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FALL 2009

**GEOLOGY 284:
MINERALOGY**

Mineralogy and the Development of Modern Chemistry

A Bit of History

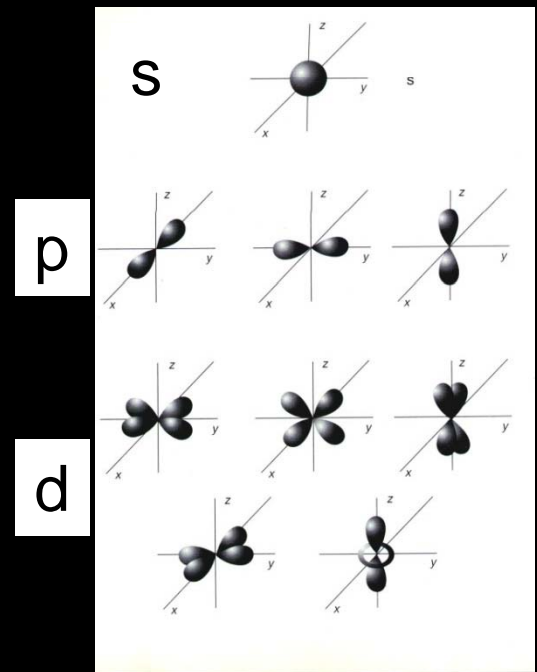
- Mineral processing and isolation of elements dates back to 2900 B.C. (gold, silver, bronze (copper-tin alloy))
- Alchemists developed techniques for purifying elements from minerals and studied mineral properties (~1500 B.C.); they hoped they could change base metals into gold
- Greeks (Aristotle, Theophrastus and others) debated the nature of matter and came up with the concept of **ATOMS** (smallest, indivisible building blocks of matter) 400-300 B.C.

History (continued)

- Then there was a big gap....
 - Philosophers & theoreticians were isolated from practitioners (ivory tower?)
 - Utility of combining theory and practice was finally realized at beginning of the Industrial Revolution
- Big advances in Chemistry and Mineralogy finally began in the 1800s

Elements

- Simple, uncombined chemical substances of which all compounds are made
- Concept of **atoms** revived. **Atoms** consist of:
 - **protons** - massive nuclear particles with + charge
 - **neutrons** - massive nuclear particles with no charge
 - **electrons** - very low mass wave/particles with negative charge, orbit nucleus in elusive **orbitals** (variously shaped areas in which electrons have a high probability of being found)



The Periodic Table

- It was recognized in about 1870 that if elements are arranged in order of increasing atomic weight (chemical combining weight), there is a periodic repetition of chemical properties
- This led to arrangement of elements in rows and columns
- And finally, to the **modern periodic table**
- Sequence numbers are **atomic numbers** = # of protons = # of electrons

WebElements: the periodic table on the world-wide web

<http://www.webelements.com/>

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
hydrogen 1 H 1.00794(7)																	helium 2 He 4.002602(2)	
lithium 3 Li 6.941(2)	beryllium 4 Be 9.012182(3)											boron 5 B 10.811(7)	carbon 6 C 12.0107(8)	nitrogen 7 N 14.00674(7)	oxygen 8 O 15.9994(3)	fluorine 9 F 18.9984032(5)	neon 10 Ne 20.1797(6)	
sodium 11 Na 22.989770(2)	magnesium 12 Mg 24.3050(6)											aluminium 13 Al 26.981538(2)	silicon 14 Si 28.0855(3)	phosphorus 15 P 30.973761(2)	sulfur 16 S 32.06(6)	chlorine 17 Cl 35.4527(9)	argon 18 Ar 39.948(1)	
potassium 19 K 39.0983(1)	calcium 20 Ca 40.078(4)		scandium 21 Sc 44.955910(8)	titanium 22 Ti 47.867(1)	vanadium 23 V 50.9415(1)	chromium 24 Cr 51.9961(6)	manganese 25 Mn 54.938049(9)	iron 26 Fe 55.845(2)	cobalt 27 Co 58.933200(9)	nickel 28 Ni 58.6934(2)	copper 29 Cu 63.546(3)	zinc 30 Zn 65.39(2)	gallium 31 Ga 69.723(1)	germanium 32 Ge 72.61(2)	arsenic 33 As 74.82160(2)	selenium 34 Se 78.96(3)	bromine 35 Br 79.904(1)	krypton 36 Kr 83.80(1)
rubidium 37 Rb 85.4678(3)	strontium 38 Sr 87.62(1)		yttrium 39 Y 88.90585(2)	zirconium 40 Zr 91.224(2)	niobium 41 Nb 92.90638(2)	molybdenum 42 Mo 95.94(1)	technetium 43 Tc [98.9063]	ruthenium 44 Ru 101.07(2)	rhodium 45 Rh 102.90550(2)	palladium 46 Pd 106.42(1)	silver 47 Ag 107.8682(2)	cadmium 48 Cd 112.411(8)	indium 49 In 114.818(3)	tin 50 Sn 118.710(7)	antimony 51 Sb 121.760(1)	tellurium 52 Te 127.60(3)	iodine 53 I 126.90447(3)	xenon 54 Xe 131.29(2)
caesium 55 Cs 132.90545(2)	barium 56 Ba 137.327(7)	57-70 *	lutetium 71 Lu 174.967(1)	hafnium 72 Hf 178.49(2)	tantalum 73 Ta 180.9479(1)	tungsten 74 W 183.84(1)	rhenium 75 Re 186.207(1)	osmium 76 Os 190.23(3)	iridium 77 Ir 192.217(3)	platinum 78 Pt 195.078(2)	gold 79 Au 196.96655(2)	mercury 80 Hg 200.59(2)	thallium 81 Tl 204.3833(2)	lead 82 Pb 207.2(1)	bismuth 83 Bi 208.98038(2)	polonium 84 Po [208.9824]	astatine 85 At [209.9871]	radon 86 Rn [222.0176]
francium 87 Fr [223.0197]	radium 88 Ra [226.0254]	89-102 **	lanthanum 103 La [262.110]	rutherfordium 104 Rf [261.1089]	dubnium 105 Db [262.1144]	seaborgium 106 Sg [263.1186]	bohrium 107 Bh [264.12]	hassium 108 Hs [265.1306]	meitnerium 109 Mt [268]	unnilium 110 Uun [269]	ununium 111 Uuu [272]	unbibium 112 Uub [277]		ununquadium 114 Uuq [289]		ununhexium 116 Uuh [289]		ununoctium 118 Uuo [293]

atomic weight

atomic number

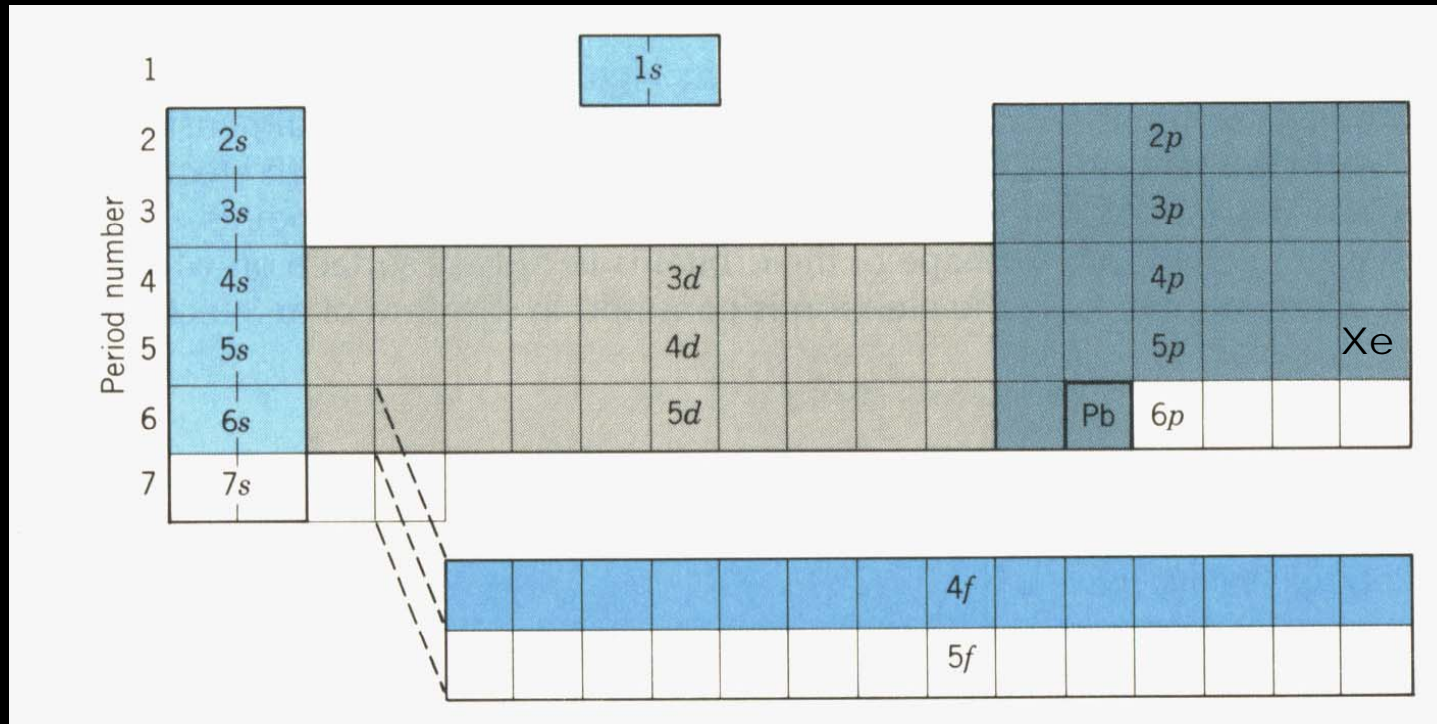
Key:
atomic number
 element symbol
 1997 atomic weight (mean relative mass)

*lanthanides

lanthanum 57 La 138.9055(2)	cerium 58 Ce 140.116(1)	praseodymium 59 Pr 140.90765(2)	neodymium 60 Nd 144.24(3)	promethium 61 Pm [144.9127]	samarium 62 Sm 150.36(3)	europium 63 Eu 151.964(1)	gadolinium 64 Gd 157.25(3)	terbium 65 Tb 158.92534(2)	dysprosium 66 Dy 162.50(3)	holmium 67 Ho 164.93032(2)	erbium 68 Er 167.26(3)	thulium 69 Tm 168.93421(2)	ytterbium 70 Yb 173.04(3)
actinium 89 Ac [227.0277]	thorium 90 Th 232.0381(1)	protactinium 91 Pa 231.03588(2)	uranium 92 U 238.02891(1)	neptunium 93 Np [237.0482]	plutonium 94 Pu [244.0642]	americium 95 Am [243.0614]	curium 96 Cm [247.0703]	berkelium 97 Bk [247.0703]	californium 98 Cf [251.0796]	einsteinium 99 Es [252.0830]	fermium 100 Fm [257.0951]	mendelevium 101 Md [258.0984]	nobelium 102 No [259.1011]

**actinides

Order of Filling of Electron Orbitals



- For example, Lead (Pb) $Z=82$ has the electron configuration
- $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^2$
- Some prefer to write it with all subshells of a given shell together
- $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^{10} 6s^2 6p^2$
- or $[\text{Xe}] 6s^2 4f^{14} 5d^{10} 6p^2$

See Periodic Table

- Properties of elements depend on which orbitals the valence (outer) electrons occupy.
- Names of Groups of Elements

Periodic Table of the Elements

	IA																	0	
1	H																		He
2	Li	Be											B	C	N	O	F	Ne	
3	Na	Mg											Al	Si	P	S	Cl	Ar	
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
6	Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
7	Fr	Ra	+Ac	Rf	Ha	Sg	Ns	Hs	Mt	110	111	112	113						

* Lanthanide Series

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

+ Actinide Series

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

Wooden Periodic Table



<http://www.theodoregray.com/PeriodicTable/index.html#tabletop>

a good book about chemistry: Uncle Tungsten by Oliver Sacks

Atomic and Molecular Weight

- Atomic weight of an atom (A) = number of protons (Z) + number of neutrons (N)
- Atomic weight of an element = weighted average of atomic weights of all its isotopes (different isotopes have different # of neutrons), properties depend mostly on # of protons/electrons
- In compounds (molecules, including minerals) elements are combined in proportion to their atomic weights

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The Fine Print

atomic numbers

chromium 24 Cr 51.9961(6)	manganese 25 Mn 54.938049(9)	iron 26 Fe 55.845(2)
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atomic weights

“The last significant figure of each value is considered reliable to ± 1 except where a larger uncertainty is given in parentheses.”

e.g., **At.Wt.(Mn) = 54.938049 \pm 0.000009**

“Elements for which the atomic weight is contained within square brackets have no stable nuclides and are represented by the element’s more important isotopes.”

Bonding

- Noble gases are particularly stable because they have completely filled electron shells
- Other elements try to fill their electron shells by “stealing” or sharing electrons, this results in **bonding**
 - When an atom gains one or more electrons it becomes a negatively charged **anion**
 - When an atom loses one or more electrons it becomes a positively charged **cation**

Types of Bonding

- Positively charged **cations** attract negatively charged **anions** to form **ionic bonds**
- When electrons are **shared**, the bonds are called **covalent bonds**
- **Metallic bonds** result when loosely bound valence (outer) electrons move freely throughout the structure (shared among many atoms, not just two as in covalent)

Covalent Bonds

- occur among identical atoms or those close together on the periodic table
- are the strongest type of bonds
 - therefore they form the hardest minerals
 - which have the highest melting temperatures
- are directional - the angle between bonds is controlled by orientation of the shared orbitals

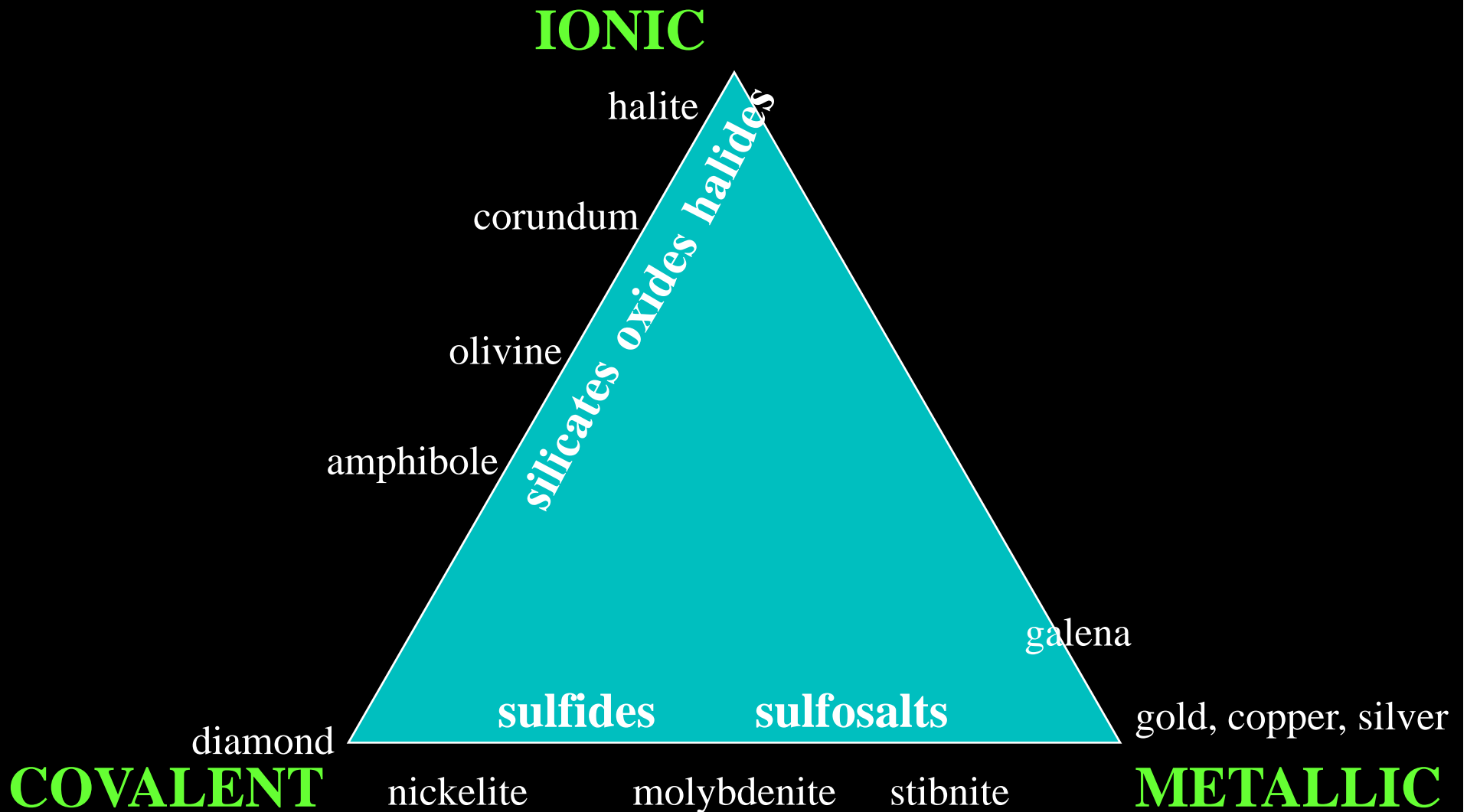
Ionic Bonds

- occur among atoms that are far apart on the periodic table
- are weaker than covalent, but stronger than metallic bonds
- form minerals that are soluble in H₂O, a polar solvent
- are non-directional - anions and cations can be approximated as charged spheres that pack closely together in mineral structures

Metallic Bonds

- are common in minerals that contain transition metals like Cu, Fe, Au, Zn...
- are the weakest of these bond types
 - therefore metallic minerals are relatively soft
- Because electrons are free to move throughout the structure, metallic minerals are good conductors of electricity

Bonding in most minerals is not purely ionic, purely covalent or purely metallic

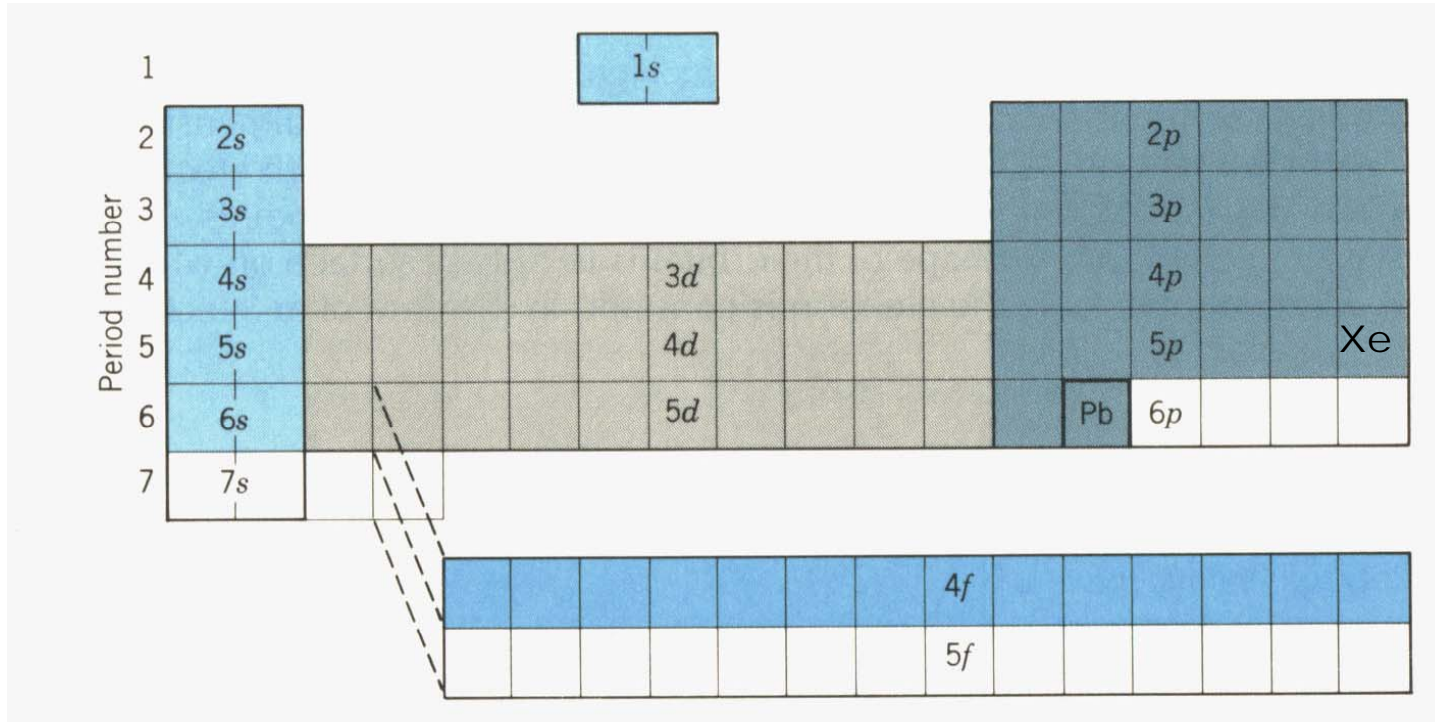


Earth Scientist's Periodic Table: A whole new approach

Bruce Railsback, U Georgia, Geology, 2003

<http://www.gly.uga.edu/railsback/PT.html>

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