Periodicity

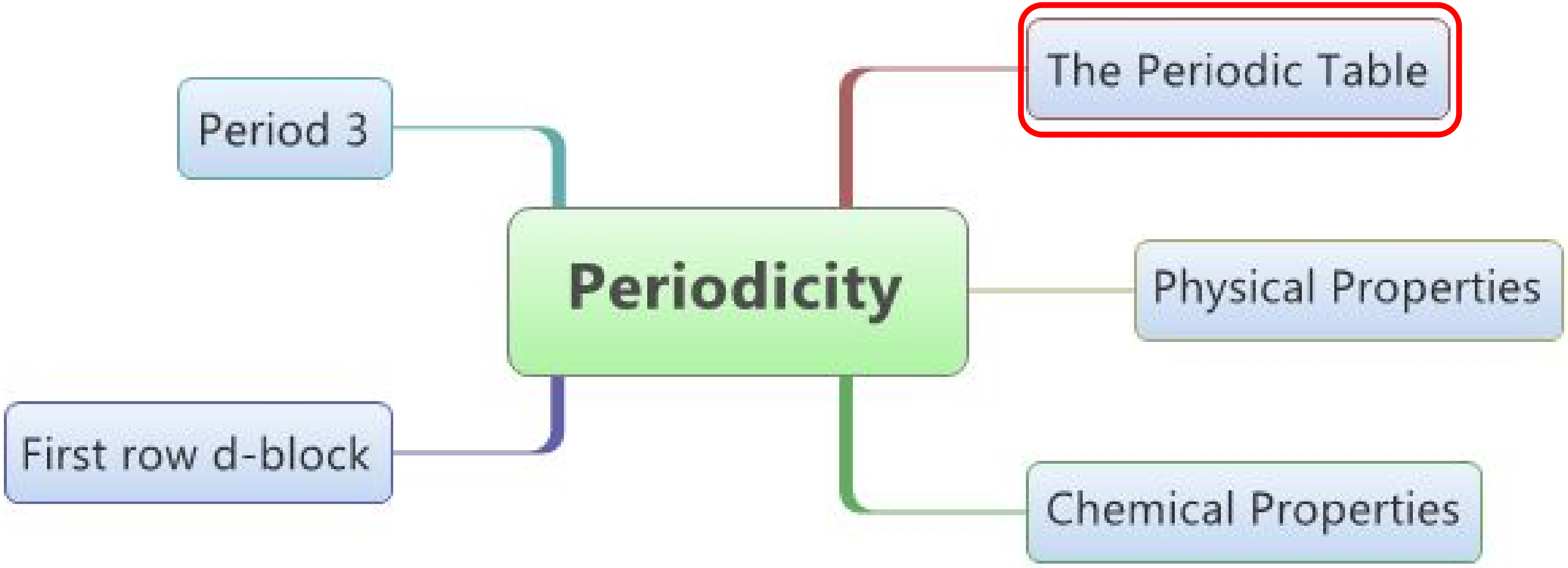
Ms. Peace

Lesson 1

3.1 The Periodic Table

Main

We Are Here



Main

The Development of the Periodic Table

1817

J.W. Döbereiner
Law of Triads-link between atomic weight and different elements in groups of threes

1865

J.A.R. Newlands
Law of Octaves-evidence of a pattern with the properties repeated in in octaves consisting of seven elements

1869

Dimitri Mendelev
The Periodic Law-elements were arranged in order of atomic weight with a repeated pattern of their properties

1913

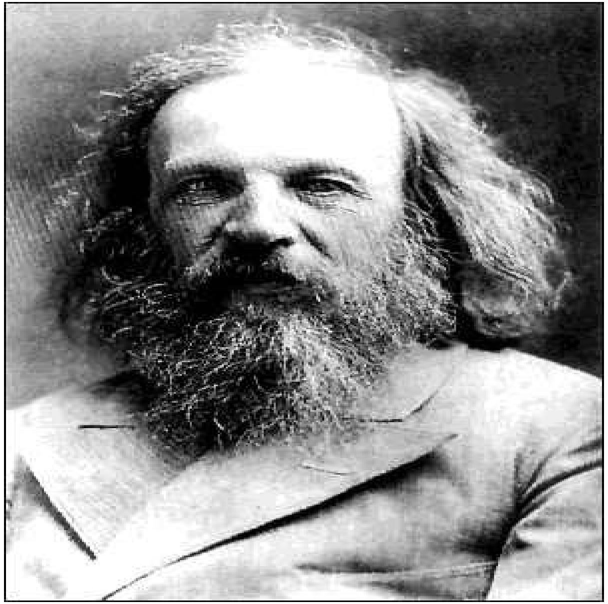
Henry Mosely
The Modern Periodic Law-elements were arranged in order of increasing atomic numbers, properties recurred periodically

Being Mendeleev

- The first widely accepted periodic table was produced by the Russian chemist Dmitri Mendeleev

- It was a tremendous example of scientists as risk-takers as it was able to make a number of predictions thought unlikely at the time

- Mendeleev claims the arrangement of elements came to him in a dream



Dmitri Mendeleev's Periodic Table

The one that started it all off.

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	—	— — — —

The Traditional

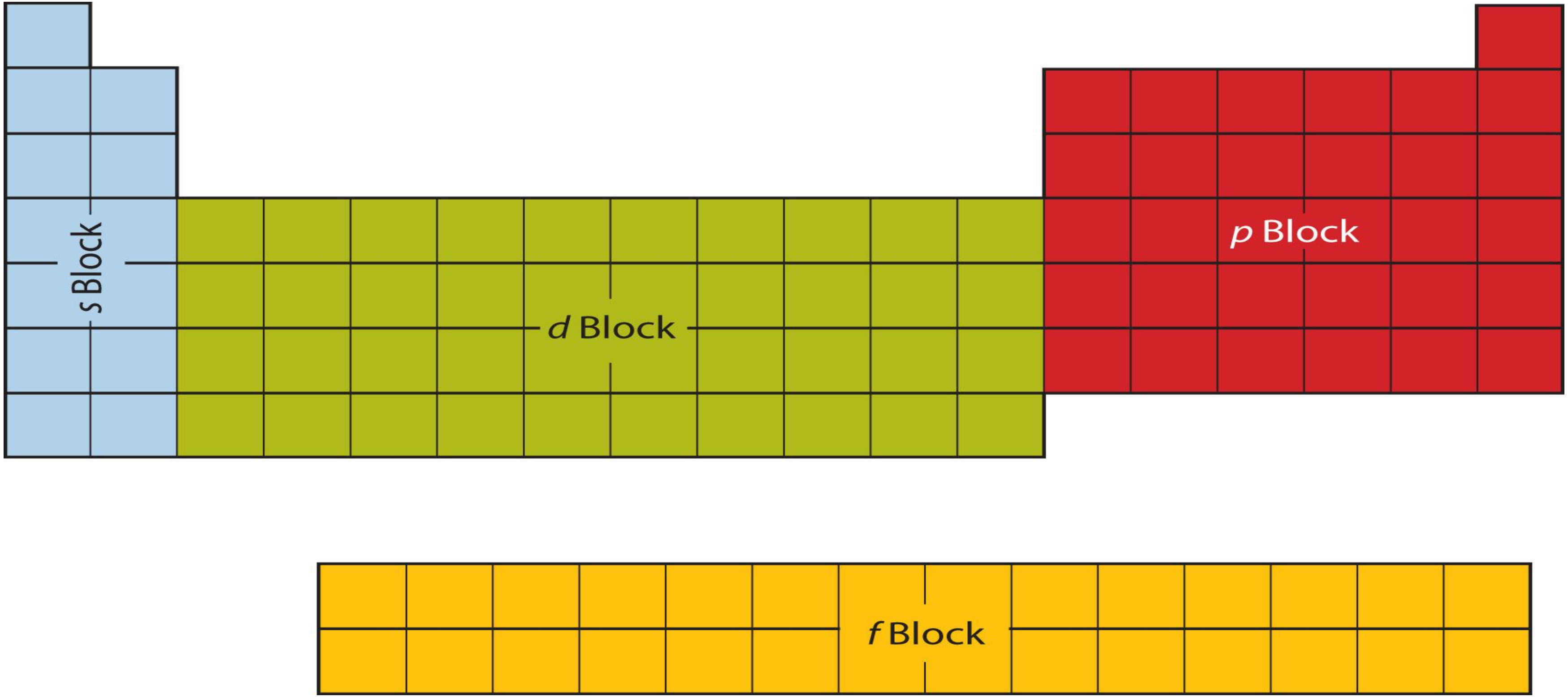
Based on Mendeleev's work. Easiest to use and display.

Atomic number
Element
Relative atomic mass

	1	2											3	4	5	6	7	0
1	1 **H** 1.01																	2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.92	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.74	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.91	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
6	55 **Cs** 132.91	56 **Ba** 137.33	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** 210	85 **At** 209.99	86 **Rn** 222.02
7	87 **Fr** 223.02	88 **Ra** 226.03	89 ‡ **Ac** 227.03	104 **Rf** 260	105 **Db** 262.11	106 **Sg** 266.12	107 **Bh** 264.12	108 **Hs** 269.13	109 **Mt** 268.13									
			†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 144.91	62 **Sm** 150.35	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97	
			‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 239.05	94 **Pu** 239.05	95 **Am** 243.06	96 **Cm** 247.07	97 **Bk** 247.07	98 **Cf** 252.08	99 **Es** 254.09	100 **Fm** 253.09	101 **Md** 257.10	102 **No** 255.09	103 **Lr** 257	

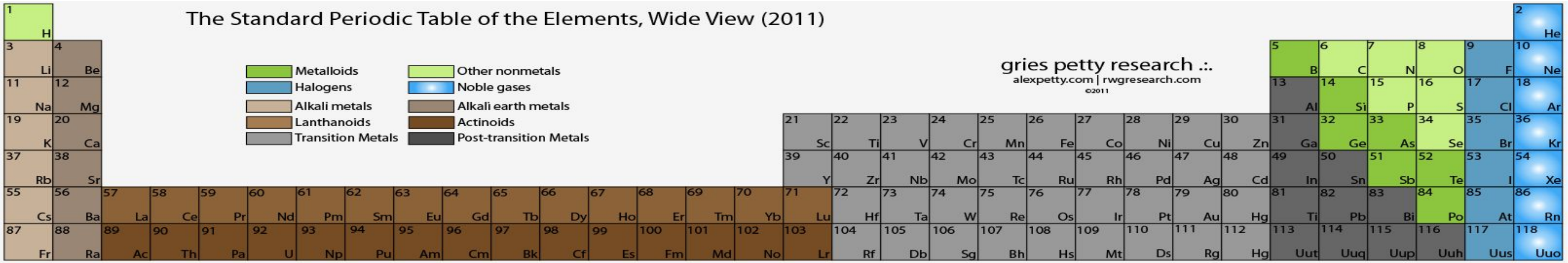
Main

s, p, d, f Blocks



Wide Format Periodic Table

Shows true position of the f-block (lanthanides and actinides)



The Structure of the Periodic Table

Atomic number
Element
Relative atomic mass

GROUPS

PERIODS

	1	2											3	4	5	6	7	0
1																		2 He 4.00
2		4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3		12 Mg 24.31											13 Al 26.92	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
4		20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.55	30 Zn 65.38	31 Ga 69.74	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	36 Kr 83.80
5		38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
6		137.33	138.91	178.49	180.95	183.85	186.21	190.23	192.22	195.09	196.97	200.59	204.37	207.19	208.98	210	209.99	22[illegible].02
7	22[illegible].02	88 Ra 226.03	89 ‡ Ac 227.03	104 Rf 260	105 Db 262.11	106 Sg 266.12	107 Bh 264.12	108 Hs 269.13	109 Mt 268.13									

†	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 144.91	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
‡	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 239.05	94 Pu 239.05	95 Am 243.06	96 Cm 247.07	97 Bk 247.07	98 Cf 252.08	99 Es 254.09	100 Fm 253.09	101 Md 257.10	102 No 255.09	103 Lr 257

Groups and Periods

- Groups
  - Elements show similar chemical properties
  - Elements show similar trends in their chemical properties

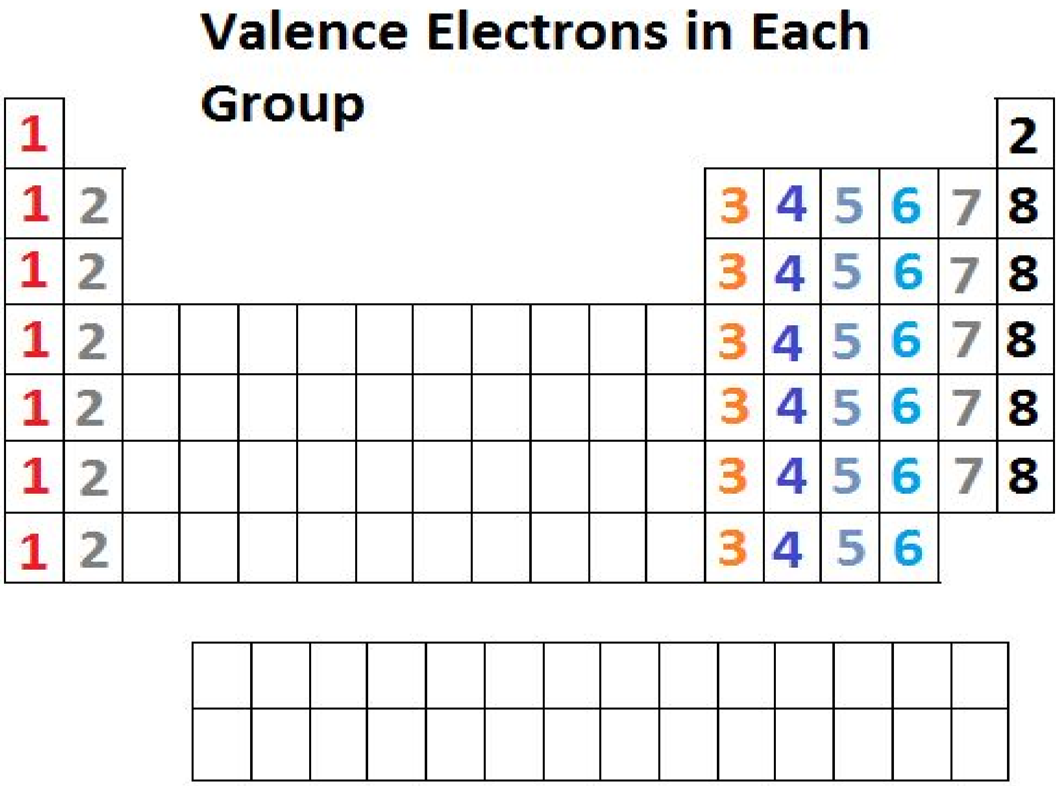
- Periods
  - As you move across periods, changes in the chemical and physical properties that are repeated in the next period
  - This is what ‘period’ and ‘periodic’ refers to

Main

Period Numbers

- The period number (*n*) is the outer energy level that is occupied by electrons

Main



Valence Electrons

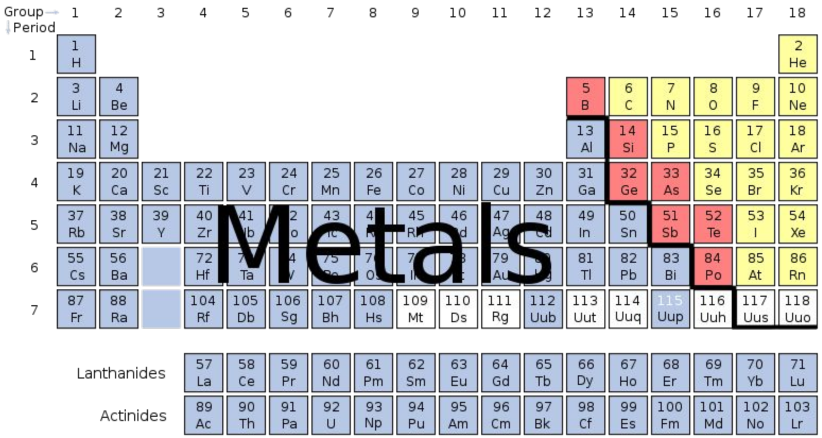
The valence electrons in an atom can be deduced from its position on the periodic table

METALS | METALLOIDS | NONMETALS

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H [1.00784; 1.00811] HYDROGEN																	2 He 4.0026 HELIUM
3 Li [6.938; 6.997] LITHIUM	4 Be 9.0122 BERYLLIUM											5 B [10.806; 10.821] BORON	6 C [12.0096; 12.0116] CARBON	7 N [14.00643; 14.00728] NITROGEN	8 O [15.99903; 15.99977] OXYGEN	9 F 18.998 FLUORINE	10 Ne 20.180 NEON
11 Na 22.990 SODIUM	12 Mg 24.305 MAGNESIUM											13 Al 26.982 ALUMINUM	14 Si [28.084; 28.086] SILICON	15 P 30.974 PHOSPHORUS	16 S [32.059; 32.076] SULFUR	17 Cl [35.446; 35.457] CHLORINE	18 Ar 39.948 ARGON
19 K 39.098 POTASSIUM	20 Ca 40.078 CALCIUM	21 Sc 44.956 SCANDIUM	22 Ti 47.867 TITANIUM	23 V 50.942 VANADIUM	24 Cr 51.996 CHROMIUM	25 Mn 54.938 MANGANESE	26 Fe 55.845 IRON	27 Co 58.933 COBALT	28 Ni 58.693 NICKEL	29 Cu 63.546 COPPER	30 Zn 65.392 ZINC	31 Ga 69.723 GALLIUM	32 Ge 69.723 GERMANIUM	33 As 74.922 ARSENIC	34 Se 78.963 SELENIUM	35 Br 79.904 BROMIUM	36 Kr 83.801 KRYPTON
37 Rb 85.468 RUBIDIUM	38 Sr 87.62 STRONTIUM	39 Y 88.906 YTTRIUM	40 Zr 91.224 ZIRCONIUM	41 Nb 92.906 NIOBIUM	42 Mo 95.94 MOLYBDENUM	43 Tc 97.907 TECHNETIUM	44 Ru 101.07 RUTHENIUM	45 Rh 102.906 RHODIUM	46 Pd 106.42 PALLADIUM	47 Ag 107.868 SILVER	48 Cd 112.411 CADMIUM	49 In 114.818 INDIUM	50 Sn 114.818 TIN	51 Sb 121.760 ANTIMONY	52 Te 127.603 TELLURIUM	53 I 126.904 IODINE	54 Xe 131.292 XENON
55 Cs 132.905 CESIUM	56 Ba 137.327 BARIUM	57-71 La-Lu LANTHANIDES	72 Hf 178.49 HAFNIUM	73 Ta 180.95 TANTALUM	74 W 183.84 TUNGSTEN	75 Re 186.207 RHENIUM	76 Os 190.233 OSMIUM	77 Ir 192.217 IRIDIUM	78 Pt 195.084 PLATINUM	79 Au 196.967 GOLD	80 Hg 200.59 MERCURY	81 Tl [204.382; 204.385] THALLIUM	82 Pb 204.383 LEAD	83 Bi 208.980 BISMUTH	84 Po 208.982 POLONIUM	85 At 209.987 ASTATINE	86 Rn 222.018 RADON
87 Fr 223.020 FRANCIUM	88 Ra 226.0254 RADIUM	89-103 Ac-Lr ACTINIDES	104 Rf 263.113 RUTHERFORDIUM	105 Db 262.114 DUBNIUM	106 Sg 266.122 SEABORGIUM	107 Bh 264.125 BOHRIUM	108 Hs 269.134 HASSIUM	109 Mt 268.139 MEITNERIUM	110 Ds 272.146 DARMSTADTIUM	111 Rg 272.154 ROENTGENIUM	112 Cn 277 COPERNICIUM	113 Uut 284 UNUNTRIUM	114 Uuq 284 UNUNQUADIUM	115 Uup 288 UNUNPENTIUM	116 Uuh 292 UNUNHEXIUM	117 Uus 294 UNUNSEPTIUM	118 Uuo 294 UNUNOCTIUM

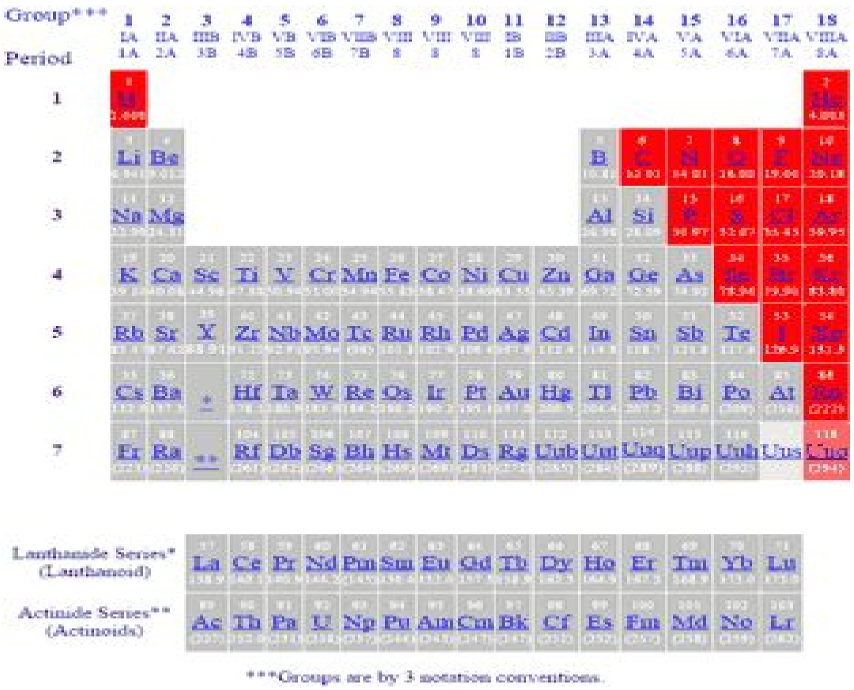
LANTHANIDES	57 La 138.905 LANTHANUM	58 Ce 140.116 CERIUM	59 Pr 140.908 PRASEODYMIUM	60 Nd 144.242 NEODYMIUM	61 Pm 144.913 PROMETHIUM	62 Sm 150.362 SAMARIUM	63 Eu 151.964 EUROPIUM	64 Gd 157.253 GADOLINIUM	65 Tb 158.925 TERBIUM	66 Dy 162.500 DYSPROSIUM	67 Ho 164.930 HOLMIUM	68 Er 167.259 ERBIUM	69 Tm 168.934 THULIUM	70 Yb 173.043 YTTERBIUM	71 Lu 174.967 LUTETIUM
ACTINIDES	89 Ac 227.027 ACTINIUM	90 Th 232.038 THORIUM	91 Pa 231.036 PROTACTINIUM	92 U 238.029 URANIUM	93 Np 237.048 NEPTUNIUM	94 Pu 244.064 PLUTONIUM	95 Am 243.061 AMERICIUM	96 Cm 247.070 CURIUM	97 Bk 247.070 BERKELIUM	98 Cf 251.080 CALIFORNIUM	99 Es 252.083 EINSTEINIUM	100 Fm 257.095 FERMIUM	101 Md 258.098 MENDELEVIUM	102 No 259.101 NOBELIUM	103 Lr 262.110 LAWRENCIUM

Metals



- Good conductors of heat and electricity
- Malleable-capable of being hammered into thin sheets
- Ductile-capable of being drawn into wires
- Lustrous-shiny

Non-Metals

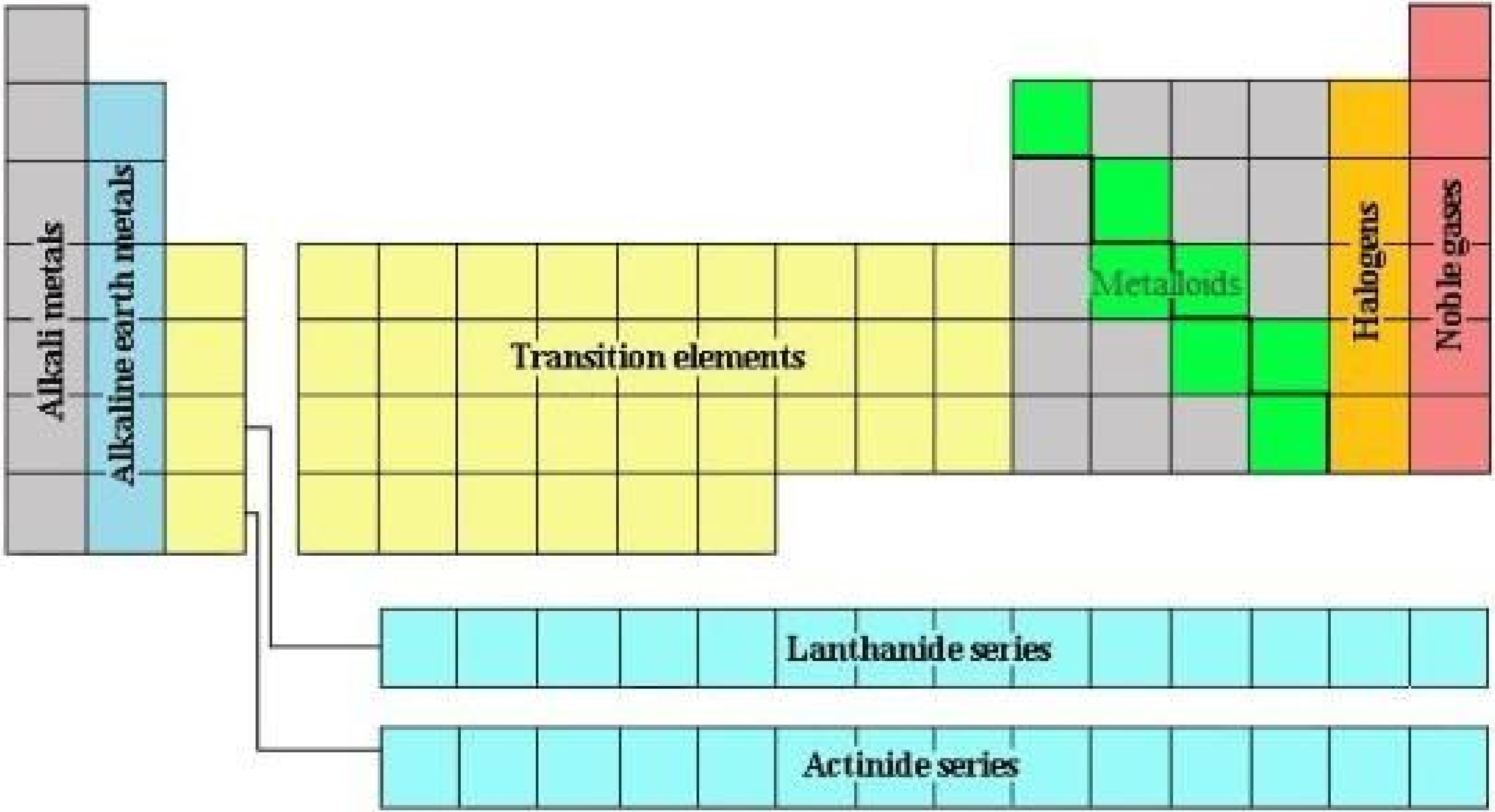


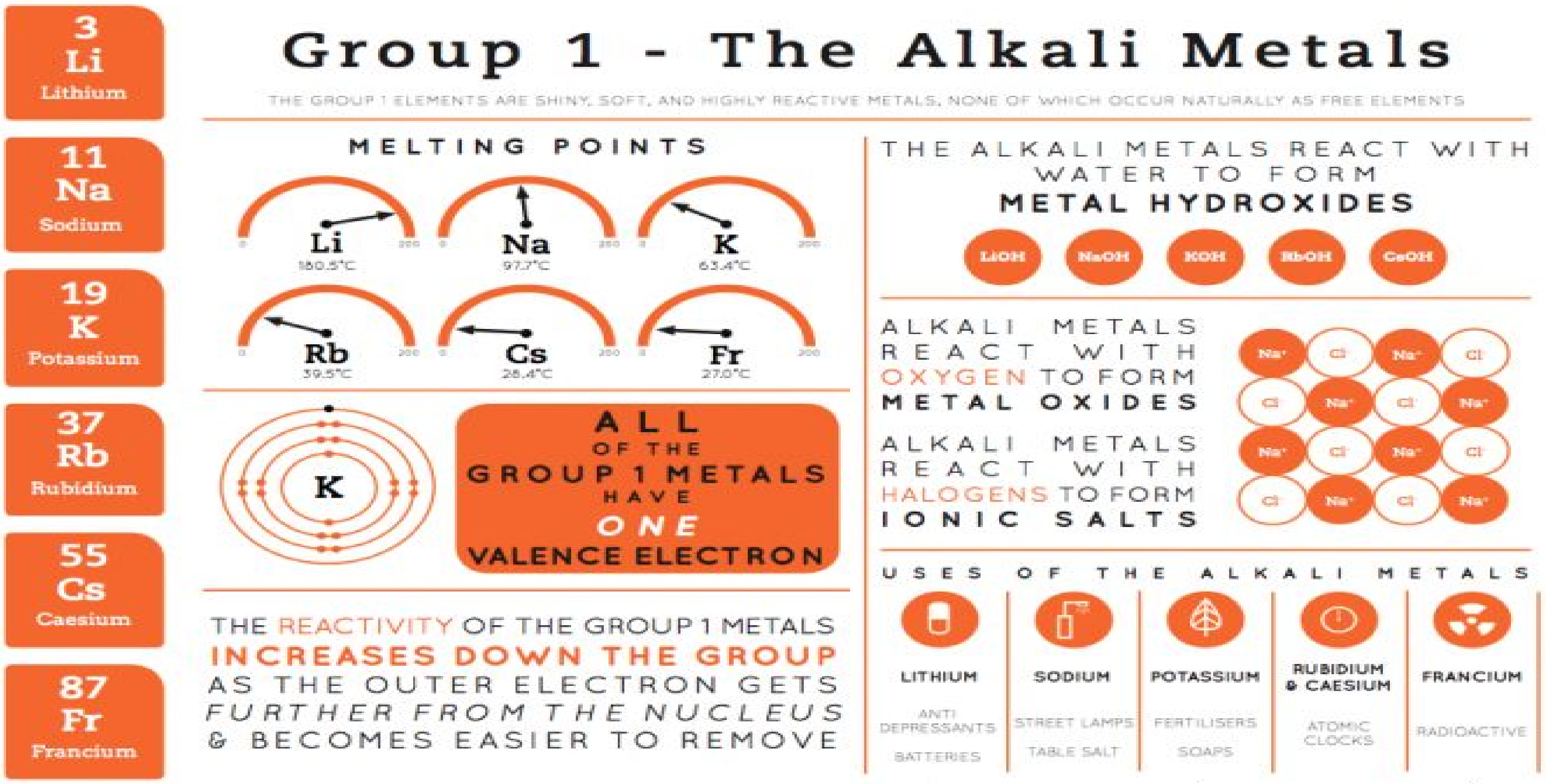
- Poor conductors of heat and electricity
- Brittle solids
- Little or no lustor

Metalloids

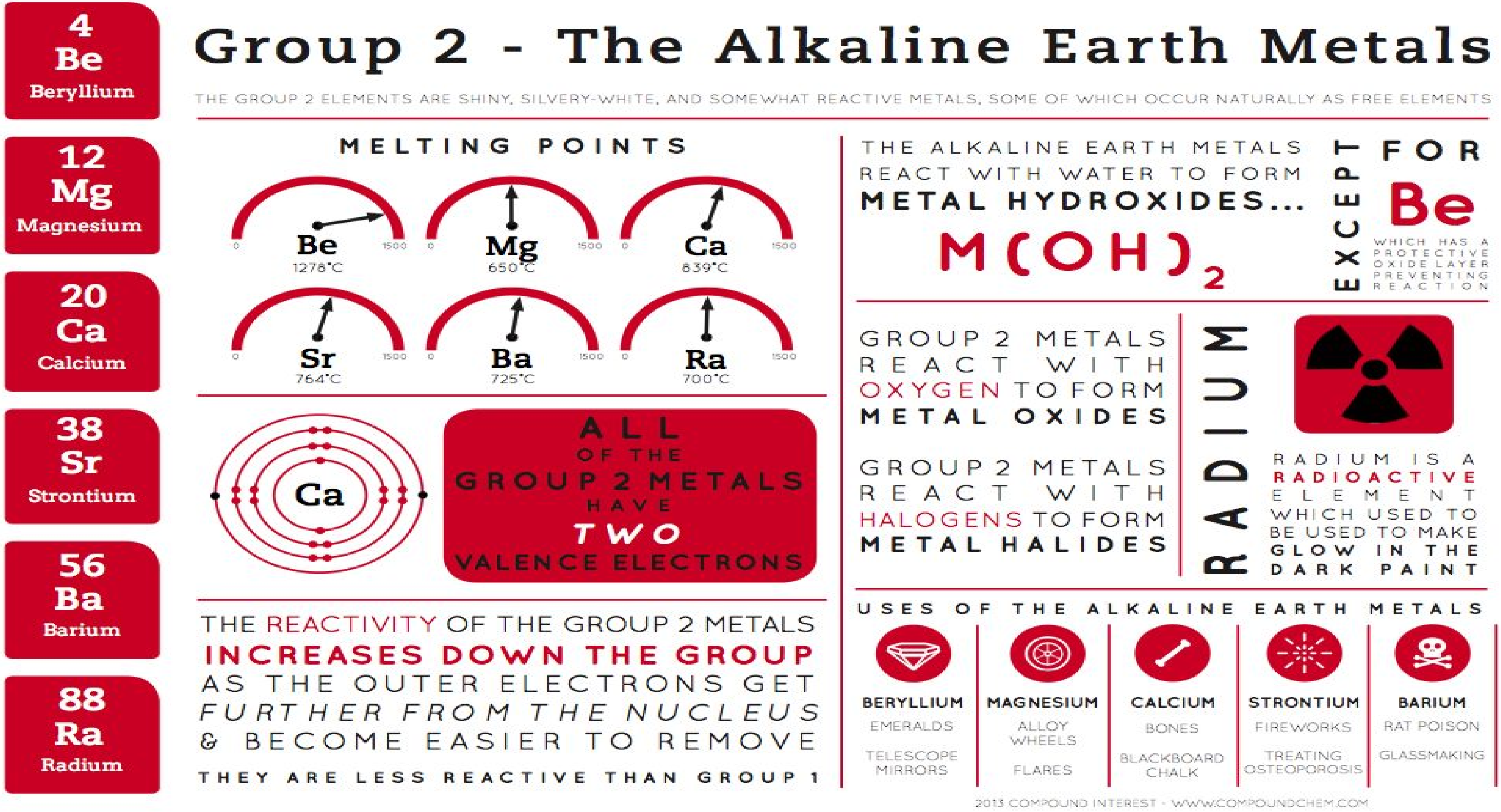
B Boron	C Carbon	N Nitrogen	O Oxygen	F Fluorine
Al Aluminium	Si Silicon	P Phosphorus	S Sulfur	Cl Chlorine
Ga Gallium	Ge Germanium	As Arsenic	Se Selenium	Br Bromine
In Indium	Sn Tin	Sb Antimony	Te Tellurium	I Iodine
Tl Thallium	Pb Lead	Bi Bismuth	Po Polonium	At Astatine

- Solid at room temperature
- Semi-conductors


Alkali metals
Alkaline earth metals
Transition elements
Metalloids
Halogens
Noble gases
Lanthanide series
Actinide series



3
Li
Lithium
11
Na
Sodium
19
K
Potassium
37
Rb
Rubidium
55
Cs
Caesium
87
Fr
Francium
Group 1 - The Alkali Metals
THE GROUP 1 ELEMENTS ARE SHINY, SOFT, AND HIGHLY REACTIVE METALS, NONE OF WHICH OCCUR NATURALLY AS FREE ELEMENTS
MELTING POINTS
Li 180.5°C
Na 97.7°C
K 63.4°C
Rb 39.5°C
Cs 28.4°C
Fr 27.0°C
K
ALL OF THE GROUP 1 METALS HAVE ONE VALENCE ELECTRON
THE REACTIVITY OF THE GROUP 1 METALS INCREASES DOWN THE GROUP AS THE OUTER ELECTRON GETS FURTHER FROM THE NUCLEUS & BECOMES EASIER TO REMOVE
THE ALKALI METALS REACT WITH WATER TO FORM METAL HYDROXIDES
LiOH
NaOH
KOH
RbOH
CsOH
ALKALI METALS REACT WITH OXYGEN TO FORM METAL OXIDES
ALKALI METALS REACT WITH HALOGENS TO FORM IONIC SALTS
USES OF THE ALKALI METALS
LITHIUM
ANTI DEPRESSANTS
BATTERIES
SODIUM
STREET LAMPS
TABLE SALT
POTASSIUM
FERTILISERS
SOAPS
RUBIDIUM & CAESIUM
ATOMIC CLOCKS
FRANCIUM
RADIOACTIVE



4 Be Beryllium
12 Mg Magnesium
20 Ca Calcium
38 Sr Strontium
56 Ba Barium
88 Ra Radium
Group 2 - The Alkaline Earth Metals
THE GROUP 2 ELEMENTS ARE SHINY, SILVERY-WHITE, AND SOMEWHAT REACTIVE METALS, SOME OF WHICH OCCUR NATURALLY AS FREE ELEMENTS
MELTING POINTS
Be 1278°C
Mg 650°C
Ca 839°C
Sr 764°C
Ba 725°C
Ra 700°C
0
1500
Ca
ALL OF THE GROUP 2 METALS HAVE TWO VALENCE ELECTRONS
THE REACTIVITY OF THE GROUP 2 METALS INCREASES DOWN THE GROUP AS THE OUTER ELECTRONS GET FURTHER FROM THE NUCLEUS & BECOME EASIER TO REMOVE
THEY ARE LESS REACTIVE THAN GROUP 1
THE ALKALINE EARTH METALS REACT WITH WATER TO FORM METAL HYDROXIDES...
M(OH)2
EXCEPT FOR Be
WHICH HAS A PROTECTIVE OXIDE LAYER PREVENTING REACTION
GROUP 2 METALS REACT WITH OXYGEN TO FORM METAL OXIDES
GROUP 2 METALS REACT WITH HALOGENS TO FORM METAL HALIDES
RADIUM
RADIUM IS A RADIOACTIVE ELEMENT WHICH USED TO BE USED TO MAKE GLOW IN THE DARK PAINT
USES OF THE ALKALINE EARTH METALS
BERYLLIUM
EMERALDS
TELESCOPE MIRRORS
MAGNESIUM
ALLOY WHEELS
FLARES
CALCIUM
BONES
BLACKBOARD CHALK
STRONTIUM
FIREWORKS
TREATING OSTEOPOROSIS
BARIUM
RAT POISON
GLASSMAKING
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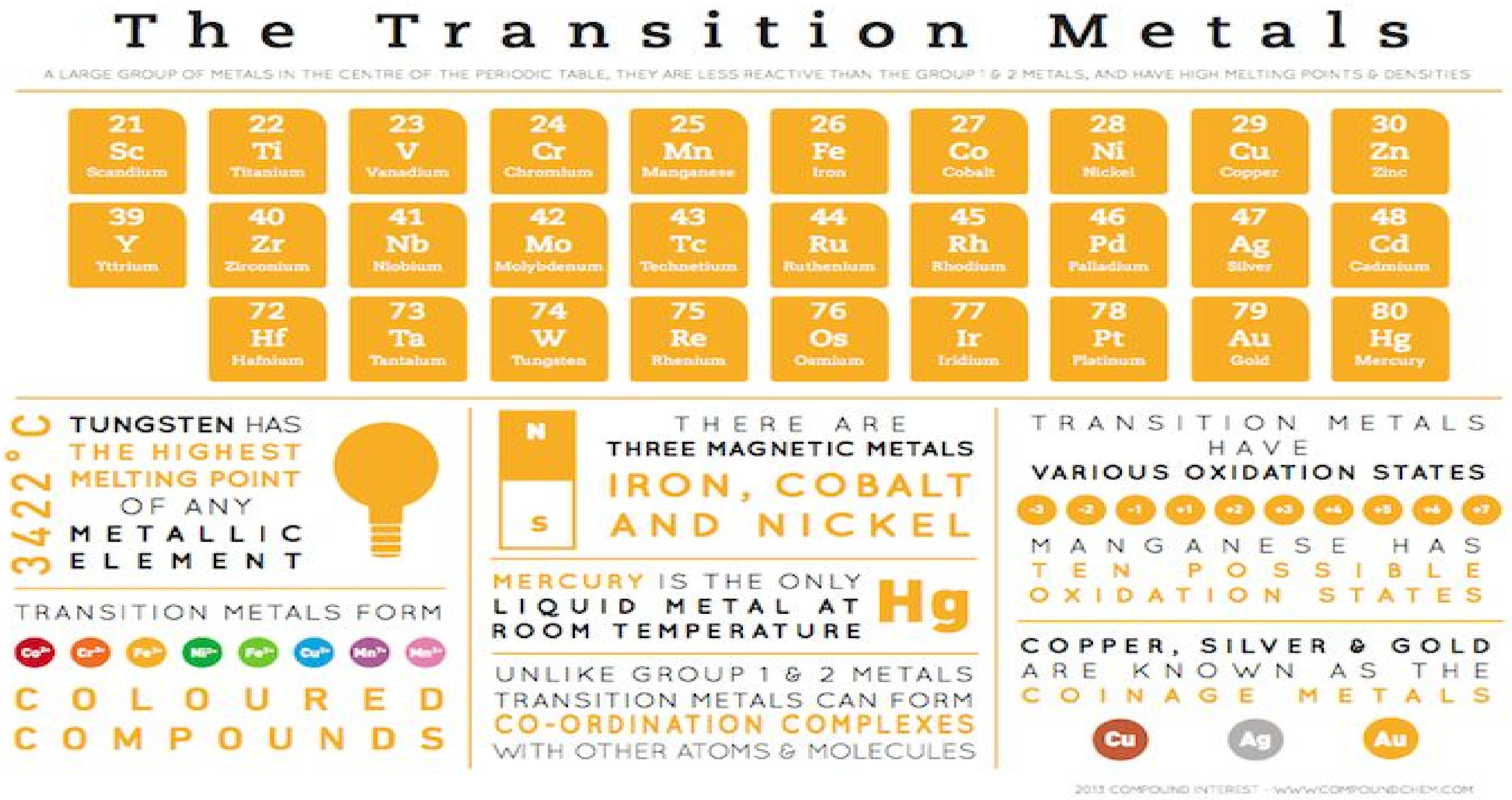
The Transition Metals
A LARGE GROUP OF METALS IN THE CENTRE OF THE PERIODIC TABLE, THEY ARE LESS REACTIVE THAN THE GROUP 1 & 2 METALS, AND HAVE HIGH MELTING POINTS & DENSITIES
21 Sc Scandium
22 Ti Titanium
23 V Vanadium
24 Cr Chromium
25 Mn Manganese
26 Fe Iron
27 Co Cobalt
28 Ni Nickel
29 Cu Copper
30 Zn Zinc
39 Y Yttrium
40 Zr Zirconium
41 Nb Niobium
42 Mo Molybdenum
43 Tc Technetium
44 Ru Ruthenium
45 Rh Rhodium
46 Pd Palladium
47 Ag Silver
48 Cd Cadmium
72 Hf Hafnium
73 Ta Tantalum
74 W Tungsten
75 Re Rhenium
76 Os Osmium
77 Ir Iridium
78 Pt Platinum
79 Au Gold
80 Hg Mercury
3422°C
TUNGSTEN HAS THE HIGHEST MELTING POINT OF ANY METALLIC ELEMENT
TRANSITION METALS FORM
COLOURED COMPOUNDS
N
S
THERE ARE THREE MAGNETIC METALS
IRON, COBALT AND NICKEL
MERCURY IS THE ONLY LIQUID METAL AT ROOM TEMPERATURE
Hg
UNLIKE GROUP 1 & 2 METALS TRANSITION METALS CAN FORM CO-ORDINATION COMPLEXES WITH OTHER ATOMS & MOLECULES
TRANSITION METALS HAVE VARIOUS OXIDATION STATES
MANGANESE HAS TEN POSSIBLE OXIDATION STATES
COPPER, SILVER & GOLD ARE KNOWN AS THE COINAGE METALS
Cu
Ag
Au
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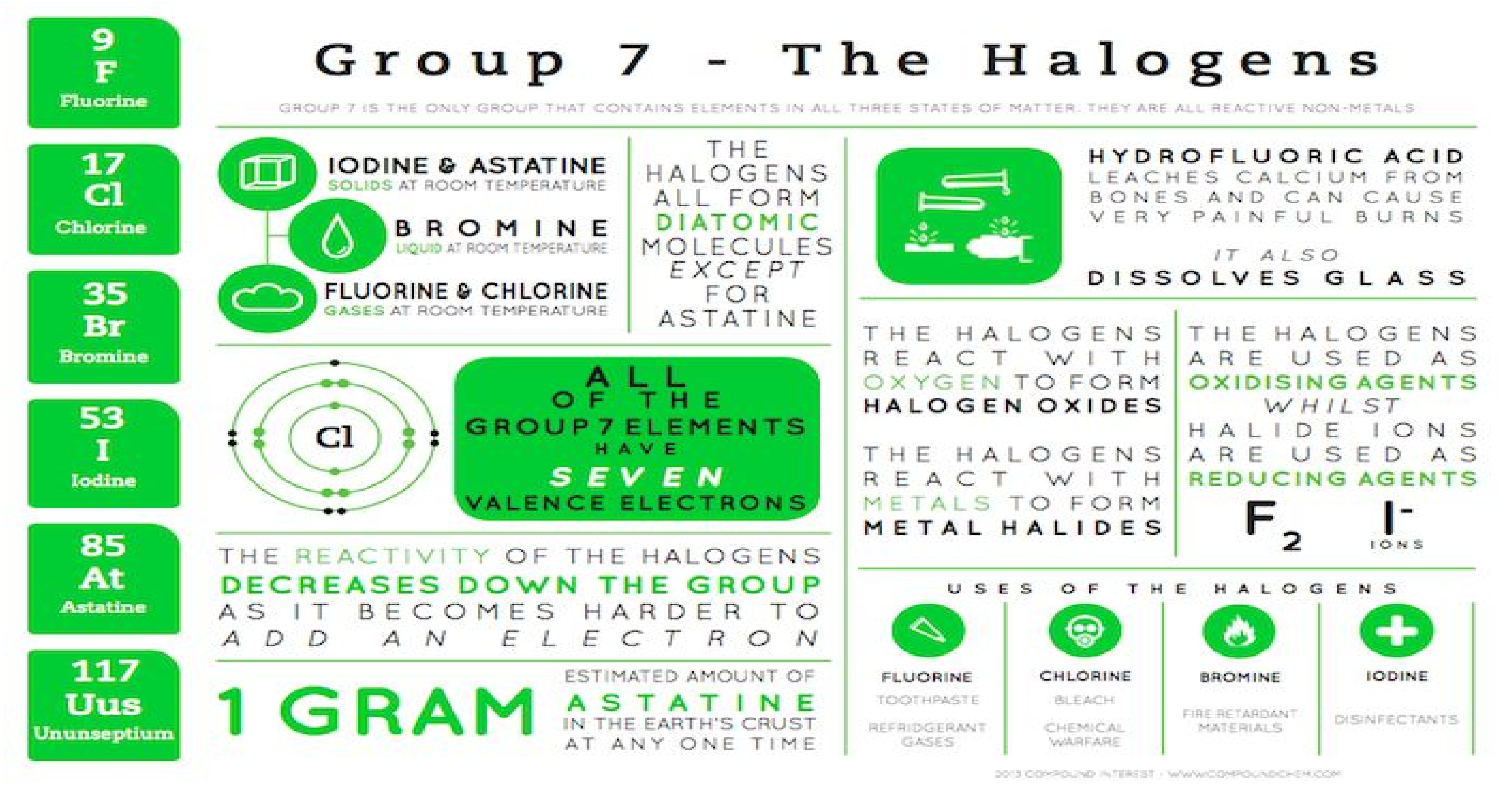
9 F Fluorine
17 Cl Chlorine
35 Br Bromine
53 I Iodine
85 At Astatine
117 Uus Ununseptium
Group 7 - The Halogens
GROUP 7 IS THE ONLY GROUP THAT CONTAINS ELEMENTS IN ALL THREE STATES OF MATTER. THEY ARE ALL REACTIVE NON-METALS
IODINE & ASTATINE
SOLIDS AT ROOM TEMPERATURE
BROMINE
LIQUID AT ROOM TEMPERATURE
FLUORINE & CHLORINE
GASES AT ROOM TEMPERATURE
THE HALOGENS ALL FORM DIATOMIC MOLECULES EXCEPT FOR ASTATINE
HYDROFLUORIC ACID
LEACHES CALCIUM FROM BONES AND CAN CAUSE VERY PAINFUL BURNS
IT ALSO
DISSOLVES GLASS
Cl
ALL OF THE GROUP 7 ELEMENTS HAVE SEVEN VALENCE ELECTRONS
THE HALOGENS REACT WITH OXYGEN TO FORM HALOGEN OXIDES
THE HALOGENS REACT WITH METALS TO FORM METAL HALIDES
THE HALOGENS ARE USED AS OXIDISING AGENTS WHILST HALIDE IONS ARE USED AS REDUCING AGENTS
F_2
I^- IONS
THE REACTIVITY OF THE HALOGENS DECREASES DOWN THE GROUP AS IT BECOMES HARDER TO ADD AN ELECTRON
USES OF THE HALOGENS
FLUORINE
TOOTHPASTE
REFRIDGERANT GASES
CHLORINE
BLEACH
CHEMICAL WARFARE
BROMINE
FIRE RETARDANT MATERIALS
IODINE
DISINFECTANTS
1 GRAM
ESTIMATED AMOUNT OF ASTATINE IN THE EARTH'S CRUST AT ANY ONE TIME
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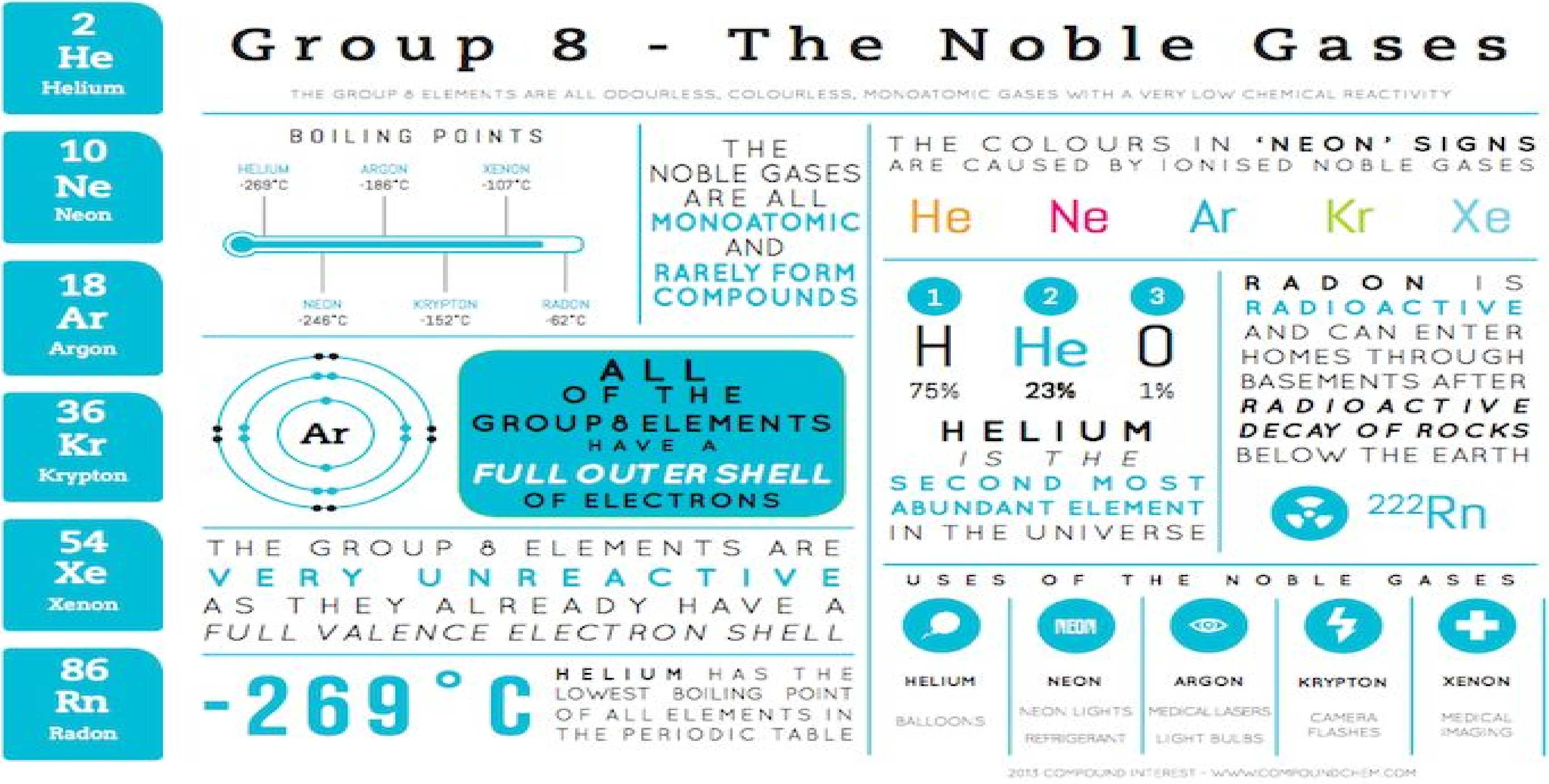
2
He
Helium
10
Ne
Neon
18
Ar
Argon
36
Kr
Krypton
54
Xe
Xenon
86
Rn
Radon
Group 8 - The Noble Gases
THE GROUP 8 ELEMENTS ARE ALL ODOURLESS, COLOURLESS, MONOATOMIC GASES WITH A VERY LOW CHEMICAL REACTIVITY
BOILING POINTS
HELIUM -269°C
ARGON -186°C
XENON -107°C
NEON -246°C
KRYPTON -152°C
RADON -62°C
THE NOBLE GASES ARE ALL MONOATOMIC AND RARELY FORM COMPOUNDS
THE COLOURS IN 'NEON' SIGNS ARE CAUSED BY IONISED NOBLE GASES
He Ne Ar Kr Xe
Ar
ALL OF THE GROUP 8 ELEMENTS HAVE A FULL OUTER SHELL OF ELECTRONS
1 H 75%
2 He 23%
3 O 1%
HELIUM IS THE SECOND MOST ABUNDANT ELEMENT IN THE UNIVERSE
RADON IS RADIOACTIVE AND CAN ENTER HOMES THROUGH BASEMENTS AFTER RADIOACTIVE DECAY OF ROCKS BELOW THE EARTH
222Rn
THE GROUP 8 ELEMENTS ARE VERY UNREACTIVE AS THEY ALREADY HAVE A FULL VALENCE ELECTRON SHELL
USES OF THE NOBLE GASES
NEON
HELIUM
BALLOONS
NEON
NEON LIGHTS
REFRIGERANT
ARGON
MEDICAL LASERS
LIGHT BULBS
KRYPTON
CAMERA FLASHES
XENON
MEDICAL IMAGING
-269°C
HELIUM HAS THE LOWEST BOILING POINT OF ALL ELEMENTS IN THE PERIODIC TABLE
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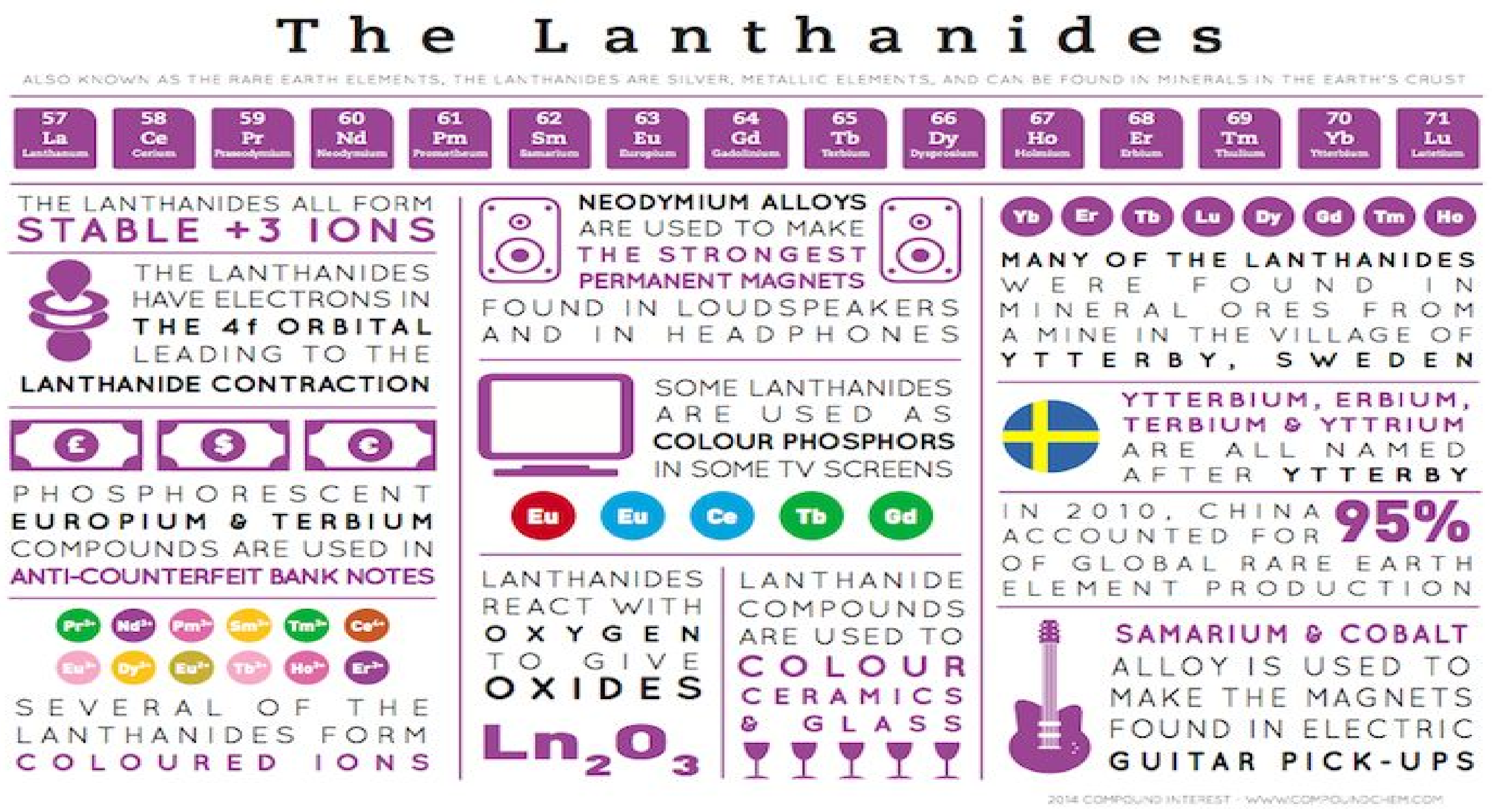
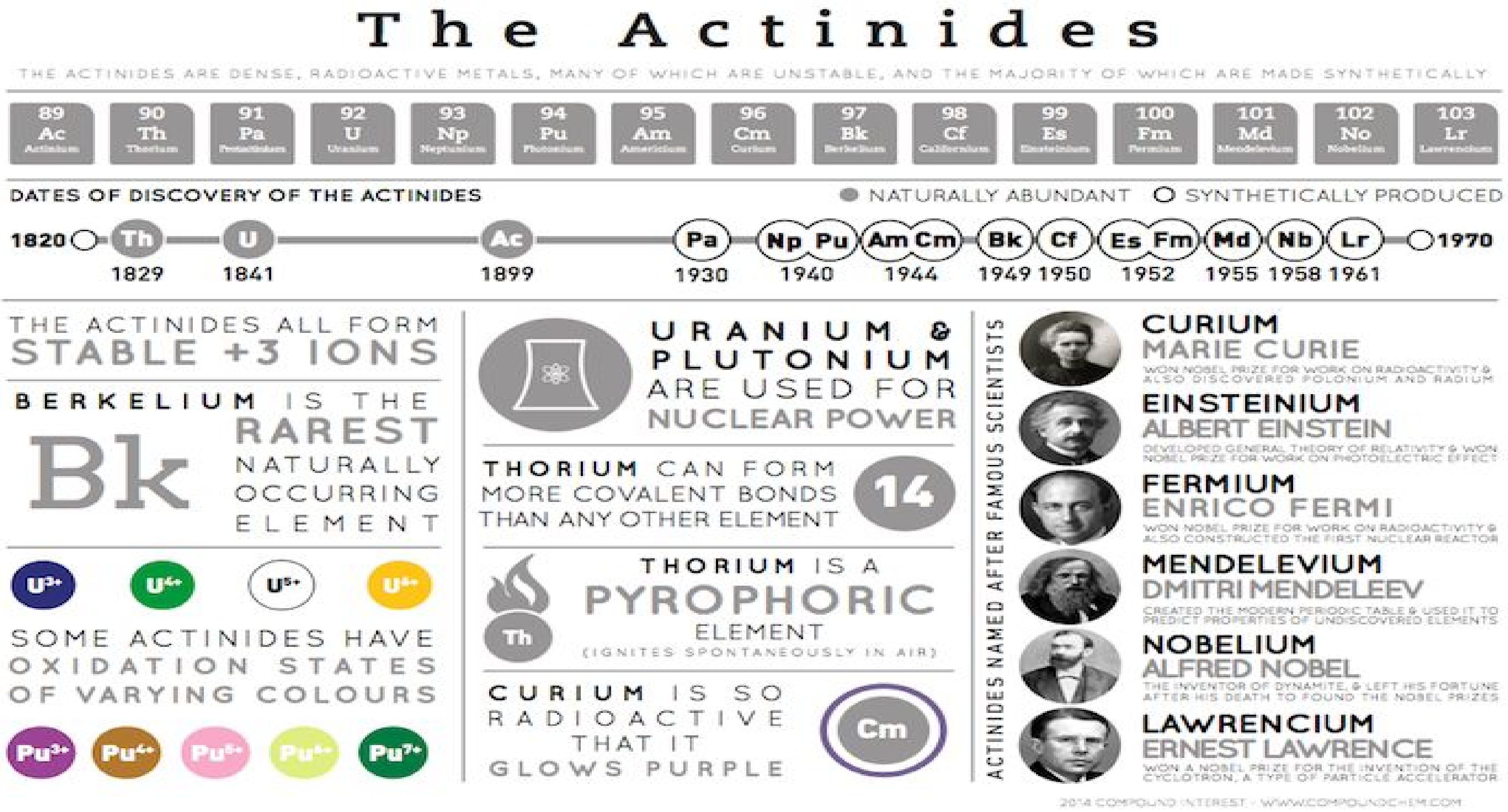

The Lanthanides
ALSO KNOWN AS THE RARE EARTH ELEMENTS, THE LANTHANIDES ARE SILVER, METALLIC ELEMENTS, AND CAN BE FOUND IN MINERALS IN THE EARTH'S CRUST
57 La
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
THE LANTHANIDES ALL FORM STABLE +3 IONS
THE LANTHANIDES HAVE ELECTRONS IN THE 4f ORBITAL LEADING TO THE LANTHANIDE CONTRACTION
£
$
€
PHOSPHORESCENT EUROPIUM & TERBIUM COMPOUNDS ARE USED IN ANTI-COUNTERFEIT BANK NOTES
Pr^{3+} Nd^{3+} Pm^{3+} Sm^{3+} Tm^{3+} Ce^{4+}
Eu^{3+} Dy^{3+} Eu^{2+} Tb^{3+} Ho^{3+} Er^{3+}
SEVERAL OF THE LANTHANIDES FORM COLOURED IONS
NEODYMIUM ALLOYS ARE USED TO MAKE THE STRONGEST PERMANENT MAGNETS FOUND IN LOUDSPEAKERS AND IN HEADPHONES
SOME LANTHANIDES ARE USED AS COLOUR PHOSPHORS IN SOME TV SCREENS
Eu Eu Ce Tb Gd
LANTHANIDES REACT WITH OXYGEN TO GIVE OXIDES
Ln_2O_3
LANTHANIDE COMPOUNDS ARE USED TO COLOUR CERAMICS & GLASS
Yb Er Tb Lu Dy Gd Tm Ho
MANY OF THE LANTHANIDES WERE FOUND IN MINERAL ORES FROM A MINE IN THE VILLAGE OF YTTERBY, SWEDEN
YTTERBIUM, ERBIUM, TERBIUM & YTTRIUM ARE ALL NAMED AFTER YTTERBY
IN 2010, CHINA ACCOUNTED FOR 95% OF GLOBAL RARE EARTH ELEMENT PRODUCTION
SAMARIUM & COBALT ALLOY IS USED TO MAKE THE MAGNETS FOUND IN ELECTRIC GUITAR PICK-UPS
2014 COMPOUND INTEREST - WWW.COMPOUNDCHEM.COM



The Actinides
THE ACTINIDES ARE DENSE, RADIOACTIVE METALS, MANY OF WHICH ARE UNSTABLE, AND THE MAJORITY OF WHICH ARE MADE SYNTHETICALLY
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
DATES OF DISCOVERY OF THE ACTINIDES
NATURALLY ABUNDANT
SYNTHETICALLY PRODUCED
1820
Th 1829
U 1841
Ac 1899
Pa 1930
Np Pu 1940
Am Cm 1944
Bk 1949
Cf 1950
Es Fm 1952
Md 1955
Nb 1958
Lr 1961
1970
THE ACTINIDES ALL FORM STABLE +3 IONS
BERKELIUM IS THE RAREST NATURALLY OCCURRING ELEMENT
Bk
U3+ U4+ U5+ U6+
SOME ACTINIDES HAVE OXIDATION STATES OF VARYING COLOURS
Pu3+ Pu4+ Pu5+ Pu6+ Pu7+
URANIUM & PLUTONIUM ARE USED FOR NUCLEAR POWER
THORIUM CAN FORM MORE COVALENT BONDS THAN ANY OTHER ELEMENT
14
Th
THORIUM IS A PYROPHORIC ELEMENT
(IGNITES SPONTANEOUSLY IN AIR)
CURIUM IS SO RADIOACTIVE THAT IT GLOWS PURPLE
Cm
ACTINIDES NAMED AFTER FAMOUS SCIENTISTS
CURIUM
MARIE CURIE
WON NOBEL PRIZE FOR WORK ON RADIOACTIVITY & ALSO DISCOVERED POLONIUM AND RADIUM
EINSTEINIUM
ALBERT EINSTEIN
DEVELOPED GENERAL THEORY OF RELATIVITY & WON NOBEL PRIZE FOR WORK ON PHOTOELECTRIC EFFECT
FERMIUM
ENRICO FERMI
WON NOBEL PRIZE FOR WORK ON RADIOACTIVITY & ALSO CONSTRUCTED THE FIRST NUCLEAR REACTOR
MENDELEVIUM
DMITRI MENDELEEV
CREATED THE MODERN PERIODIC TABLE & USED IT TO PREDICT PROPERTIES OF UNDISCOVERED ELEMENTS
NOBELIUM
ALFRED NOBEL
THE INVENTOR OF DYNAMITE, & LEFT HIS FORTUNE AFTER HIS DEATH TO FOUND THE NOBEL PRIZES
LAWRENCIUM
ERNEST LAWRENCE
WON A NOBEL PRIZE FOR THE INVENTION OF THE CYCLOTRON, A TYPE OF PARTICLE ACCELERATOR
2014 COMPOUND INTEREST - WWW.COMPOUNDCHEM.COM

Element Poster

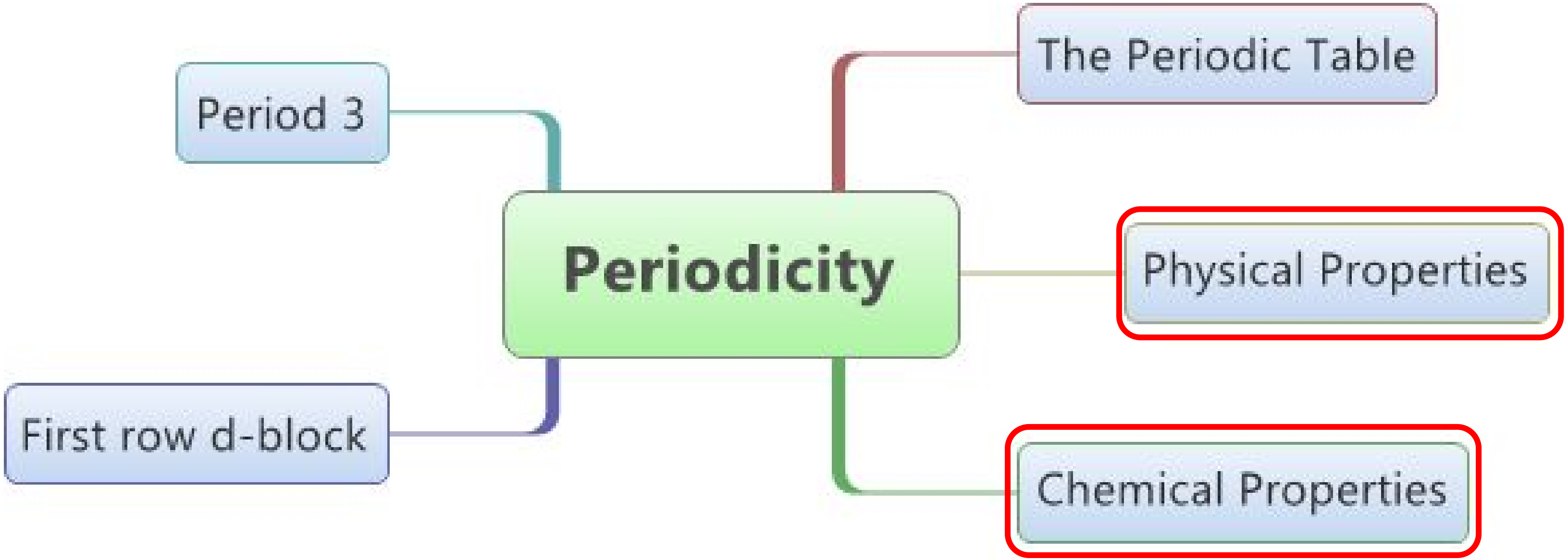
- You will each pick one different element and create a poster
- Things to include:
  - Name and symbol
  - Period # and group # on periodic table
  - Is it a metal, metalloid, or nonmetal
  - Number of valence electrons
  - Name of the group it is in
  - The block it is in
  - Electron configuration
  - 3 fun facts

Main

Lesson 2

3.2 Periodic Trends

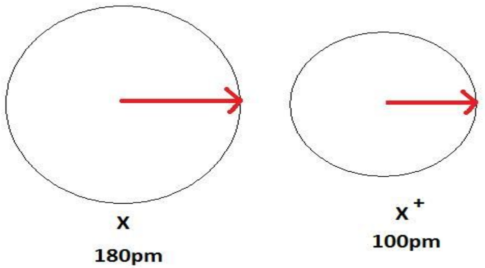
We Are Here



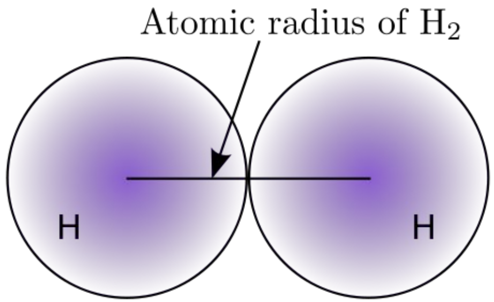
Main

Atomic Radius

- This is the ‘size’ of an atom
- The radius is the distance from the center of the circle to a point on the circumference
- The position of an electron is not fixed so we cannot measure the radius of an atom in the same way we measure the radius of a circle



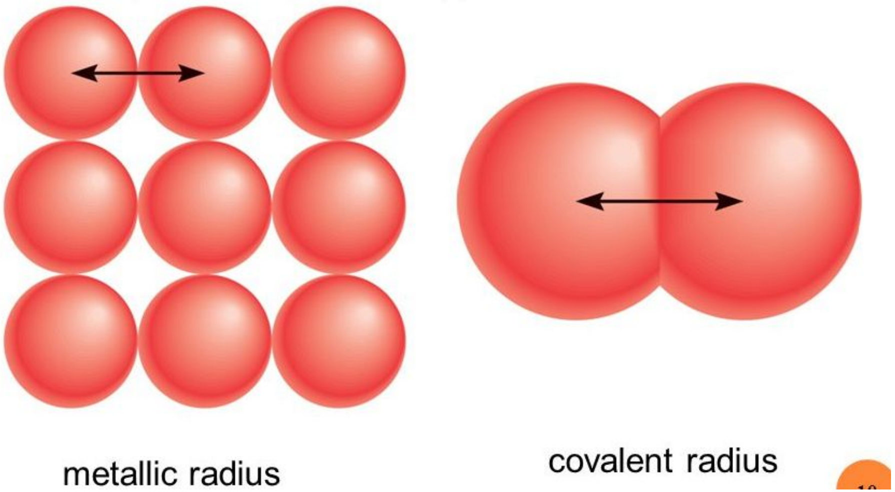
- In a diatomic molecule, the distance between the two nuclei is given by d, and the bonding atomic radius, R_b
- $R_b = ½ d$
- The bonding atomic radius is often referred to as the covalent radius



Main

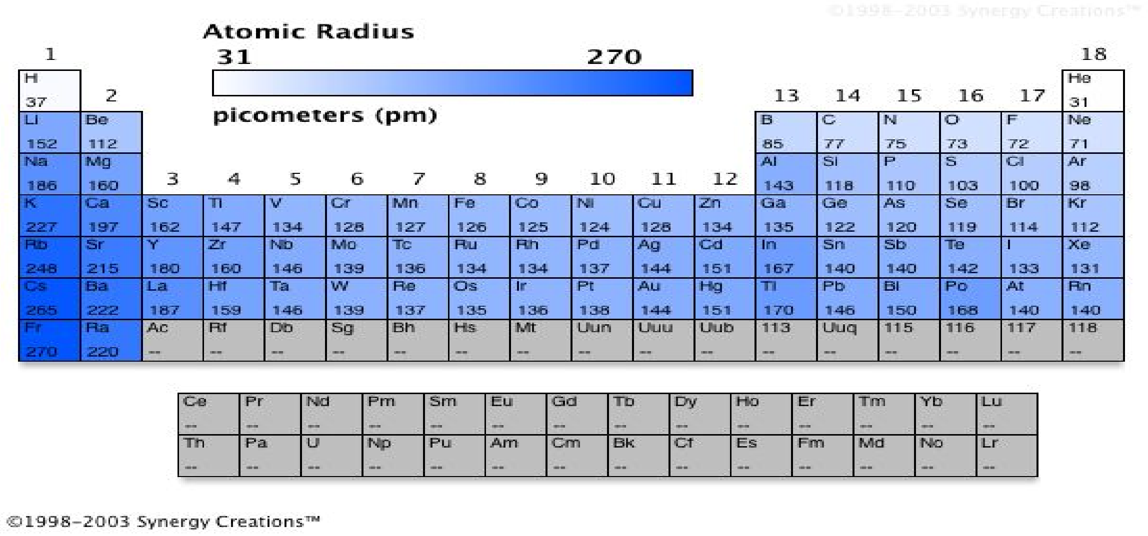
Atomic Radius

- For non-bonding atomic radius, two atoms collide with one another with little penetration.
- The atoms touch each other but will not be chemically bonded.
- $d=2R_{nb}$



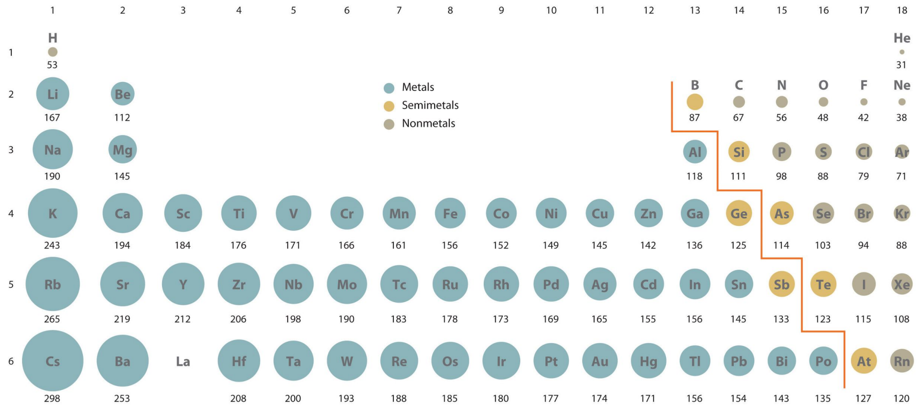
Atomic Radius

- Section 9 of your data booklet provides data for the covalent atomic radii of the elements



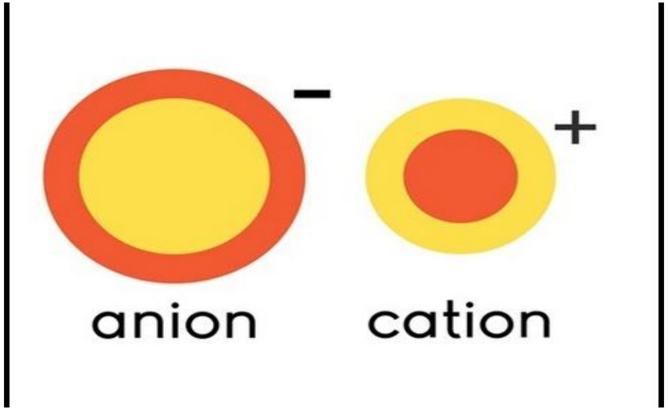
Atomic Radius Trend

- Atomic radius decreases from left to right across a period due to the increasing effective nuclear charge, Z_{eff}.
- Z_{eff} pulls the valence electrons closer to the nucleus reducing the atomic radius
- Atomic radius increases down a group from top to bottom due to the addition of new energy levels that are located further away from the nucleus and more shielding from the nucleus



Ionic Radius

- Cation- positively charged ion
- Anion- negatively charged ion
- The radii of cations and anions vary from the neutral atom from which they are formed



Ionic Radius

- The radii of cations are smaller than those of their parent ions because there are less electrons
- The radii of anions are larger than those of their parent ions due to the gain of electrons

Main

Ionic Radius

- Na is larger than Na^+ because the former has one extra shell of electrons

$$Na: 1s^2 2s^2 2p^6 3s^1$$

$$Na^+: 1s^2 2s^2 2p^6$$

- This also has to deal with the electron cloud that is formed and the electrons repelling from each other
- There are more protons than electrons so the valence electrons are more strongly attracted to the nucleus

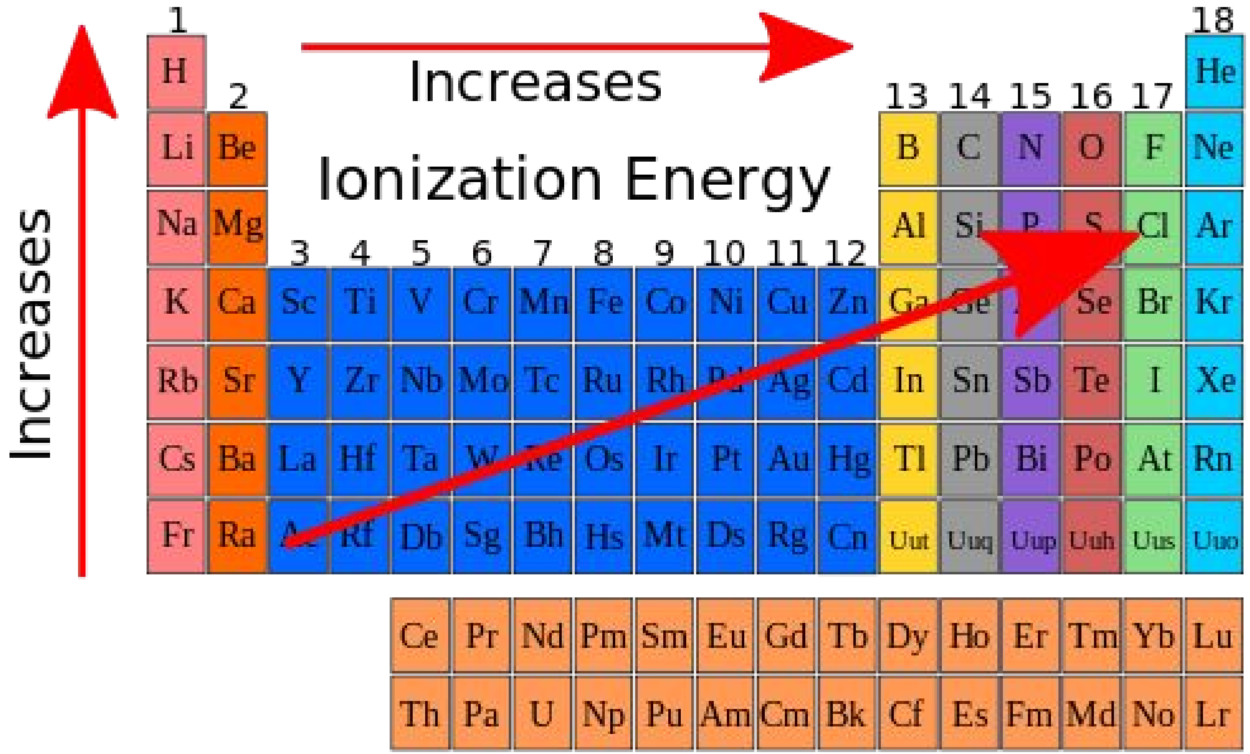
Ionization Energy

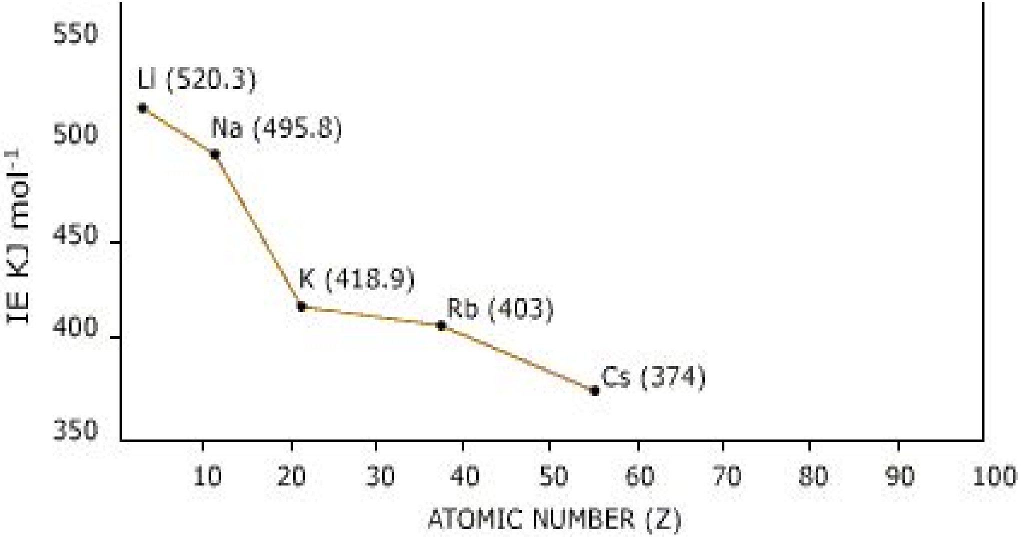
- Minimum energy required to remove an electron from a neutral gaseous atom in its ground state

$$X(g) \rightarrow X^{+}(g) + e^{-}$$

- The second ionization energy relates to the removal of an additional electron, etc.
- Ionization energy values are always positive because there is an input of energy in order to remove an electron
- Section 8 of the Data booklet provides ionization energy values

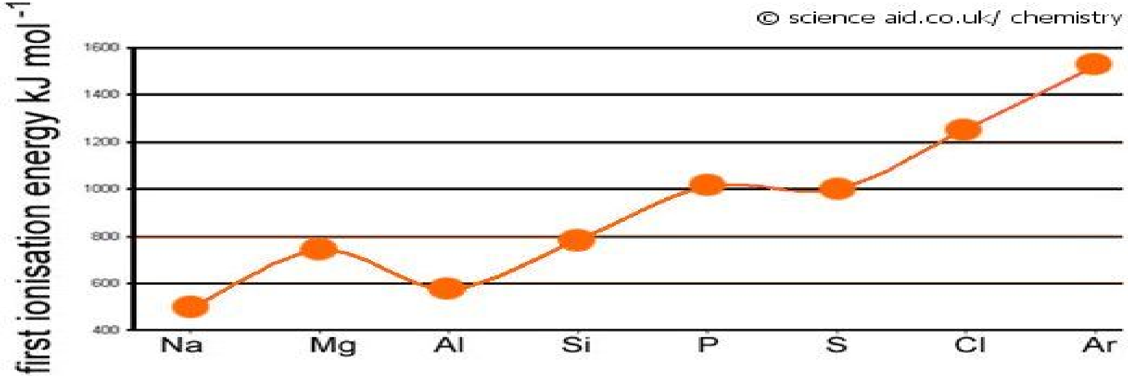
Ionization Energy

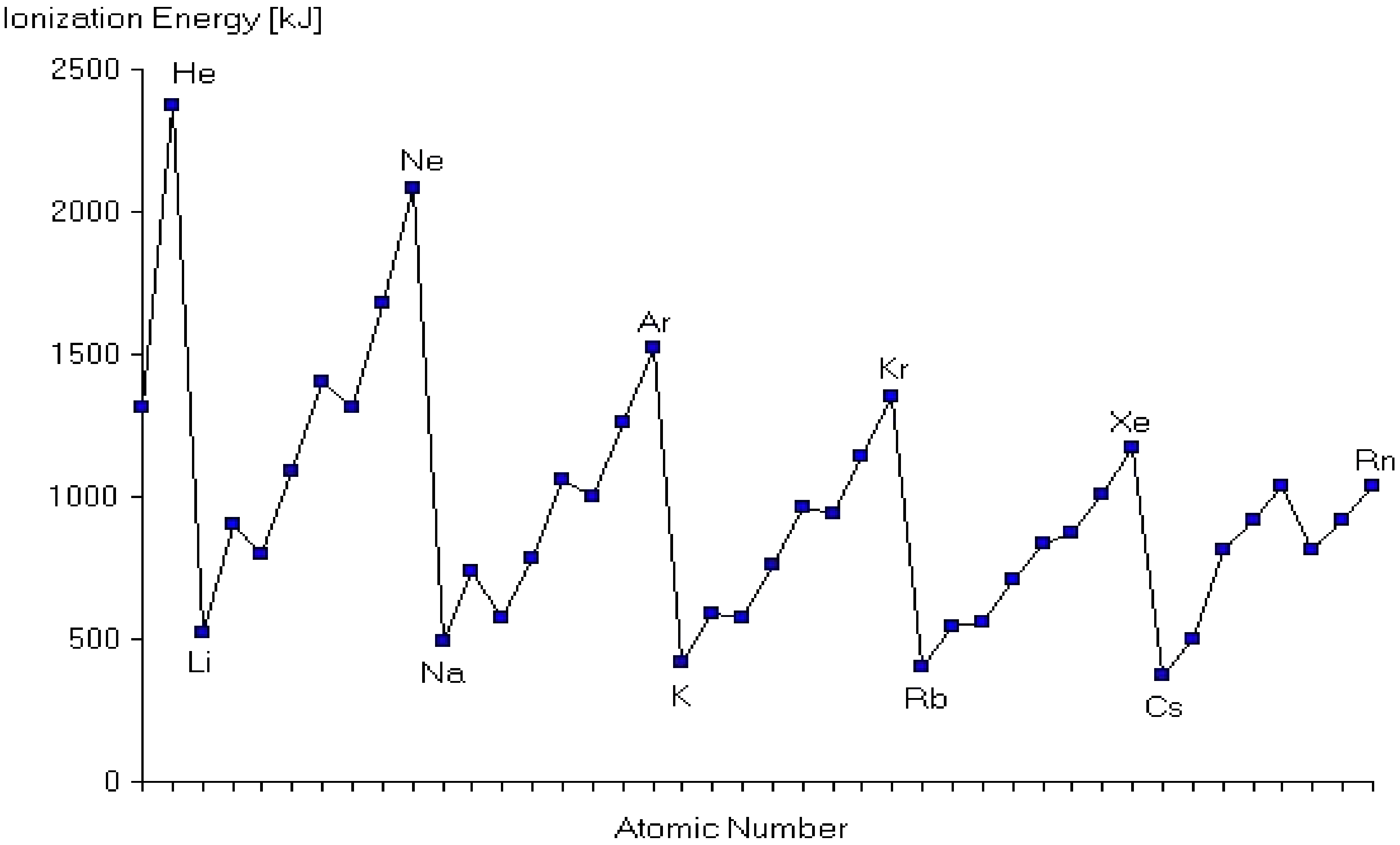




GROUP

PERIOD





Ionization Energy [kJ]
2500
2000
1500
1000
500
0
He
Ne
Ar
Kr
Xe
Rn
Li
Na
K
Rb
Cs
Atomic Number

Ionization Energy

- Across a period from left to right:
  - As the effective nuclear charge, Z_{eff}, increases from left to right across a period the valence electrons are pulled closer to the nucleus, so the attraction between the electrons and the nucleus increases becoming more difficult to remove an electron
  - Atomic radii decrease across a period because the distance between the valence electrons and the nucleus decreases, it becomes more difficult to remove an electron from an atom

Ionization Energy

- Down a group from top to bottom:
  - Atomic radii increase down a group, making it easier to remove an electron from the atom
  - The shielding effect of the core electrons increases faster than the nuclear charge, weakening the attractive force between the nucleus and the outer electrons in the atom

Electron Affinity

- The energy that is released ($E_{initial}$-E_{final}) when 1 mole of electrons is attached to 1 mol of neutral atoms or molecules in the gas phase

$$X(g) + e^- \rightarrow X^-(g)$$

$$F(g) + e^- \rightarrow F^-(g) \qquad E_a = -328 \text{ kJ mol}^{-1}$$

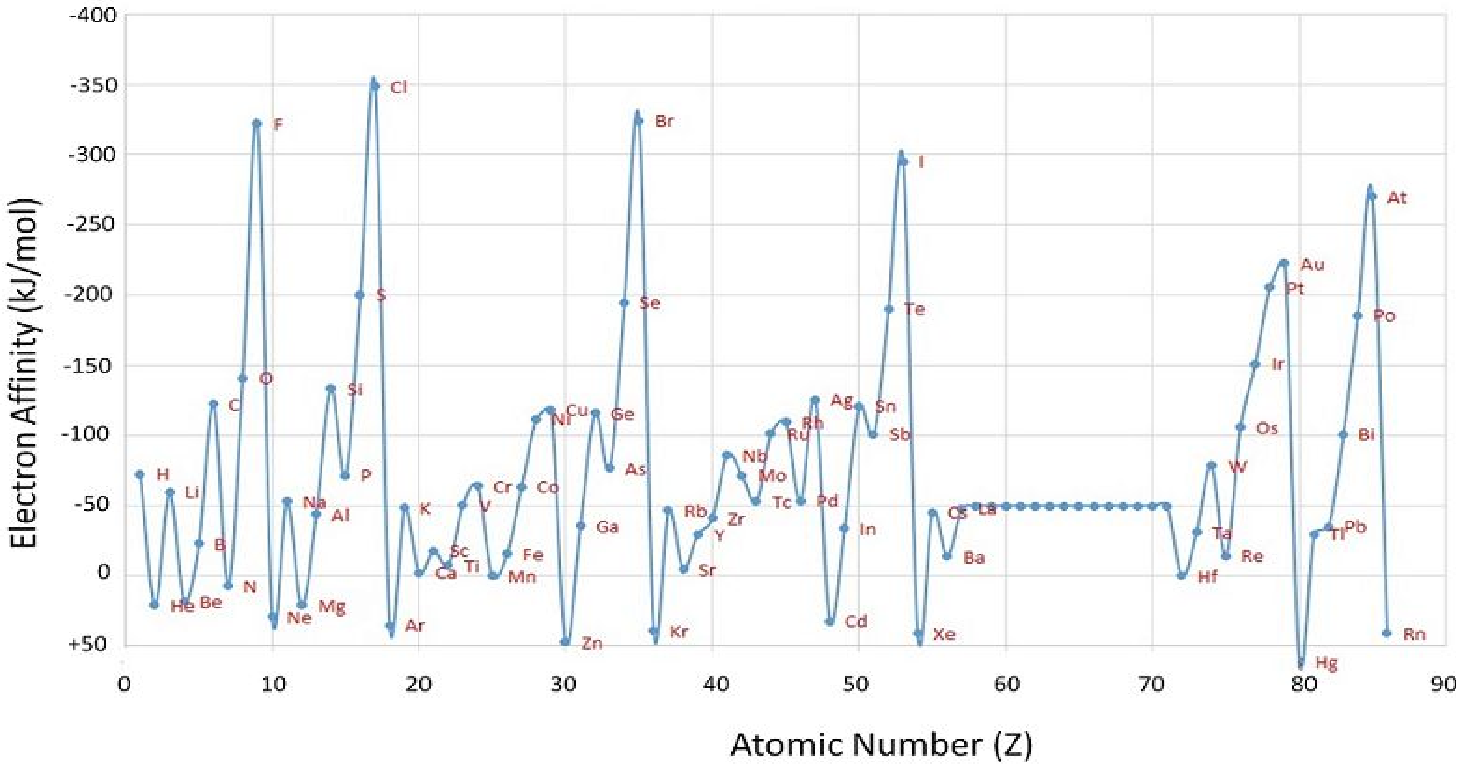
- The negative sign indicates that energy is released during the process
- The more negative the E_{ea} value, the greater the attraction of the ion for the electron
- Some E_{ea} value may be positive, such as noble gases

Electron Affinity

Electron Affinities (kJ/mol)

1A	2A	3A	4A	5A	6A	7A	8A
H −73							He >0
Li −60	Be >0	B −27	C −122	N >0	O −141	F −328	Ne >0
Na −53	Mg >0	Al −43	Si −134	P −72	S −200	Cl −349	Ar >0
K −48	Ca −2	Ga −30	Ge −119	As −78	Se −195	Br −325	Kr >0
Rb −47	Sr −5	In −30	Sn −107	Sb −103	Te −190	I −295	Xe >0

Electron Affinity



Electron Affinity

- Trends in electron affinity are not as well highlighted as other observed trends
- Across a period from left to right E_{ea} values become more negative, with some exceptions
- Halogens have the most negative E_{ea} value since gaining an electron for these elements gives them a stable noble gas configuration

Electron Affinity

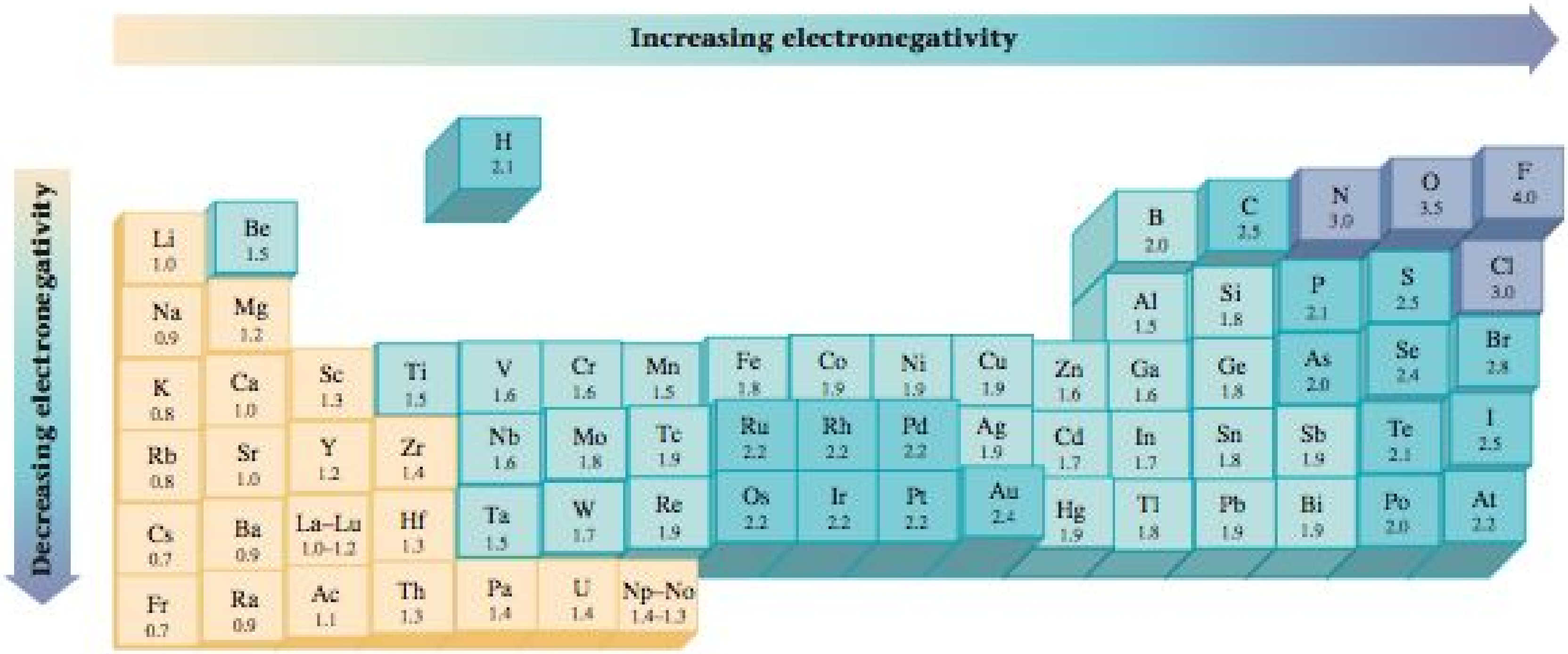
- In alkali metals, values of E_{ea} generally become less negative going down the group

- The patterns for electron affinity vary by group and do not show clear trends down a group

Electronegativity

- The relative attraction that an atom has for the shared pair of electrons in a covalent bond
- In 1932 Linus Pauling proposed the concept of electronegativity
- Section 8 of the Data booklet is the Pauling scale, X_p
- Fluorine is the most electronegative element on the periodic table and has a value of 4.0

Electronegativity



Electronegativity

- Across a period from left to right electronegativity values increase because the effective nuclear charge and atomic radius both increase

- Down a group from top to bottom electronegativity values decrease because atomic radii increases, and the nuclear charge increases but its effect is shielded by the core electrons

Melting Point

- The melting point is the amount of energy required to break a bond(s) to change the solid phase of a substance to a liquid.
- Bonding and structure are factors that affect the melting point of elements
  - Melting points are varied and do not generally form a distinguishable trend across the periodic table.
  - The non-metal carbon possesses the highest boiling point of all the elements.

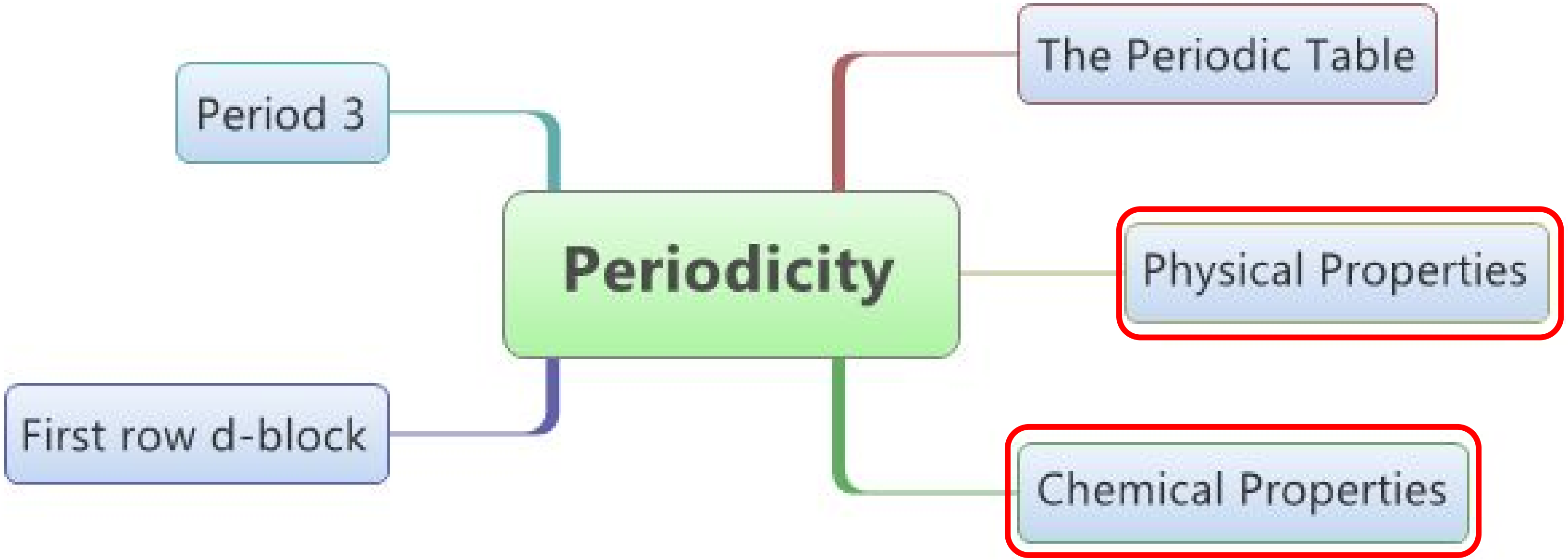
Main

Lesson 3

3.2 Periodic Trends

Main

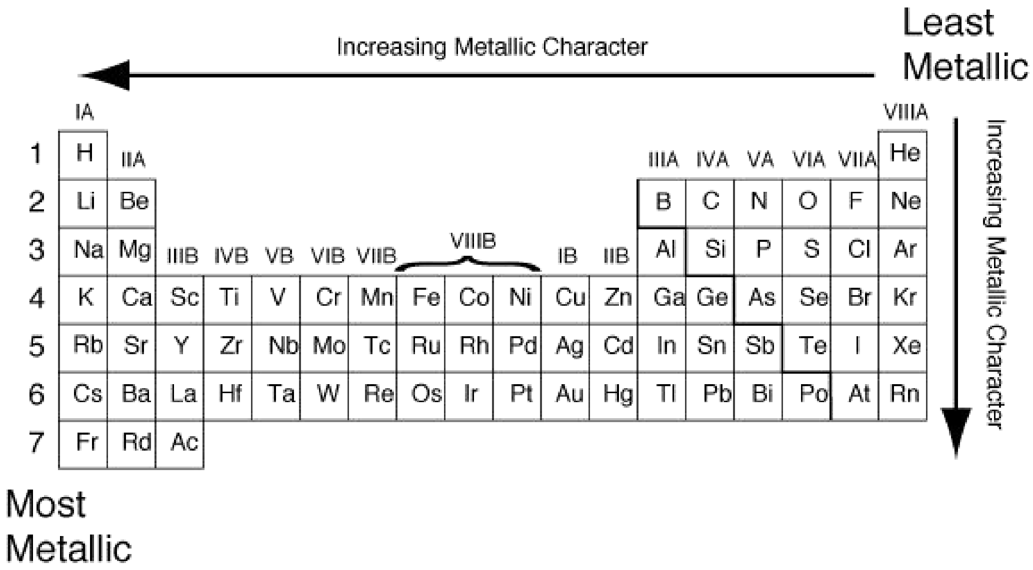
We Are Here



Period 3
The Periodic Table
Periodicity
Physical Properties
First row d-block
Chemical Properties

Metallic and Non-metallic Character

- Metallic character decreases across a period and increases down a group



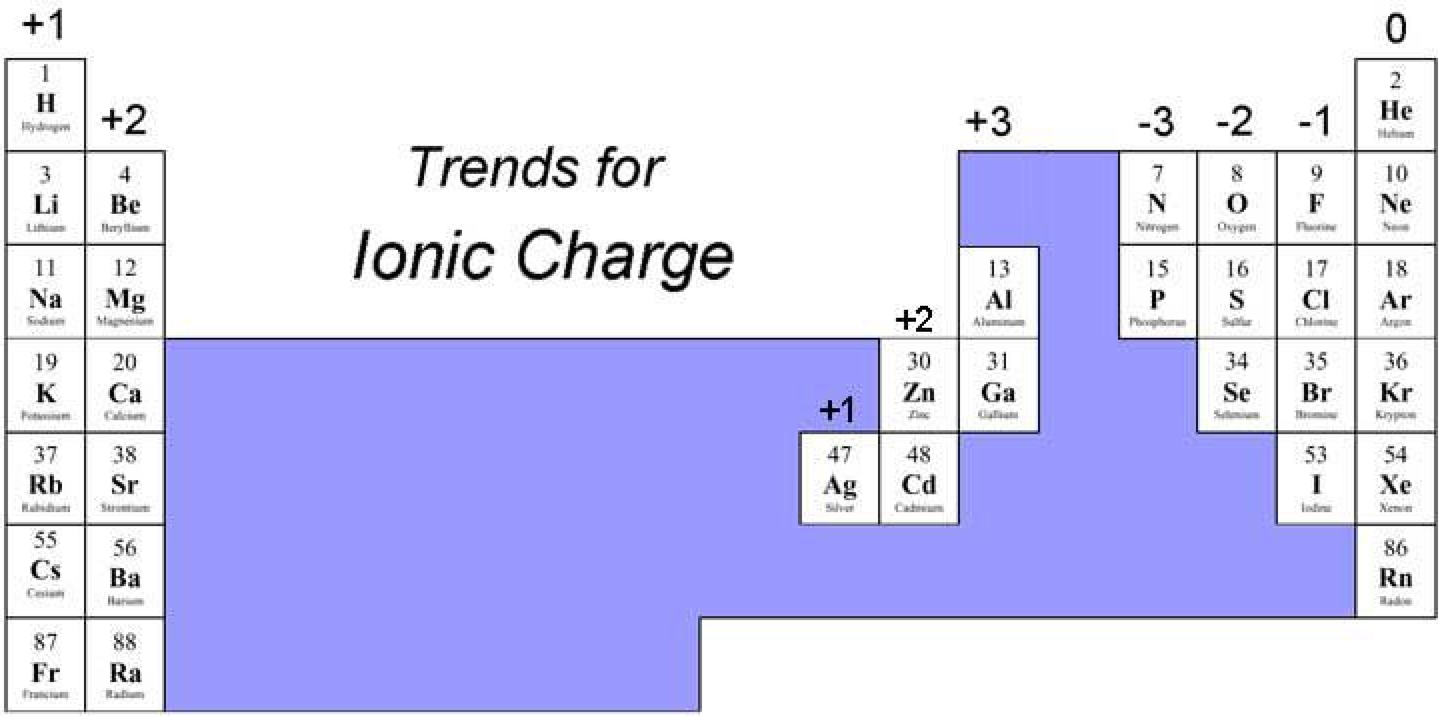
Main

Metallic and Non-metallic Character

- Metals have low ionization energy values-they have a tendency to lose electrons during chemical reactions
  - They tend to be oxidized

- Non-metals have high electron affinities-they have a tendency to gain electrons during chemical reactions
  - They tend to be reduced

Metallic and Non-metallic Character



Metal and Non-metal Oxides

- An oxide is formed from the combination of an element with oxygen

Na^{+} combines with O^{2-} to form Na_2O

Ca^{2+} combines with O^{2-} to form CaO

Al^{3+} combines with O^{2-} to form Al_2O_3

Metal and Non-metal Oxides

- Metal oxides are basic and react with water to form metal hydroxides

$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$ calcium hydroxide

$Na_2O(s) + H_2O(l) \rightarrow 2Na(OH)(aq)$ sodium hydroxide

Metal and Non-metal Oxides

- Non-metal oxides are acidic and react with water to form acidic solutions

$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$	carbonic acid
$SO_3(l) + H_2O(l) \rightarrow H_2SO_4(aq)$	sulfuric acid
$SO_2(l) + H_2O(l) \rightarrow H_2SO_3(aq)$	sulfurous acid
$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$	phosphoric acid

Metal and Non-metal Oxides

- SiO_2 does not dissolve in water, however it is classified as an acidic oxide because it can react with sodium hydroxide to form sodium silicate and water

$$SiO_2(s) + 2NaOH(aq) \rightarrow Na_2SiO_3(aq) + H_2O(l)$$

- Al_2O_3 is classified as an amphoteric oxide-it can react as both an acid and as a base
  - As an acid:

$$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$$

  - As a base:

$$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$$

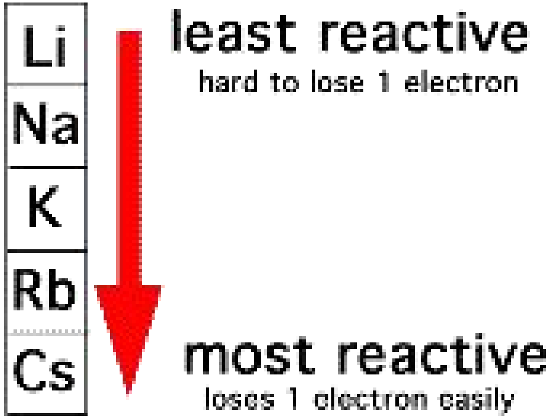
Metal and Non-metal Oxides

- Trends in period 3

Formulas of Oxide	$Na_2O(s)$	$MgO(s)$	$Al_2O_3(s)$	$SiO_2(s)$	$P_4O_{10}(s)$	$SO_3(l)$ and $SO_2(g)$
Nature of Oxide	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic

Group 1 Reactivity

- Group 1 metals react with water to form a metal hydroxide, MOH(aq)
- This reaction gives an alkaline solution and hydrogen gas



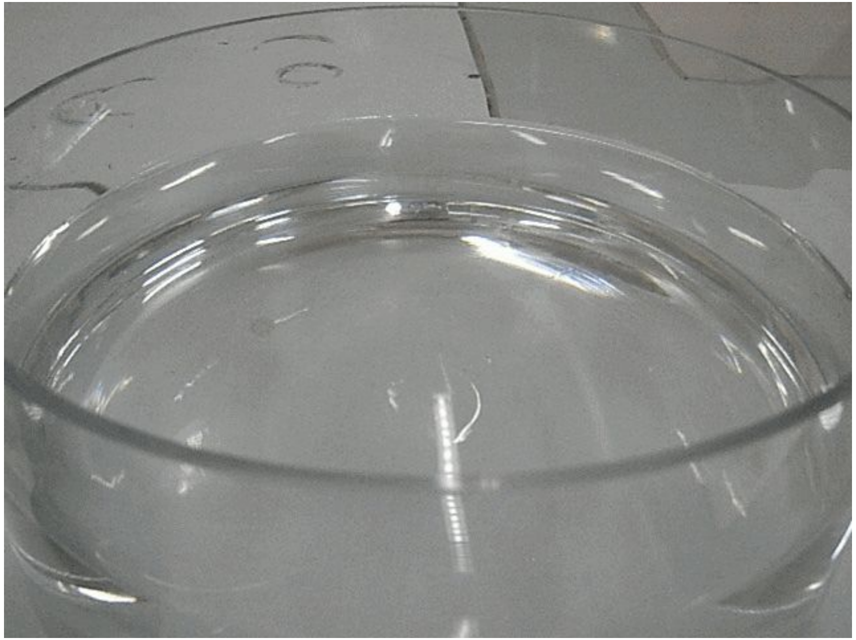
Main

Group 1 Reactivity

Group 1 Metal	Reaction with Water	Description
Li	$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$	Lithium reacts slowly and floats on water. Bubbling observed.
Na	$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$	Sodium reacts vigorously. Heat is evolved and sodium melts.
K	$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$	Potassium reacts more vigorously. The reaction is violent. It evolves enough heat to ignite hydrogen, so it bursts into flames instantly.
Rb	$2Rb(s) + 2H_2O(l) \rightarrow 2RbOH(aq) + H_2(g)$	Both rubidium and caesium react explosively with water.
Cs	$2Cs(s) + 2H_2O(l) \rightarrow 2CsOH(aq) + H_2(g)$	

Group 1 Reactivity

Lithium in Water



Sodium in Water

Reactivity

Group 17 Reactivity

- Halogens in general are highly reactive, although reactivity decreases going down the group with the most reactive element being fluorine

- The decrease in reactivity is due to the increase in atomic radius down a group, making it less easy to gain an electron

Group 17 Reactivity

- Halogens, X_2, react with alkali metals $M(s)$ to form ionic alkali metal halide salts $MX(s)$.
- In the ionic compound, $MX(s)$, the cation is M^+ and the anion is X^-

$$2M(s) + X_2(g) \rightarrow 2MX(s)$$

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

Group 17 Reactivity

- A solution of a more reactive halogen, $X_2(aq)$, will react with a solution of halide ions, $X^-(aq)$, formed by a less reactive halogen

$$Cl_2(aq) + 2KBr(aq) \rightarrow 2KCl(aq) + Br_2(aq)$$

- Chlorine has a stronger attraction for an electron than bromine.

- Chlorine forms the chloride anion more readily than bromide

Group 17 Reactivity

- Going down group 17 the ability to gain an electron decreases

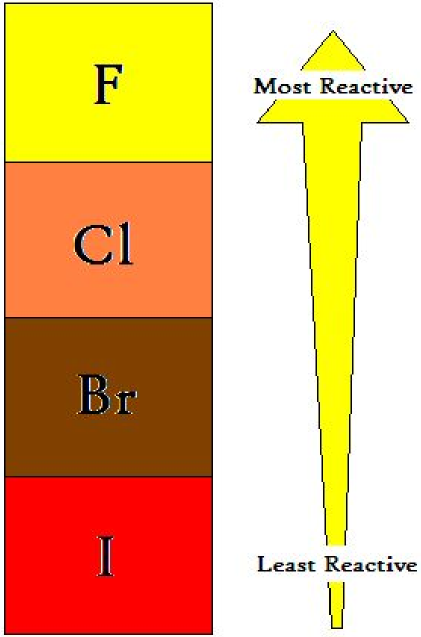
$F_{2(g)} + 2e^- \rightarrow 2F^-_{(aq)}$

$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(aq)}$

$Br_{2(l)} + 2e^- \rightarrow 2Br^-_{(aq)}$

$I_{2(s)} + 2e^- \rightarrow 2I^-_{(aq)}$

The formation of the hydrated ions happens much more easily at the top of the Group.



Group 17 Reactivity

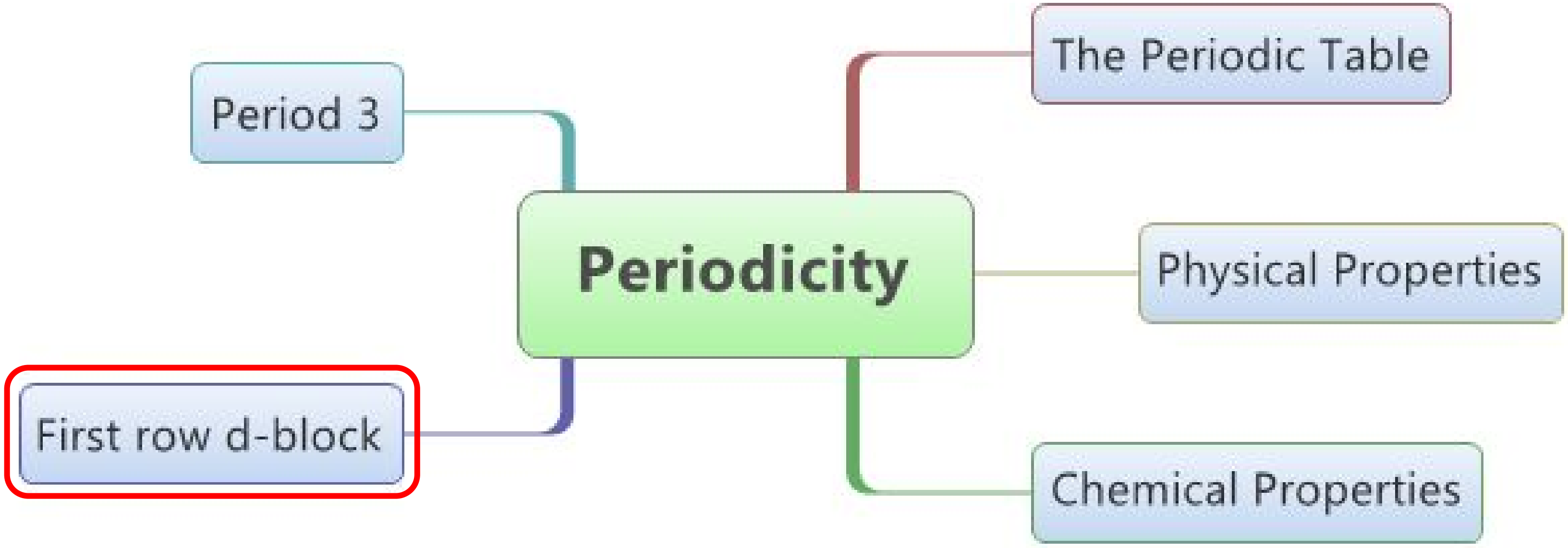
$X_2(aq)$	$Cl^-(aq)$	$Br^-(aq)$	$I^-(aq)$
$Cl_2(aq)$	No reaction	$Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$ Observation: yellow/orange solution due to the formation of $Br_2(aq)$	$Cl_2(aq) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$ Observation: dark red/brown solution due to the formation of $I_2(aq)$
$Br_2(aq)$	No reaction	No reaction	$Br_2(aq) + 2I^-(aq) \rightarrow 2Br^-(aq) + I_2(aq)$ Observation: dark red/brown solution due to the formation of $I_2(aq)$
$I_2(aq)$	No reaction	No reaction	No reaction

Lesson 4

13.1 The Periodic Table-Transition Metals

Main

We Are Here


Period 3
The Periodic Table
Periodicity
Physical Properties
First row d-block
Chemical Properties

Transition Metals

- A transition metal is an element that has an atom with an incomplete d-sublevel
- The f-block elements are sometimes described as the inner transition elements
- The elements of group 12, Zn, Cd, Hg, and Cn, are not classified as transition metals because all four elements have full d-sublevels containing ten d-electrons

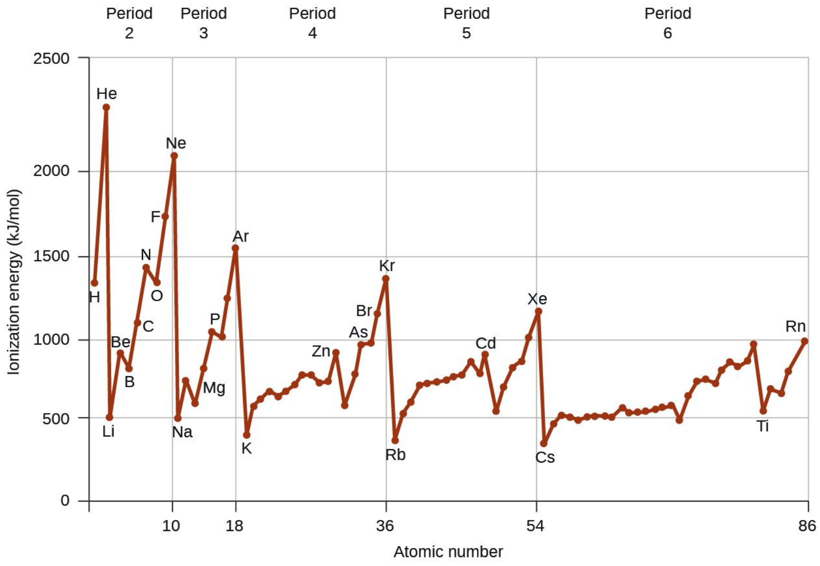
Transition Metals

- Zn
  - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$
- Zn^{+2}
  - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

- Zn still has a full sublevel

Characteristics of Transition Elements

- There is a gradual increase in the first IE across the period at a rate that is much lower compared to that of the main-group elements



Main

Characteristics of Transition Elements

- They have variable oxidation states
- Compounds of transition elements and their ions are often colored
- Transition metals form complexes with ligands
- Transition metals are often catalysts
- Magnetic properties of transition metals depend on their oxidation states and coordination number

Variable Oxidation States

- In contrast to an alkali metal, where the oxidation state is always +1 in its ion and compounds, transition metals are often found with different oxidation states
- The range of different oxidation states for the first-row d-block elements can be found in section 14 of the data booklet
- Transition elements show an oxidation state of +2 when the 4s-electrons are removed

14. Common oxidation numbers of the 3d ions

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
								+1	
	+2	+2	+2	+2	+2	+2	+2	+2	+2
+3	+3	+3	+3	+3	+3	+3			
	+4	+4		+4					
		+5							
			+6	+6					
				+7					

Oxidation States of Transition Metals

$$+2 + 4(0) = +2$$

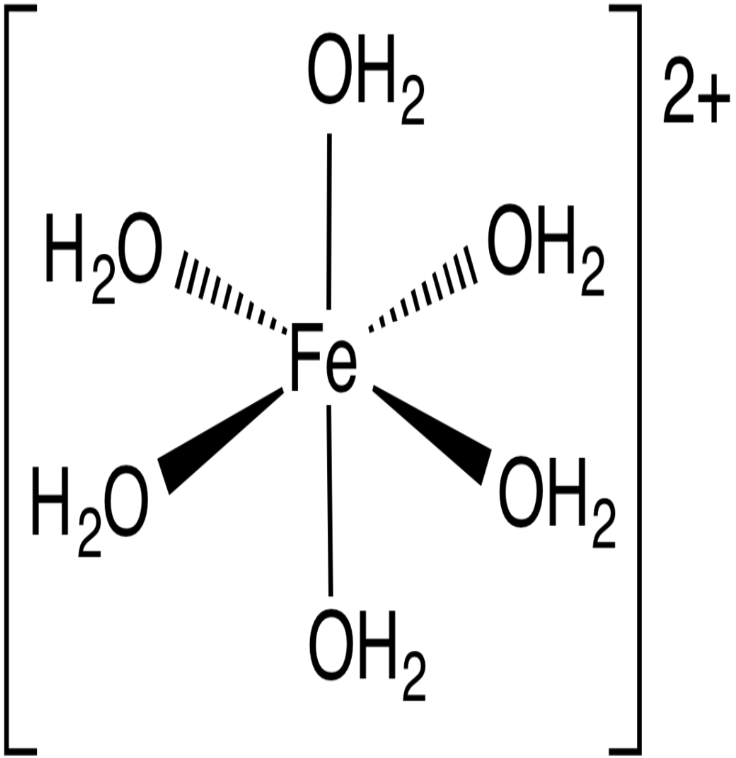
$$[Cu(NH_3)_4]^{2+}$$

$$+3 + 4(0) + 2(-1) = +1$$

$$Cr(H_2O)_4Cl_2$$

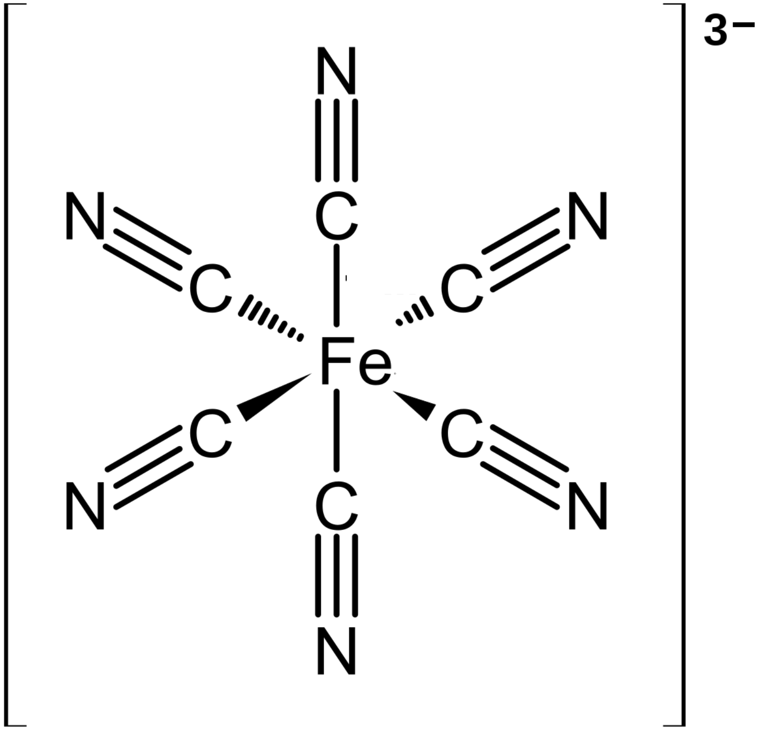
Oxidation States of Transition Metals

- Water is a neutral molecule
- The charge on the complex ion is +2
- The oxidation state of Fe is +2



Oxidation State of Transition Metals

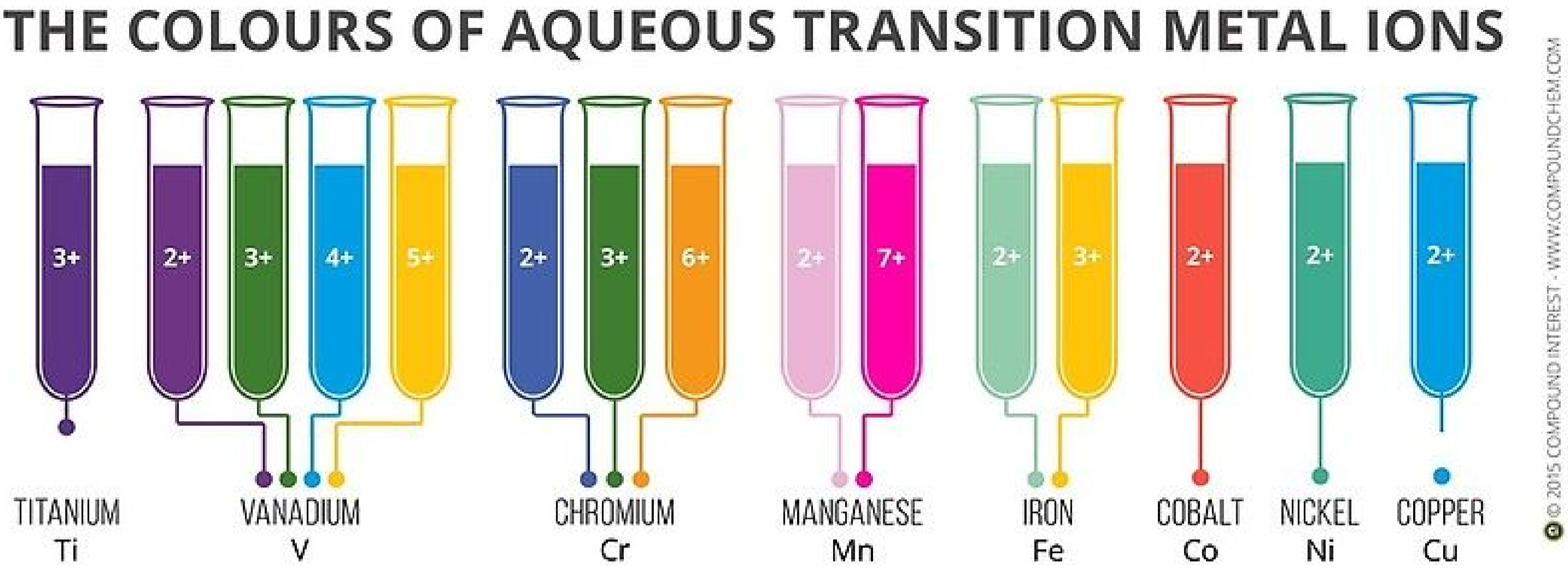
- CN has a charge of -1
- There are 6 CN with a -1 charge
  - 6 x -1 = -6
- The charge of the complex ion is -3
- The oxidation state of Fe is +3



Colored Compounds of Transition Metals

Transition Metal Compound	Color
$KMnO_4$	Burgundy (purple)
$[Mn(H_2O)_6]^{2+}$	Almost colorless; slight pink tint
$K_2Cr_2O_7$	Orange
$[Cr(H_2O)_6]^{3+}$	Green
$CuSO_4 \cdot 5H_2O$	Blue
$[NH_4]_2[Fe(H_2O)_6][SO_4]_2$	Pale Green

Colored Compounds of Transition Metals



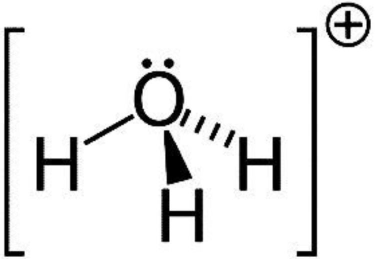
Complexes of Transition Metals

- Compounds that contain transition elements and in which the central metal ion is bonded to a group of molecules or ions are transitional metal complexes

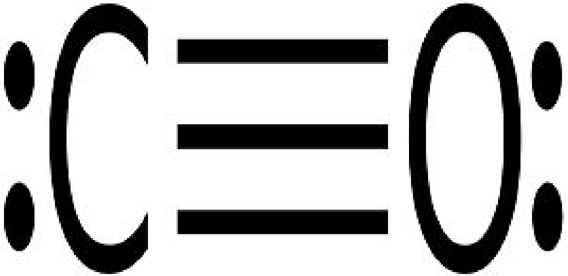
- A ligand is an atom, molecule, or ion that contains a lone pair of electrons (non-bonding) that coordinates, through coordinate bonding aka covalent bonding, to a central transition metal ion to form a complex

Coordinate Bonding

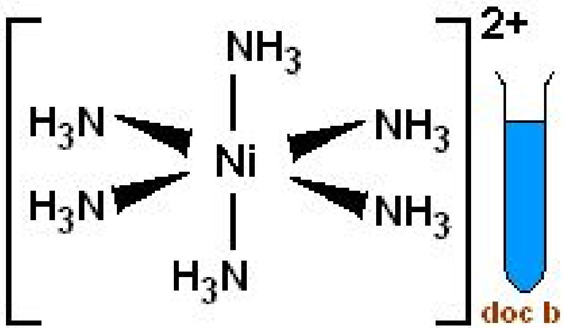
Hydronium Ion, H_3O^+



Carbon Monoxide, CO



$[Ni(NH_3)_6]^{2+}$



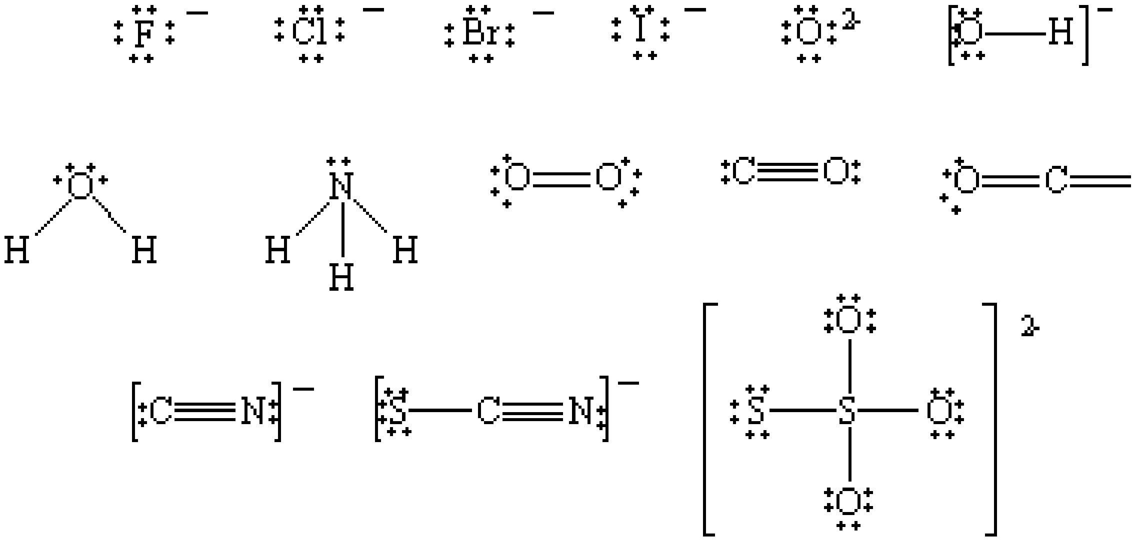
Main

Classification of Ligands

- The number of coordinate bonds formed by one ligand with a metal ion depends on the number of donor centers (atoms with lone electron pairs) in the ligand
- Monodentate ligands-able to form only one coordinate bond with a metal ion
- Polydentate ligands (chelate ligands)-can form two or more bonds

Monodentate Ligands

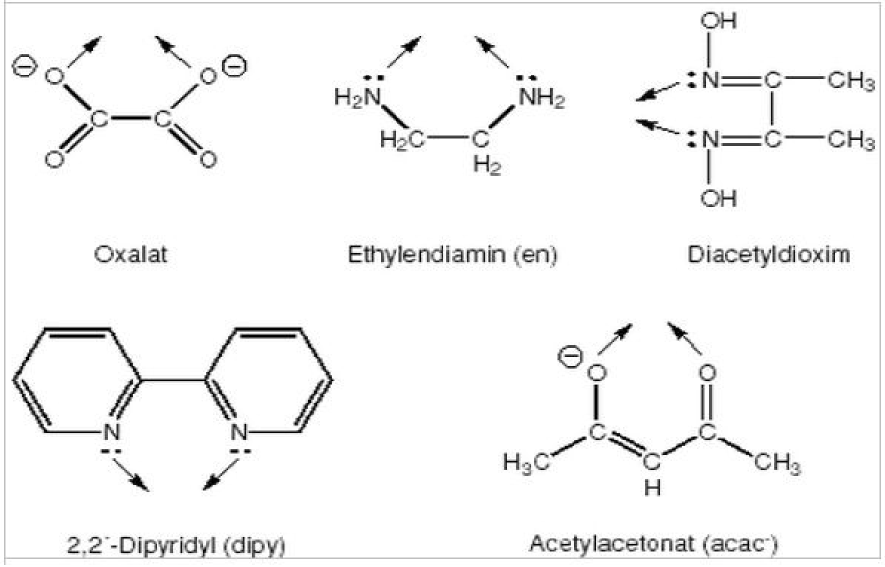
- Contain a single donor atom and have one lone pair contributing to the coordinate bond in a complex



Main

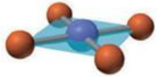
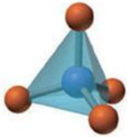
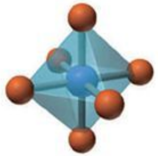
Polydentate (Chelate) Ligands

- Ligands which have two or more donor atoms that form coordinate bonds with a transition metal center



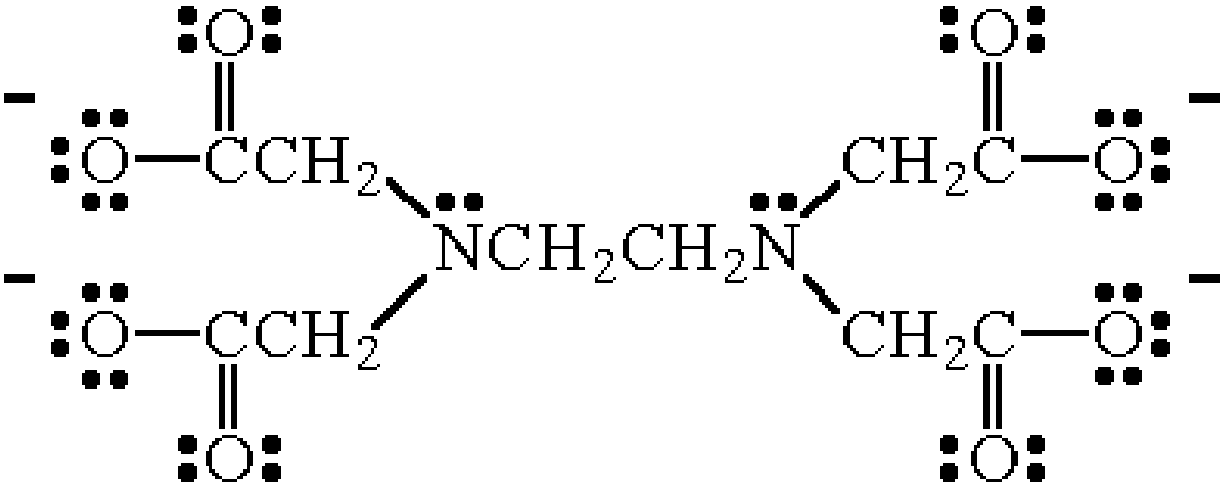
Geometry of Complex Ions

Coordination numbers and shapes of some complex ions

Coordination Number	Shape		Examples
2	Linear		$[CuCl_2]^-$, $[Ag(NH_3)_2]^+$, $[AuCl_2]^-$
4	Square planar		$[Ni(CN)_4]^{2-}$, $[PdCl_4]^{2-}$, $[Pt(NH_3)_4]^{2+}$, $[Cu(NH_3)_4]^{2+}$
4	Tetrahedral		$[Cu(CN)_4]^{3-}$, $[Zn(NH_3)_4]^{2+}$, $[CdCl_4]^{2-}$, $[MnCl_4]^{2-}$
6	Octahedral		$[Ti(H_2O)_6]^{3+}$, $[V(CN)_6]^{4-}$, $[Cr(NH_3)_4Cl_2]^+$, $[Mn(H_2O)_6]^{2+}$, $[FeCl_6]^{3-}$, $[Co(en)_3]^{3+}$

Ethylenediaminetetraacetate (EDTA)$^{4-}$

- Polydentate ligand that can form up to 6 coordinate bonds; hexadentate ligand



$(EDTA)^{4-}$ Uses

- Removal of heavy metals
  - Used to treat lead poisoning
- Chelation Therapy
  - Used in heart by-pass surgery
- Water Softening
  - Ensures that no free calcium or magnesium ions remain
  - Used in shampoos for the same reason

$(EDTA)^{4-}$ Uses

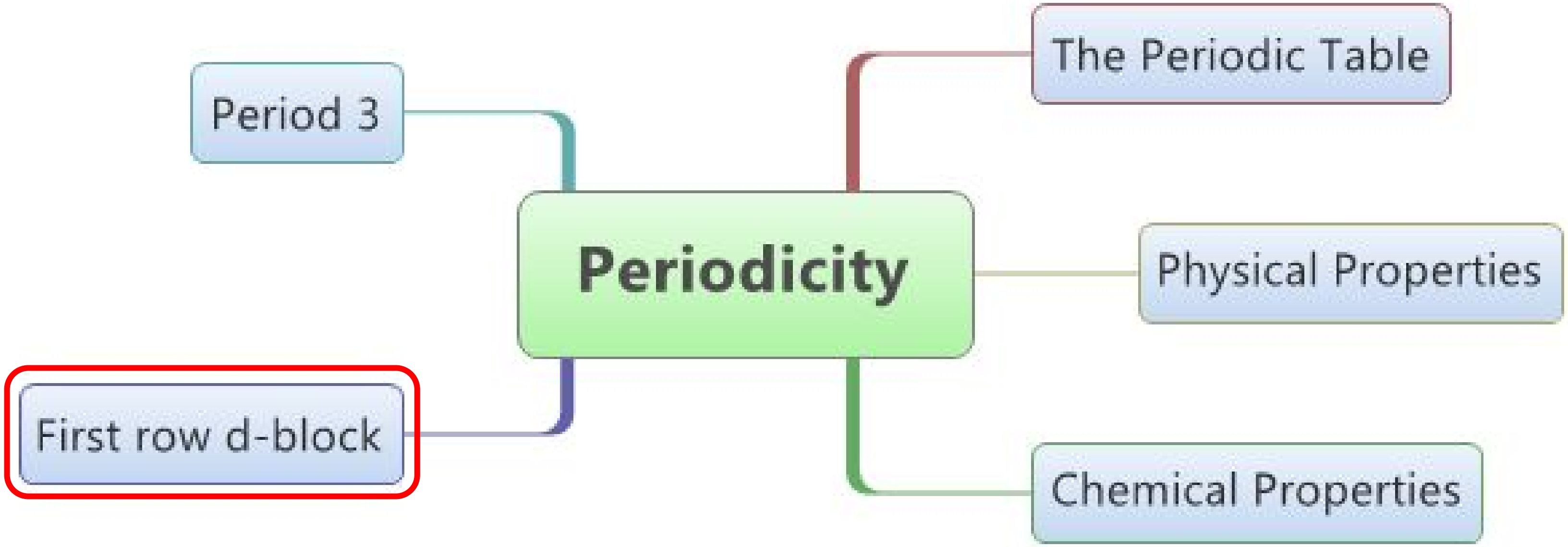
- Food Preservation
  - EDTA replaces metal ions that cause rancidity, bad odor, taste, smell, in foods
- Restorative Sculpture
  - Bonds with copper to become soluble and easy to remove
- Cosmetics
  - Used as a preservative

Lesson 5

13.1 The Periodic Table-Transition Metals

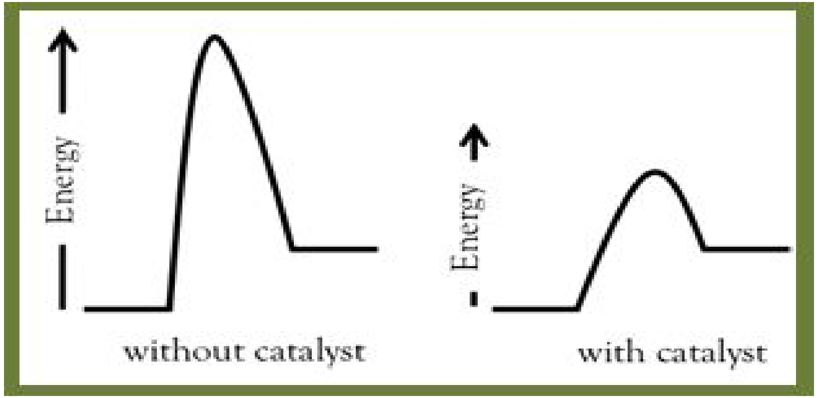
Main

We Are Here


Period 3
The Periodic Table
Periodicity
Physical Properties
First row d-block
Chemical Properties

Catalyst

- A catalyst is a substance that speeds up a chemical reaction, but is not consumed by the reaction
- A catalyst can be recovered chemically unchanged at the end of the reaction it has been used to speed up, or catalyze.



Transition Metals as Catalysts

- Haber Process: Main industrial procedure for the production of ammonia
  - $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$
  - Catalyst: Fe(s)

- Decomposition of hydrogen peroxide
  - $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$
  - Catalyst: $MnO_2(s)$

Transition Metals as Catalysts

- Hydrogenation of Alkenes: Addition of two hydrogens across a double bond
  - $H_2C=CH_2(g) + H_2(g) \rightarrow CH_3CH_3(g)$
  - Catalyst: Ni(s), Pd(s), Pt(s)
- Hydrogenation of Oils: Unsaturated oils can be turned into saturated oils and hardened
  - $RCH=CHR' + H_2(g) \rightarrow RCH_2CH_2R'$
  - Catalyst: Ni(s)

Hydrogenation of Oils

- Used for cooking purposes
- Disadvantages of hydrogenation
  - Unsaturated oils are healthier for the heart
  - Difficulties metabolizing and can accumulate in the fatty tissues of the body
  - Increase cholesterol

Catalytic Converters in Cars

- In a running car engine, gaseous nitrogen and oxygen react under high temperature conditions (1500°C) to form nitrogen monoxide
  - $N_2(g) + O_2(g) \rightarrow 2NO(g)$

- When NO(g) is released into the atmosphere, it combines with $O_2(g)$ to form $NO_2(g)$
  - $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

Catalytic Converters in Cars

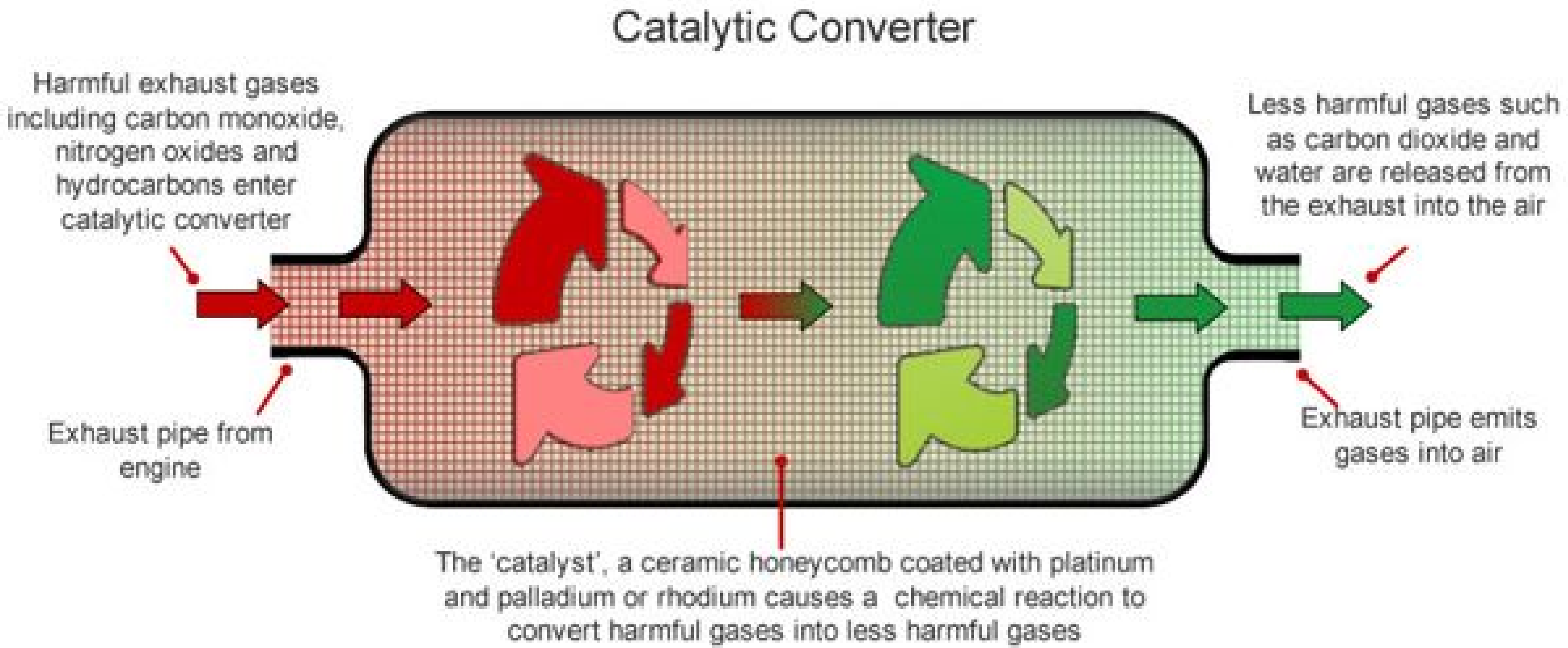
- Nitrogen dioxide is a secondary pollutant that is primarily responsible for the brown color of smog
- Nitrogen dioxide is toxic and can result in respiratory problems

Main

Catalytic Converters in Cars

- Carbon monoxide, CO(g), is a highly toxic, odorless, and colorless gas that is emitted from the exhaust of cars
- Most modern cars have catalytic converters that reduce NO(g) and NO_2(g) to N_2(g) while oxidizing CO(g) and unburned hydrocarbons to CO_2(g) and H_2O(g)

Catalytic Converters in Cars

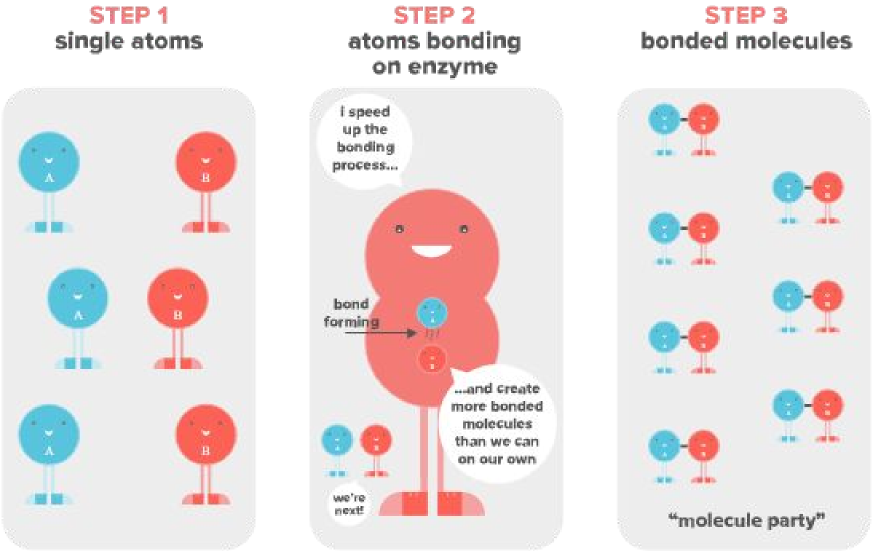


Catalysts in Green Chemistry

- Green chemistry is the design, development, and implementation of chemical products and processes to reduce or eliminate the use and generation of substances hazardous to human health and the environment

Biological Catalysts

- An enzyme is a biological catalyst
- Enzyme catalyst reactions occur in cells and involve transition metals



Main

Catalysts

- Homogeneous Catalyst
  - One that is in the same phase or physical state as the substances involved in the reaction that it is catalysing

- Heterogeneous Catalyst
  - One that is in a different phase to the substances involved in the reaction that is catalysing
  - Industrial catalysts that involve transition metals are usually heterogeneous catalyst

Magnetic Properties of Transition Metals

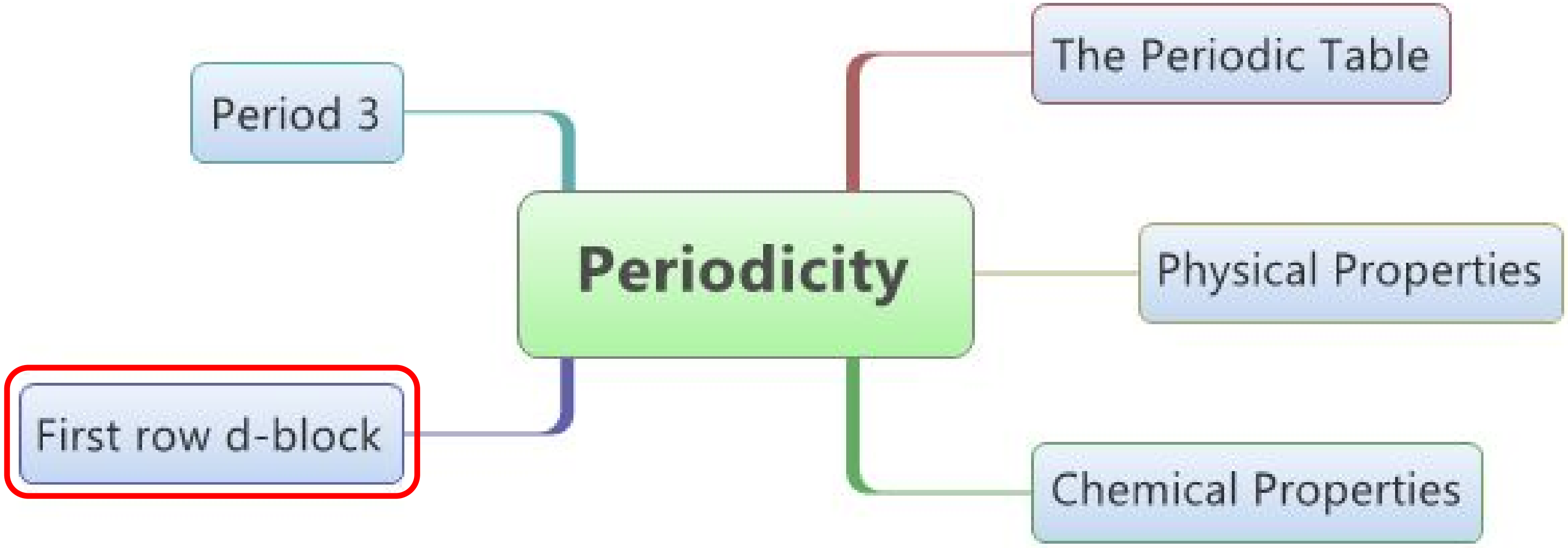
- Paramagnetic Materials
  - Contain unpaired electrons that behave as tiny magnets and are attracted by an external magnetic field
- Diamagentic Materials:
  - Do not contain unpaired electrons and therefore are repelled by magnetic fields

- Magnetic Properties of Transition Metals

Lesson 6

13.2 Colored Complexes

We Are Here



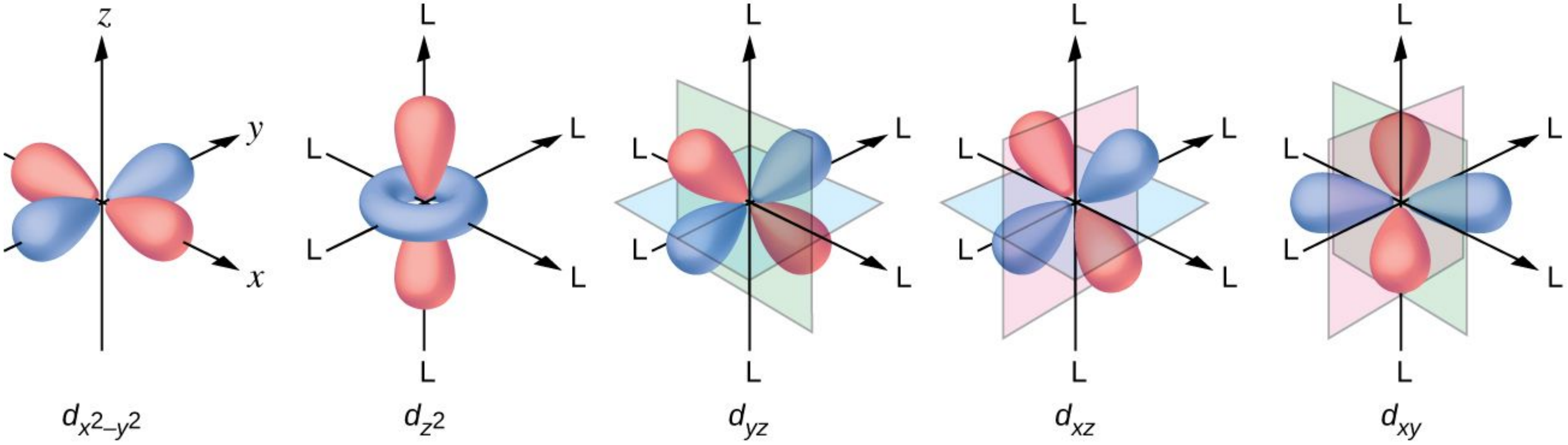
Period 3
The Periodic Table
Periodicity
Physical Properties
First row d-block
Chemical Properties

D-Orbitals

- When ligands bond to the central metal ion, there is repulsion between the electrons in the ligand and the electrons in the d sublevel of the metal ion

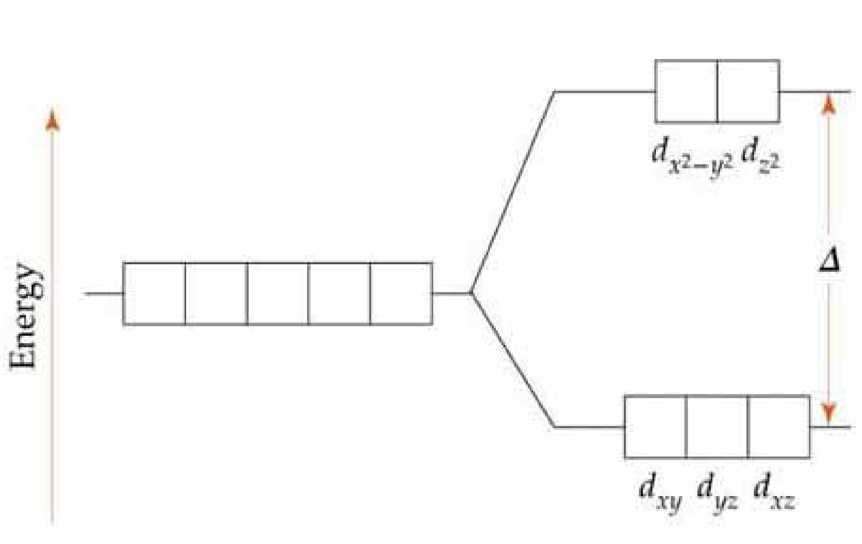
- This repulsion causes the five d orbitals to to split into two different sets; two with higher energy and three with lower energy

D-Orbitals



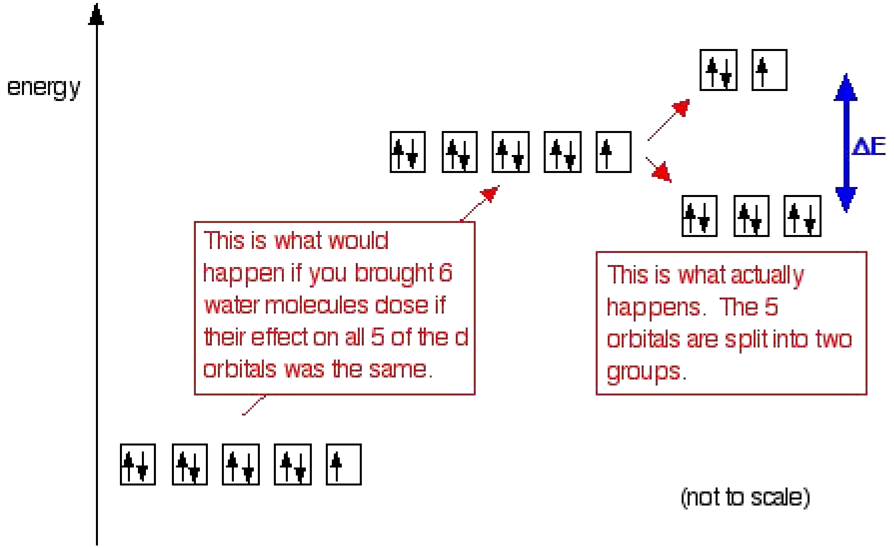
D-Orbitals

- The energy difference between the two sets of the d orbitals corresponds to the wavelengths of visible light



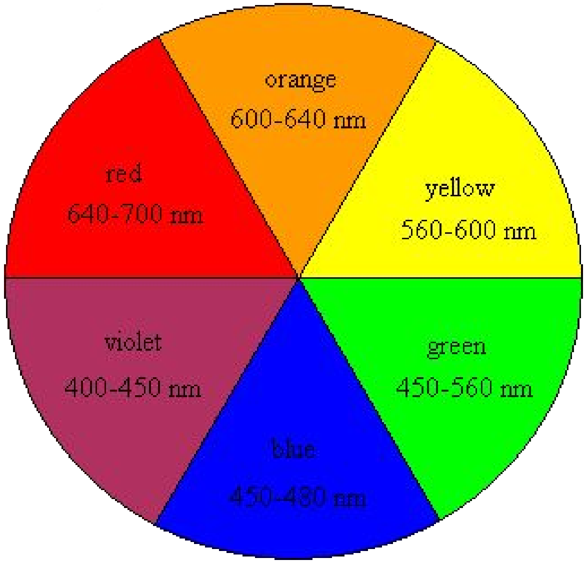
D-Orbitals

- Ions of transition metals have incomplete d sublevels
- Electrons can transition from the lower set to the higher set of d orbitals



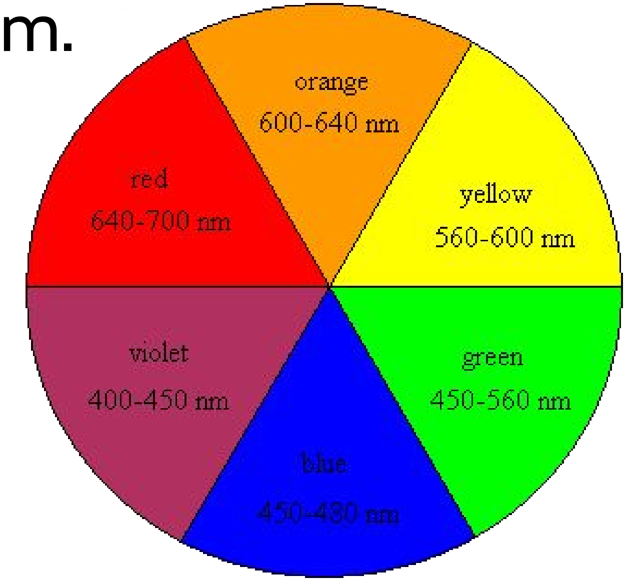
Color of Transition Metal Complexes

- For the color that is being absorbed, the opposite or complementary color is being transmitted



Example

- In $[Cu(H_2O)_6]^{2+}$, the energy, ΔE, required to promote an electron to the higher set of d-orbitals corresponds to a wavelength of 650-700 nm.
- Red is being absorbed
- Green is being transmitted



Main

Color of Transition Metal Complexes

- Any factor that changes the difference in energy between the two sets of d-orbitals will change the wavelength of light that is absorbed when the electron transitions from the lower to higher set, and therefore the color of the complex ion

Factors That Affect the Color of Complex Ions

- Identity of the metal ion
- Oxidation state of the metal ion
- Nature of the ligands
- Geometry of the complex ion (octahedral, tetrahedral,linear)

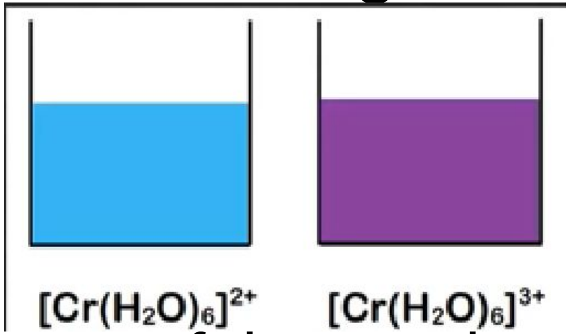
Identity of the Metal Ion

- The identity of the metal can influence the extent of splitting
- The change in energy, ΔE, increases descending a group with the metal ion the same oxidation state

Group 9 Complex	ΔE, cm^{-1}
$[Co(NH_3)_6]^{3+}$	22900
$[Rh(NH_3)_6]^{3+}$	34100
$[Ir(NH_3)_6]^{3+}$	41100

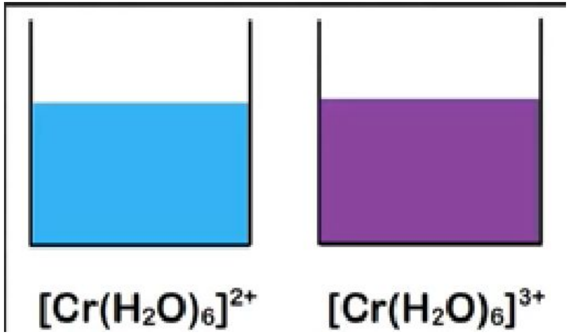
Example

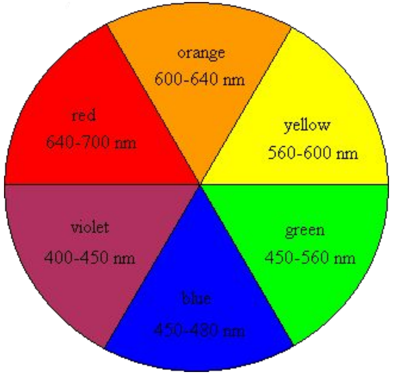
- The oxidation state of Cr changes from +2 to +3



- As the oxidation state of the metal increases, the amount of splitting in the d orbital also increases
- A change in oxidation state of Cr ion changes from +2 to +3 increases the difference in energy between the two sets of d orbitals

Example





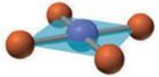
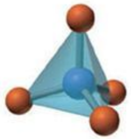
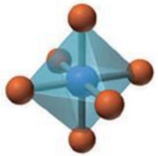
- The blue color indicates that orange is being absorbed, purple color indicates that yellow is being absorbed.
- As the energy difference between the two sets of d orbitals increases, the wavelength of light absorbed decreases

Nature of the Ligand

- Ligands may have different charge densities
- Ammonia had a greater charge density than water
- The splitting caused by ammonia will be greater than that of water

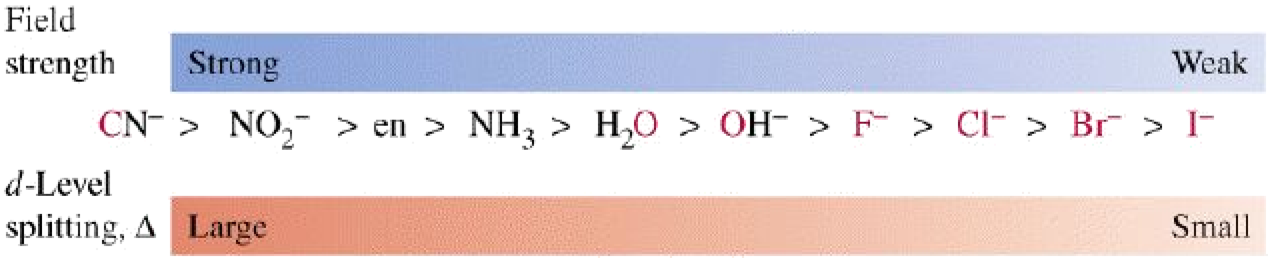
Geometry of Complex Ions

Coordination numbers and shapes of some complex ions

Coordination Number	Shape		Examples
2	Linear		$[CuCl_2]^-$, $[Ag(NH_3)_2]^+$, $[AuCl_2]^-$
4	Square planar		$[Ni(CN)_4]^{2-}$, $[PdCl_4]^{2-}$, $[Pt(NH_3)_4]^{2+}$, $[Cu(NH_3)_4]^{2+}$
4	Tetrahedral		$[Cu(CN)_4]^{3-}$, $[Zn(NH_3)_4]^{2+}$, $[CdCl_4]^{2-}$, $[MnCl_4]^{2-}$
6	Octahedral		$[Ti(H_2O)_6]^{3+}$, $[V(CN)_6]^{4-}$, $[Cr(NH_3)_4Cl_2]^+$, $[Mn(H_2O)_6]^{2+}$, $[FeCl_6]^{3-}$, $[Co(en)_3]^{3+}$

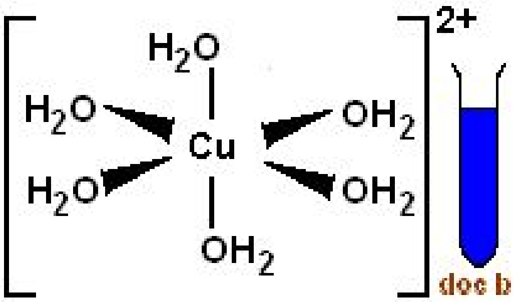
Spectrochemical Series

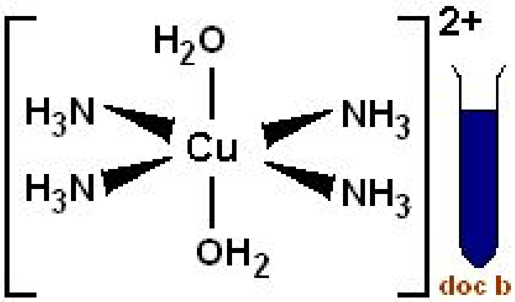
- The spectrochemical series arranges ligands in order of their ability to split d orbitals in an octahedral complex



- The greater the splitting, the greater the energy difference between the two sets of d orbitals

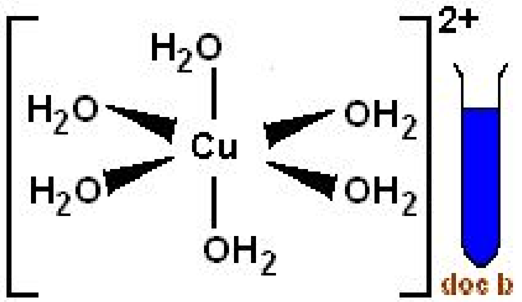
Spectrochemical Series

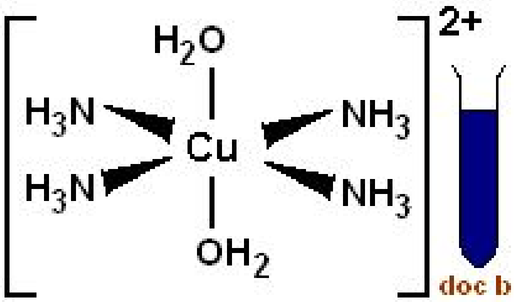


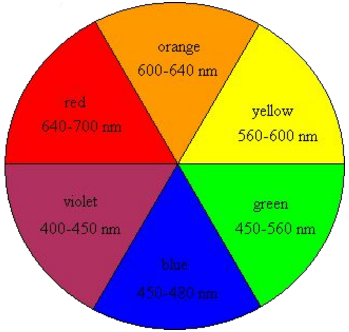


- NH_3 produces the greatest splitting and the largest difference in energy between the two sets of d orbitals
- More energy is absorbed by the electron transitions from the lower to upper set of d orbitals, decreasing the wavelength of light absorbed

Spectrochemical Series







- $[Cu(H_2O)_6]^{2+}$: red/orange is absorbed, blue/green light is transmitted
- $[Cu(NH_3)_4(H_2O)_2]^{2+}$: yellow is absorbed, violet is transmitted
- Yellow light has a shorter wavelength, higher energy than red/orange

Main