

Periodic Table

Lecture 1



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PERIODIC TABLE –BASIC TOOLBOX OF EVERY CHEMIST

Periodic Table of the Elements

6
C
Carbon
12.01

→ Atomic number
 → Element symbol
 → Element name
 → Atomic mass

1 H Hydrogen 1.008	2 He Helium 4.003																
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.293
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	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 [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]
Lanthanide Series			57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
Actinide Series			89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]
			Alkali Metal	Alkaline Earth	Transition Metal	Basic Metal	Metalloid	Nonmetal	Halogen	Noble Gas	Lanthanide	Actinide					



organize and display the elements in a way that provides information about their characteristics

WHY DO WE NEED A PERIODIC TABLE?

- Organized to provide a great deal of information about elements and how they relate to one another
- Elements within a specific group have similar chemical properties
- Provides information on relative size, ionization energy, electron affinity, electronegativity

OME related questions:

Why NH_3 is stable and NCl_3 is not

Why is nitrogen used in explosives?

Why is glycerin not explosive but nitroglycerine is?

Why carbon can form only four bonds in high-energy materials?

Why white phosphorus is more reactive than red?



<https://youtu.be/kqe9tEcZkno>

Braving the Elements

An Introduction to
the Periodic Table

by Dr Peter Wothers
Department of Chemistry
University of Cambridge



FEW DEFINITIONS AS REMINDER

- An **element** is a substance that cannot be broken down into any other substance



There are 92 elements occurring naturally on Earth

Elements formed in the process of fusion of He and H

Every element is made up of its own type of **atom** therefore the chemical elements are all very different from each other.

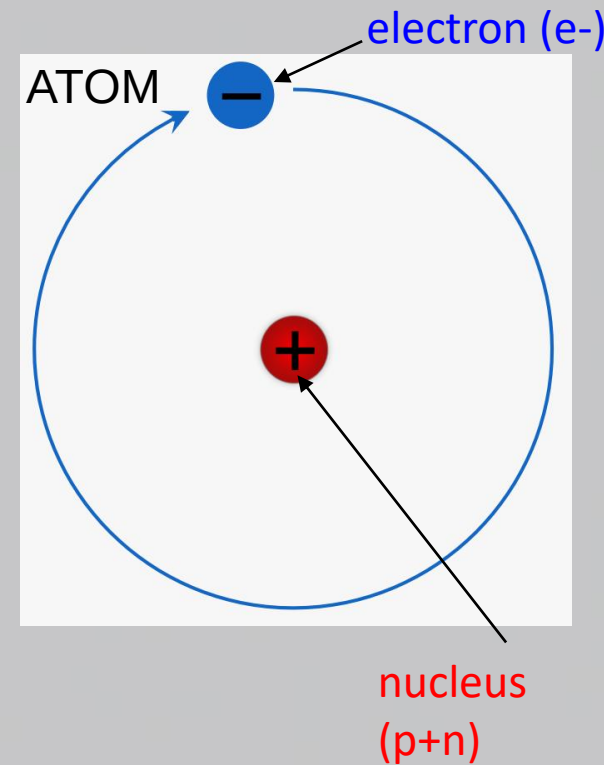
Atoms of the same element have the same size, mass, and other properties

Atoms of different elements differ in size, mass, and other properties



FEW DEFINITIONS AS REMINDER

- an **atom** the smallest part of an element that can ever exist
- the **subatomic particles**: proton, neutron (in nucleus), electron
- Atoms of a given element have the same mass
- Elements are arranged in a periodic table according to their number of protons



- The **periodic table** lists all the known elements and groups together those with similar properties.



PERIODIC TABLE HALL OF FAME



John Dalton discovered that elements consisted of atoms.
He also realised that atoms of the different elements had different masses

Johann Wolfgang Dobereiner noticed that groups of elements (TRIADS) were similar (1829).

Lithium, sodium, and potassium have similar properties and equally spaced masses 7, 23 and 39.



John Newlands ordered atoms in order of atomic masses in rows of 8
This was to fit in with Dobereiner's triads
The problem was that the pattern only fitted for the first 15 elements

Copper in the same group as sodium !!?

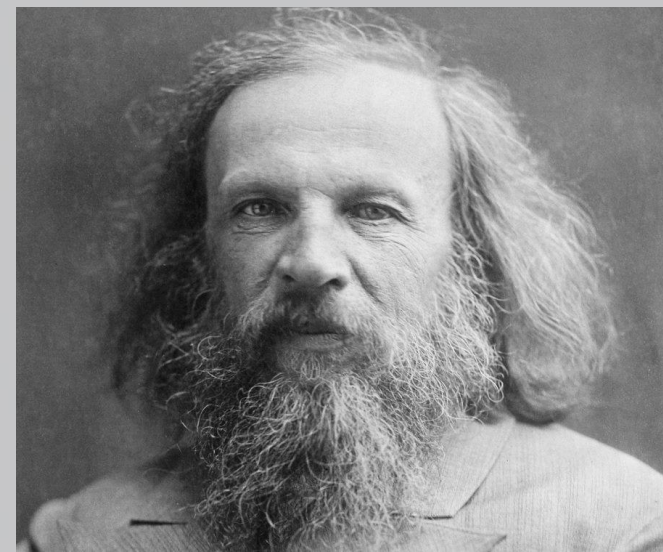
HALL OF FAME – Dmitri MENDELEEV

Periodic Table Oscar Winner

Decided to ignore the elements that did not fit

He recognised that some elements might not have been discovered

He was vindicated by the discovery of Germanium in 1885



1834-1907

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



Can you work out which elements are missing?



	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VII
Period 1	H							
Period 2	Li	Be	B	C	N	O	F	
Period 3	Na	Mg	Al	Si	P	S	Cl	
Period 4	K Cu	Ca Zn	* *	Ti *	V As	Cr Se	Mn Br	Fe Co Ni
Period 5	Rb Ag	Sr Cd	Y In	Zr Sn	Nb Sb	Mo Te	* I	Ru Rh Pd

Sc

Ga

Ge

Tc



HALL OF FAME – Henry MOSELEY



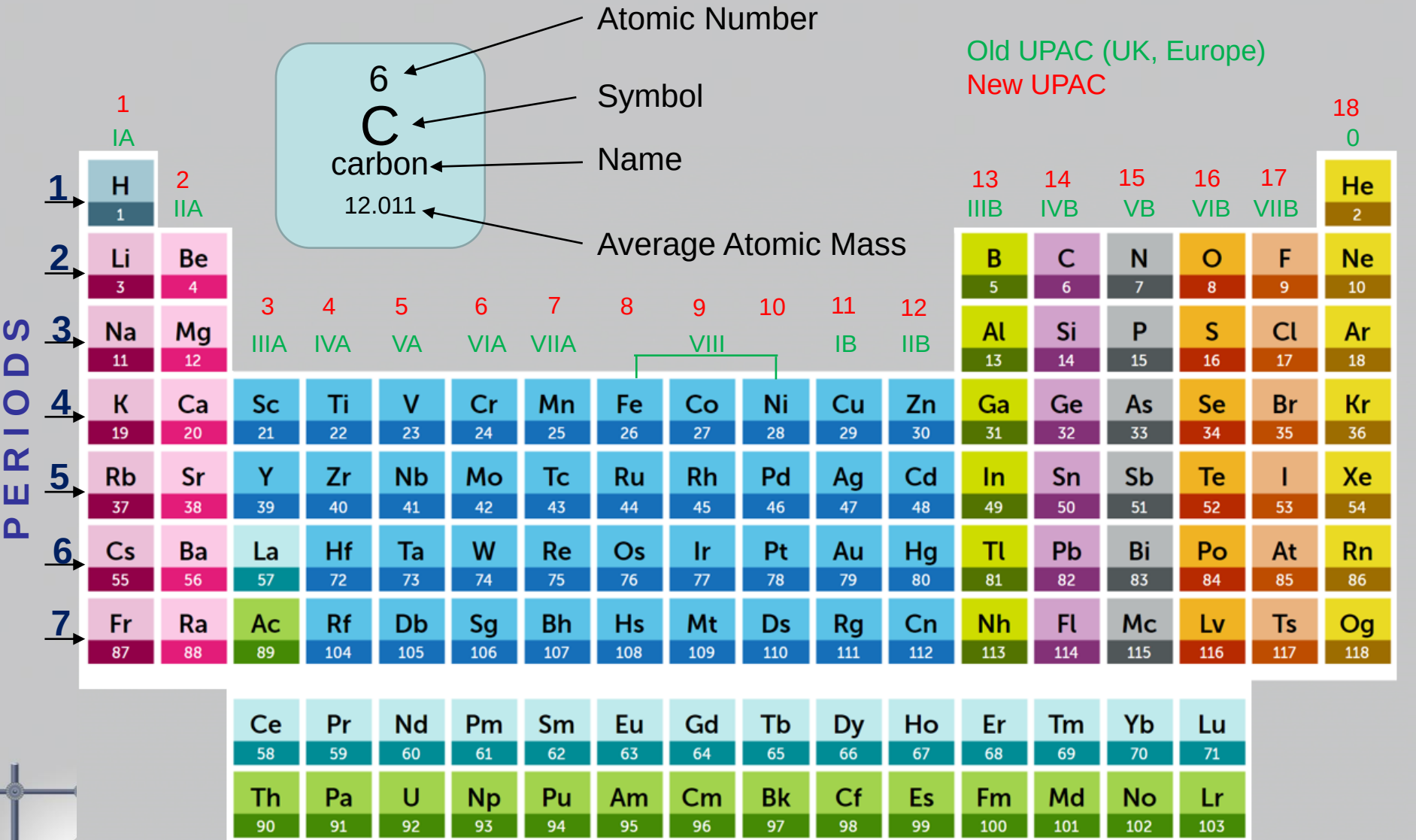
There was still the problem of ignoring some of the elements

Moseley solved this when he used X-ray studies to work out the number of electrons in the atom

By arranging elements in order of the number of electrons the modern Periodic Table dropped out.



STRUCTURE OF PERIODIC TABLE



NAMES of GROUPS

										Nitrogen group		Halogens		Noble gases			
										Carbon group		Oxygen group					
										Boron group							
H 1										B 5	C 6	N 7	O 8	F 9	He 2		
Li 3	Be 4										Al 13	Si 14	P 15	S 16	Cl 17	Ar 18	
Na 11	Mg 12	Transition metals										Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Nh 113	Fl 114	Mc 115	Lv 116	Ts 117	Og 118
Fr 87	Ra 88	Ac 89	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Ds 110	Rg 111	Cn 112						

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

Lanthanides
Actinides



PERIODIC PROPERTIES: GROUP 1

Group 1 elements: Li, Na, K, Rb, Cs, Fr

Reaction with water



<https://youtu.be/6ZY6d6jrq-0>

Flame test



https://youtu.be/MGUPKA_pOEE



PERIODIC PROPERTIES: GROUP 17 (VIIB)

Similar properties of HALOGENS



Chlorine

Bromine

Iodine

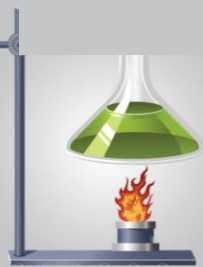
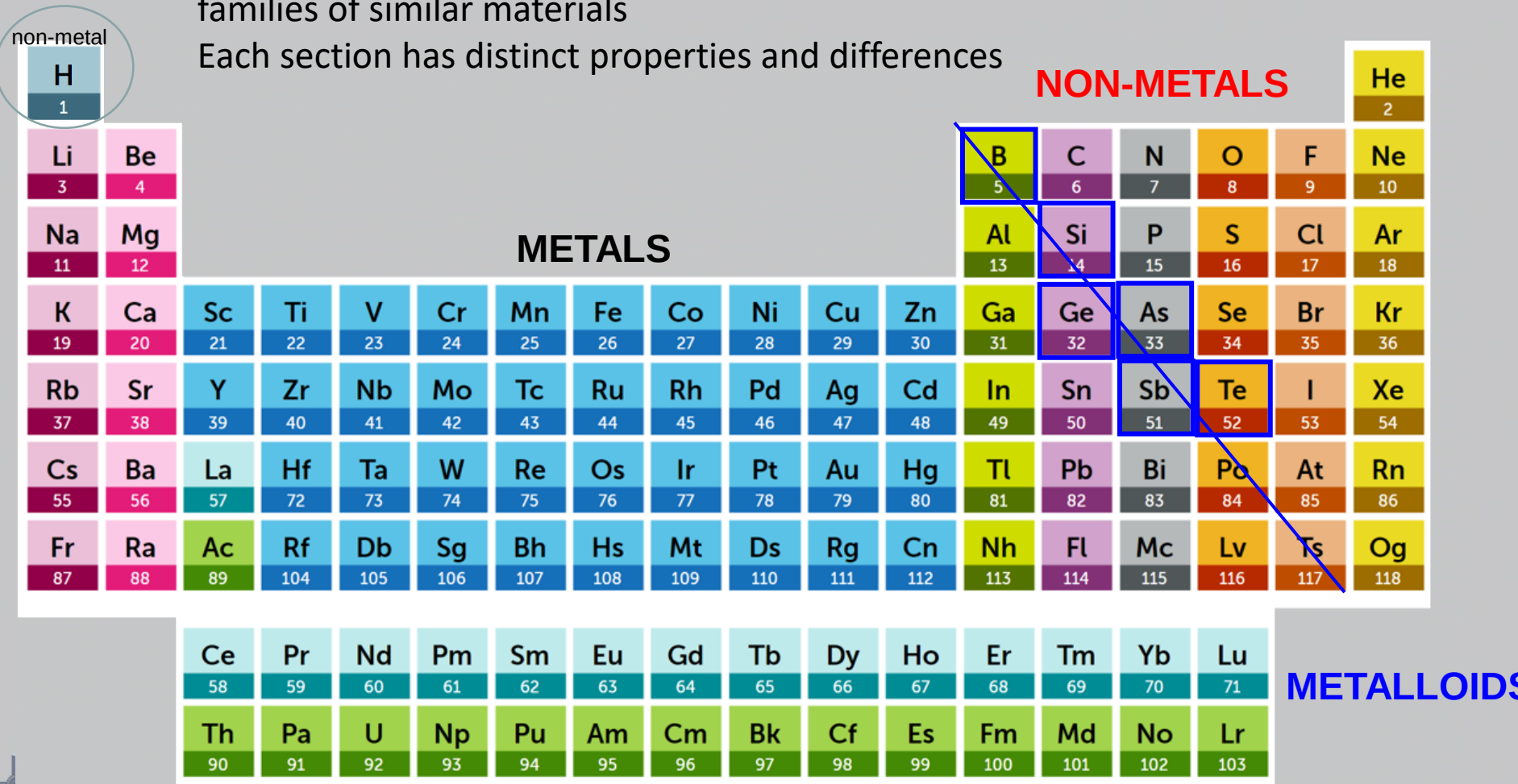
- halogens contain elements in all three states of matter (solid, liquid, and gas) at standard temperature and pressure
- diatomic molecules, non-metals
- very strong oxidizing agents



METALS, NON-METALS, METALLOIDS

A simple classification that splits the periodic table into families of similar materials

Each section has distinct properties and differences



METALS, NON-METALS, METALLOIDS

Metals:

- Lustrous solids
- High melting points
- Conduct electricity
- Malleable and ductile
- Act as reducing agents in reactions

Metalloids:

- Solids
- Giant molecular structures
- High melting points
- Semiconductors (Silicon)

Non-Metals:

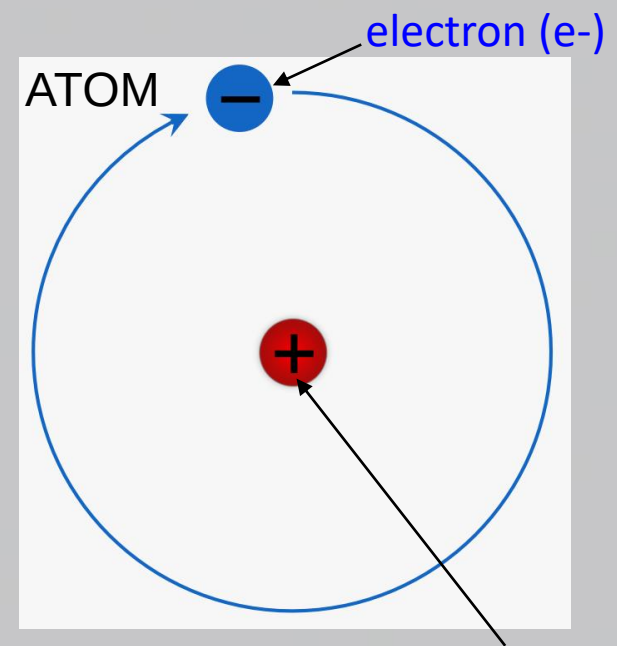
- Poor structural materials
- Low melting points
- Often gases or liquids
- Non conductors
- Discrete molecular structures
- Often act as oxidising agents (oxygen)



WHAT IS IN THE ATOM?

Subatomic particles:

proton	mass = 1	charge = +1
neutron	mass = 1	charge = 0
electron	mass = 0	charge = -1



Atomic Number **Z** **DEFINES ATOM TYPE**

Symbol

Name

Average Atomic Mass

17
Cl
chlorine
35.453

Number of protons = atomic number (**Z**) = number of electrons

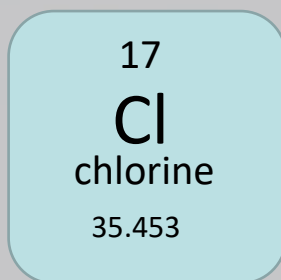
Mass of atom = mass number = number of protons + number of neutrons

$$A = Z + n$$



ISOTOPES

- two or more types of atoms that have the **same atomic number** (number of protons) and **same number of electrons (Z)** but **different numbers of neutrons** in their nuclei
- all isotopes of a given element have almost the same chemical properties but they have different atomic masses and physical properties



Two stable isotopes :

one with 18 neutrons

one with 20 neutrons

Z = 17

17 protons in every chlorine atom

n = 18

A = Z + n = 17 + 18 = 35

Cl-35 or ^{35}Cl

n = 20

A = Z + n = 17 + 20 = 37

Cl-37 or ^{37}Cl



(AVERAGE) ATOMIC MASS

In a sample of element, all isotopes are present. **So, need average mass**

$$\text{weighted average mass} = \sum (\text{mass of isotope}) \times \text{fraction of atoms of this isotope}$$

~~average mass = total mass $\div$ number of atoms~~

NOT simple average of isotopes

Chlorine: $\frac{3}{4}$ are Cl-35 and $\frac{1}{4}$ are Cl-37

$$\begin{aligned} \text{Average atomic mass} &= \\ &= (35)(0.75) + (37)(0.25) = 35.5 \end{aligned}$$



SUMMARY

- Elements of the same kind are made of the same atoms
- Atoms of a given element have the same mass
- Elements are arranged in a periodic table according to their number of electrons
- Periodic table consists of vertical groups and horizontal periods
- Elements are either metals, non-metals, or metalloids



Practice problem 1:

List the names, chemical symbols, and atomic numbers of the alkali metals. Describe their reaction with water



Practice problem 2:

List the names, chemical symbols, and atomic numbers of the halogens. Identify the normal physical state of each.

