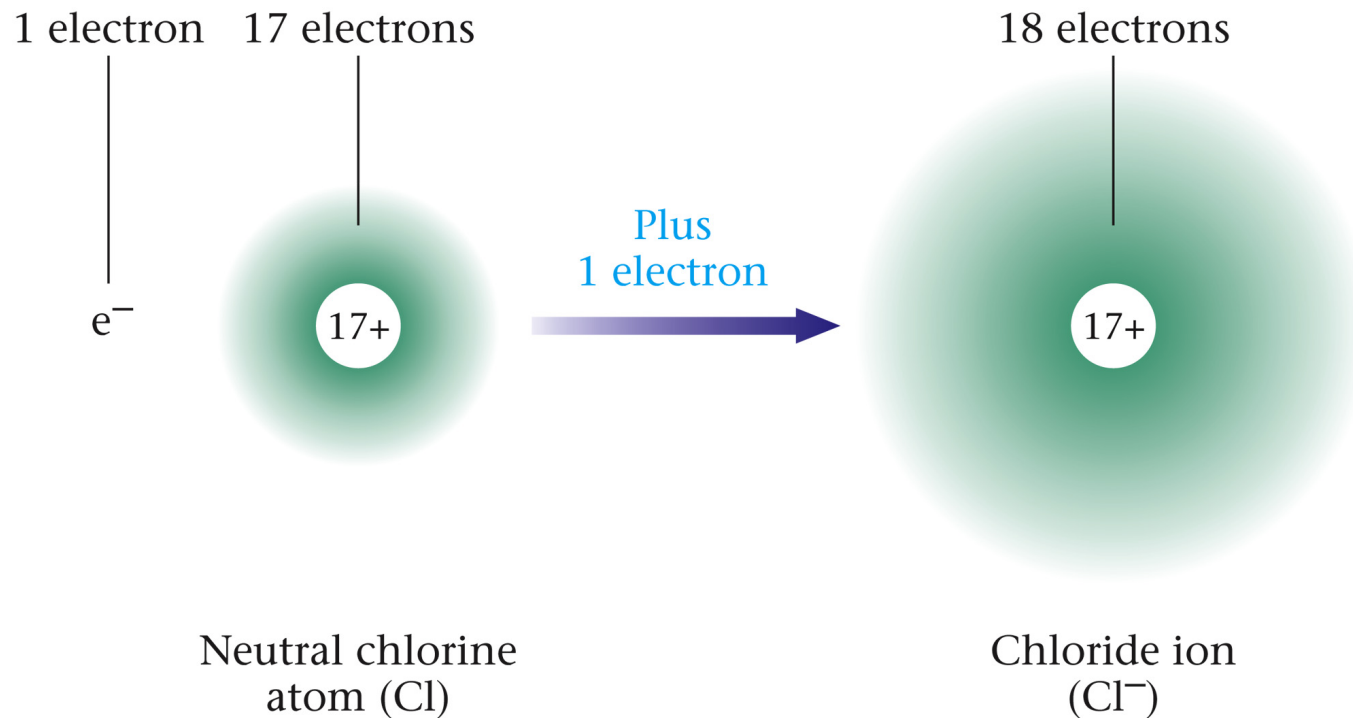
Cations

- Atoms lose one or more electrons to form **positive** ions called **cations**.



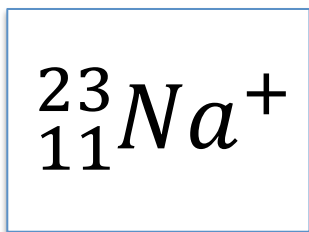
Anions

- Atoms gain one or more electrons to form **negative** ions called **anions**.



Isotope Symbols for Ions

- Ions can also be represented by isotope symbols.



Elements and the Periodic Table

Elements and the Periodic Table

Periodic Table

- A way of organizing elements
- First arranged by Dmitri Mendeleev in 1869
- Modern periodic table is arranged by atomic number.
- Shows recurring properties, so helps predict properties of elements

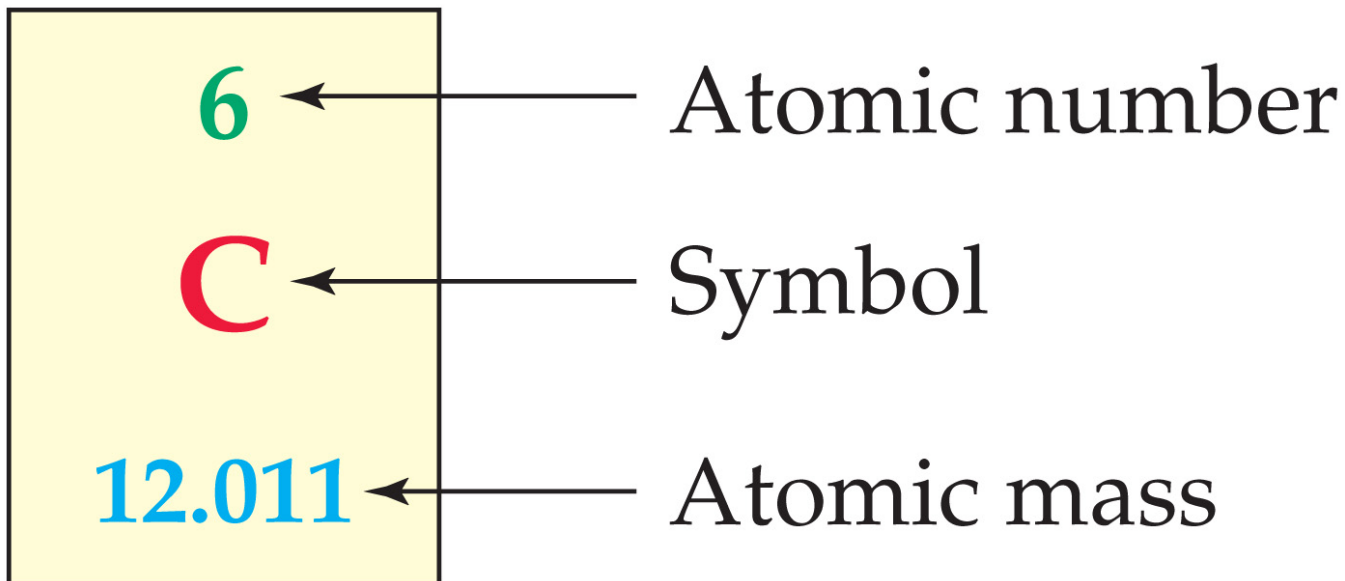
The properties (colors) of these elements form a repeating pattern.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca

The Periodic Table of the Elements

		Metals										Nonmetals					Metalloids		
		Metals										Nonmetals					Metalloids		
1A	1											3A	4A	5A	6A	7A	8A		
	1	2A											13	14	15	16	17	18	
1	1	2											5	6	7	8	9	10	
	H	He											B	C	N	O	F	Ne	
2	3	4											13	14	15	16	17	18	
	Li	Be											Al	Si	P	S	Cl	Ar	
3	11	12	3B	4B	5B	6B	7B	8B		1B	2B	13	14	15	16	17	18		
	Na	Mg	3	4	5	6	7	8	9	10	11	12	Al	Si	P	S	Cl	Ar	
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
6	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
7	87	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	
	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	
			Lanthanides																
			58	59	60	61	62	63	64	65	66	67	68	69	70	71			
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu			
			Actinides																
			90	91	92	93	94	95	96	97	98	99	100	101	102	103			
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr			

Periodic Table Entries



Element Symbols

- Each element has a unique one- or two-letter symbol.
- First letter is always capitalized and the second is not.
- The symbol usually consists of the first one or two letters of the element's name.

Oxygen O

Krypton Kr

- Sometimes the symbol is taken from the element's original Latin or Greek name.

Gold Au (aurum)
Lead Pb (plumbum)

Names and Symbols of Common Elements

Table 4.3 The Names and Symbols of the Most Common Elements

Element	Symbol	Element	Symbol
aluminum	Al	lithium	Li
antimony (stibium)*	Sb	magnesium	Mg
argon	Ar	manganese	Mn
arsenic	As	mercury (hydrargyrum)	Hg
barium	Ba	neon	Ne
bismuth	Bi	nickel	Ni
boron	B	nitrogen	N
bromine	Br	oxygen	O
cadmium	Cd	phosphorus	P
calcium	Ca	platinum	Pt
carbon	C	potassium (kalium)	K
chlorine	Cl	radium	Ra
chromium	Cr	silicon	Si
cobalt	Co	silver (argentium)	Ag
copper (cuprum)	Cu	sodium (natrium)	Na
fluorine	F	strontium	Sr
gold (aurum)	Au	sulfur	S
helium	He	tin (stannum)	Sn
hydrogen	H	titanium	Ti
iodine	I	tungsten (wolfram)	W
iron (ferrum)	Fe	uranium	U
lead (plumbum)	Pb	zinc	Zn

*Where appropriate, the original name is shown in parentheses so that you can see where some of the symbols came from.

Periodic Table

		Main-group elements		Transition elements										Main-group elements						
		Group number																		
		1A	2A											3A	4A	5A	6A	7A	8A	
1		1 H																		2 He
2		3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3		11 Na	12 Mg	3B	4B	5B	6B	7B	8B		1B	2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar		
4		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	
5		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	
6		55 Cs	56 Ba	57 La	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	
7		87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og	

Periodic Table

Alkali metals

Alkaline earth metals

Noble gases

Halogens

Group numbers

Transition metals

Lanthanides

Actinides

1A	2A	Transition metals										3A	4A	5A	6A	7A	8A																											
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	57 La	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	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og																											
		<table border="1"> <tbody> <tr> <td>58 Ce</td> <td>59 Pr</td> <td>60 Nd</td> <td>61 Pm</td> <td>62 Sm</td> <td>63 Eu</td> <td>64 Gd</td> <td>65 Tb</td> <td>66 Dy</td> <td>67 Ho</td> <td>68 Er</td> <td>69 Tm</td> <td>70 Yb</td> <td>71 Lu</td> </tr> <tr> <td>90 Th</td> <td>91 Pa</td> <td>92 U</td> <td>93 Np</td> <td>94 Pu</td> <td>95 Am</td> <td>96 Cm</td> <td>97 Bk</td> <td>98 Cf</td> <td>99 Es</td> <td>100 Fm</td> <td>101 Md</td> <td>102 No</td> <td>103 Lr</td> </tr> </tbody> </table>															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	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
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																															
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																															

Features of the Periodic Table

- Row = Period
 - Numbering of periods (7 periods)
 - Some periods are named: Lanthanides, Actinides

Features of the Periodic Table, cont'd

- Column = Group = Family
 - Numbering of groups (18 groups, A and B groups)
 - Names of groups:
 - A groups = Main Group elements
 - B groups = Transition Metal elements
 - 1A = alkali metals
 - 2A = alkaline earth metals
 - 7A = halogens
 - 8A = noble gases


Periodic Table Shows Periodic Patterns

Members of same groups have similar chemical and physical properties.

- **Group 1A (alkali metals)**: Shiny soft metals, low melt pts, react rapidly with water to form alkaline (basic) products.
- **Group 2A (alkaline earth metals)**: Shiny metals, less reactive than 1A metals.
- **Group 7A (halogens)**: Colorful, corrosive nonmetals.
- **Group 8A (noble gases)**: Colorless gases, distinct lack of chemical reactivity.

Metals, Nonmetals, and Metalloids

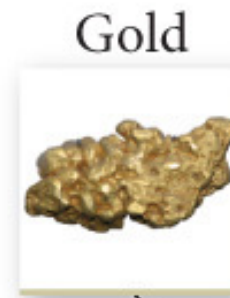
- Metals: Left of stair-step line
- Nonmetals: Right of stair-step line
- Metalloids/ semimetals: Along stair-step line

	1A 1	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	8A 18	
1	1 H																		
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na	12 Mg	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8 9 10		1B 11	2B 12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar		
4	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	
5	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	
6	55 Cs	56 Ba	57 La	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	
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og	
																			
Lanthanides			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			
Actinides			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			

Metal Elements

Physical Properties of Metals

- Efficiently conducts heat and electricity
- Malleable (can be hammered into thin sheets)
- Ductile (can be pulled into wires)
- Lustrous (shiny)
- Almost all metals are solids at normal temperatures (Exception: Mercury is liquid.)



Nonmetal Elements

Physical Properties of Nonmetals

- Do not conduct electricity.
- More variable than metals.
- Solid nonmetals are usually hard, brittle.
- Most nonmetals are gases or solids [Exception: Bromine is liquid.]

Carbon



Sulfur



Iodine



Bromine



Metalloid or Semimetal Elements

Physical Properties of Metalloids

- Have both metallic and nonmetallic properties.
- Good semiconductors: Poor conductors of electricity at room temperature, but become moderately good conductors at higher temperature or with addition of impurities

Silicon



Arsenic



Periodic Table Shows Ion Formation Trend

In a chemical reaction:

- Metal elements tend to lose electrons and form cations (positive ions).
- Nonmetal elements tend to gain electrons and form anions (negative ions).

Common Ion Charges (Know!)

1A	2A							3A	4A	5A	6A	7A	8A	
Li ⁺										N ³⁻	O ²⁻	F ⁻		
Na ⁺	Mg ²⁺							Al ³⁺			S ²⁻	Cl ⁻		
K ⁺	Ca ²⁺			Cr ²⁺	Mn ²⁺	Fe ²⁺	Co ²⁺		Cu ⁺	Zn ²⁺	Ga ³⁺		Br ⁻	
				Cr ³⁺	Mn ³⁺	Fe ³⁺	Co ³⁺		Cu ²⁺					
Rb ⁺	Sr ²⁺								Ag ⁺	Cd ²⁺		Sn ²⁺		I ⁻
												Sn ⁴⁺		
Cs ⁺	Ba ²⁺									Hg ₂ ²⁺		Pb ²⁺		
										Hg ²⁺		Pb ⁴⁺		

Metals form cations.

- Groups 1A,2A,3A:
charge = group #
- Transitions metals:
Many have variable charges.

Nonmetals form anions.

- Group 5A: charge = -3
- Group 6A: charge = -2
- Group 7A (halogens):
charge = -1
- Group 8A (noble gases):
charge = 0

Ex Probs

Periodic Table: Natural States of Elements

Most elements are solids at room temperature.

Periodic Table of the Elements
Natural Form

<http://chemistry.about.com>
©2010 Todd Helmenstine
About Chemistry

Solid Liquid Gas

1A												3A						4A	5A	6A	7A	8A						
1 H ₂ GAS												5 B RHOM	6 C HEX	7 N GAS	8 O GAS	9 F GAS	10 Ne GAS									2 He GAS		
3 Li BCC	4 Be HEX											13 Al FCC	14 Si FCC	15 P CUBIC	16 S ORTHO	17 Cl GAS	18 Ar GAS											
11 Na BCC	12 Mg HEX	3B	4B	5B	6B	7B	8B		1B	2B	19 K BCC	20 Ca FCC	21 Sc HEX	22 Ti HEX	23 V BCC	24 Cr BCC	25 Mn BCC	26 Fe BCC	27 Co HEX	28 Ni FCC	29 Cu FCC	30 Zn HEX	31 Ga ORTHO	32 Ge FCC	33 As RHOM	34 Se HEX	35 Br LIQUID	36 Kr GAS
37 Rb BCC	38 Sr FCC	39 Y HEX	40 Zr HEX	41 Nb BCC	42 Mo BCC	43 Tc HEX	44 Ru HEX	45 Rh FCC	46 Pd FCC	47 Ag FCC	48 Cd HEX	49 In TETRA	50 Sn TETRA	51 Sb RHOM	52 Te HEX	53 I ORTHO	54 Xe GAS											
55 Cs BCC	56 Ba BCC	57-71 Lanthanides	72 Hf HEX	73 Ta BCC	74 W BCC	75 Re HEX	76 Os HEX	77 Ir FCC	78 Pt FCC	79 Au FCC	80 Hg LIQUID	81 Tl HEX	82 Pb FCC	83 Bi RHOM	84 Po CUBIC	85 At UNK	86 Rn GAS											
87 Fr UNK	88 Ra BCC	89-103 Actinides																										

*** Elements > 104 exist only for very short half-lives and the data is unknown.***

Lanthanides	57 La HEX	58 Ce FCC	59 Pr HEX	60 Nd HEX	61 Pm HEX	62 Sm RHOM	63 Eu BCC	64 Gd HEX	65 Tb HEX	66 Dy HEX	67 Ho HEX	68 Er HEX	69 Tm HEX	70 Yb FCC	71 Lu HEX
Actinides	89 Ac FCC	90 Th FCC	91 Pa TETRA	92 U ORTHO	93 Np ORTHO	94 Pu MONO	95 Am HEX	96 Cm HEX	97 Bk HEX	98 Cf HEX	99 Es HEX	100 Fm UNK	101 Md UNK	102 No UNK	103 Lr UNK

Most stable crystalline structure of solids

CUBIC	Simple Cubic	FCC	Face Centered Cubic	ORTHO	Orthorhombic	TETRA	Tetragonal	UNK	Unknown
BCC	Body Centered Cubic	HEX	Hexagonal	RHOM	Rhombohedral	MONO	Monoclinic		

Periodic Table: Natural States of Elements

Some elements exist as diatomic molecules (molecules of two atoms): H_2 , N_2 , O_2 , all group 7A elements

The periodic table below shows the natural states of elements. Elements that exist as diatomic molecules are highlighted in light blue: Hydrogen (H), Nitrogen (N), Oxygen (O), and the elements of Group 7A (Fluorine (F), Chlorine (Cl), Bromine (Br), and Iodine (I)).

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	57 La	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	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo	
			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		
			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		

Hydrogen

- In natural state, hydrogen is a nonmetal (It is NOT an alkali metal).
- In natural state, hydrogen is a diatomic element.
- Hydrogen can form cation (H^+ = proton) or anion (H^- = hydride).
- A hydrogen atom does not have a neutron!

Expanded Periodic Table of the Elements

1	1 H																	2 He														
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne														
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar														
4	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				
5	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				
6	55 Cs	56 Ba	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	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
7	87 Fr	88 Ra	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	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

Alkali metals	Alkaline earth metals	Lanthanides	Actinides	Transition metals
Poor metals	Metalloids	Nonmetals	Halogens	Noble gases