

Physics 100 - February 23, 2009

- Exam 1 March 2 - in Hoyt - reg lecture time
- Allowed 3x5 in index card w/ notes
- Bring calculator ... be able to do "powers of ten"
- Q+A session Friday, Feb 27 4pm
in Meliora 208
- No lecture in Hoyt on March 4
I'll post PDF lecture slides and
accompanying mp3 audio file
- No recitations next week
(March 2-6)

Last
Time



Bohr Model of the atom

What characterizes it?

Why is it important?

In what ways was it a successful Model?

What were shortcomings?



Heisenberg

Quantum Mechanics

wave equation for matter waves



Schrödinger

$$-\frac{\hbar^2}{2m} \frac{d^2 \psi(x)}{dx^2} + V \psi(x) = E \psi(x) \quad \text{Schrödinger's Equation}$$

Plug in "potential" describing the physical situation

Solve for $\psi(x)$ and possible energies

Wave function

Put in e^- + Coulomb

→ get discrete allowed orbitals and energies for e^- in atom.

Only discrete energies and spatial states allowed for the electron to occupy $\rightarrow$ orbital

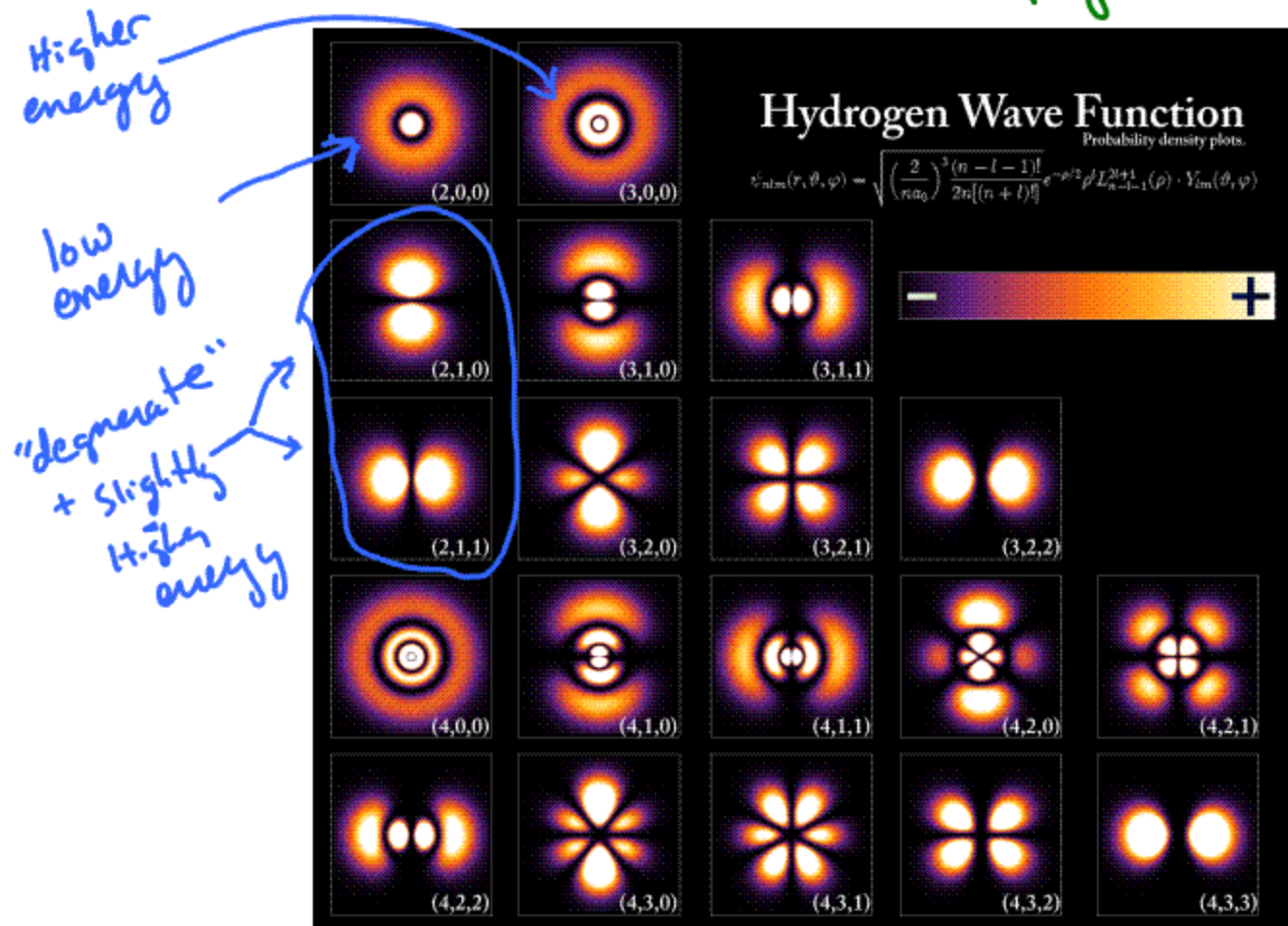
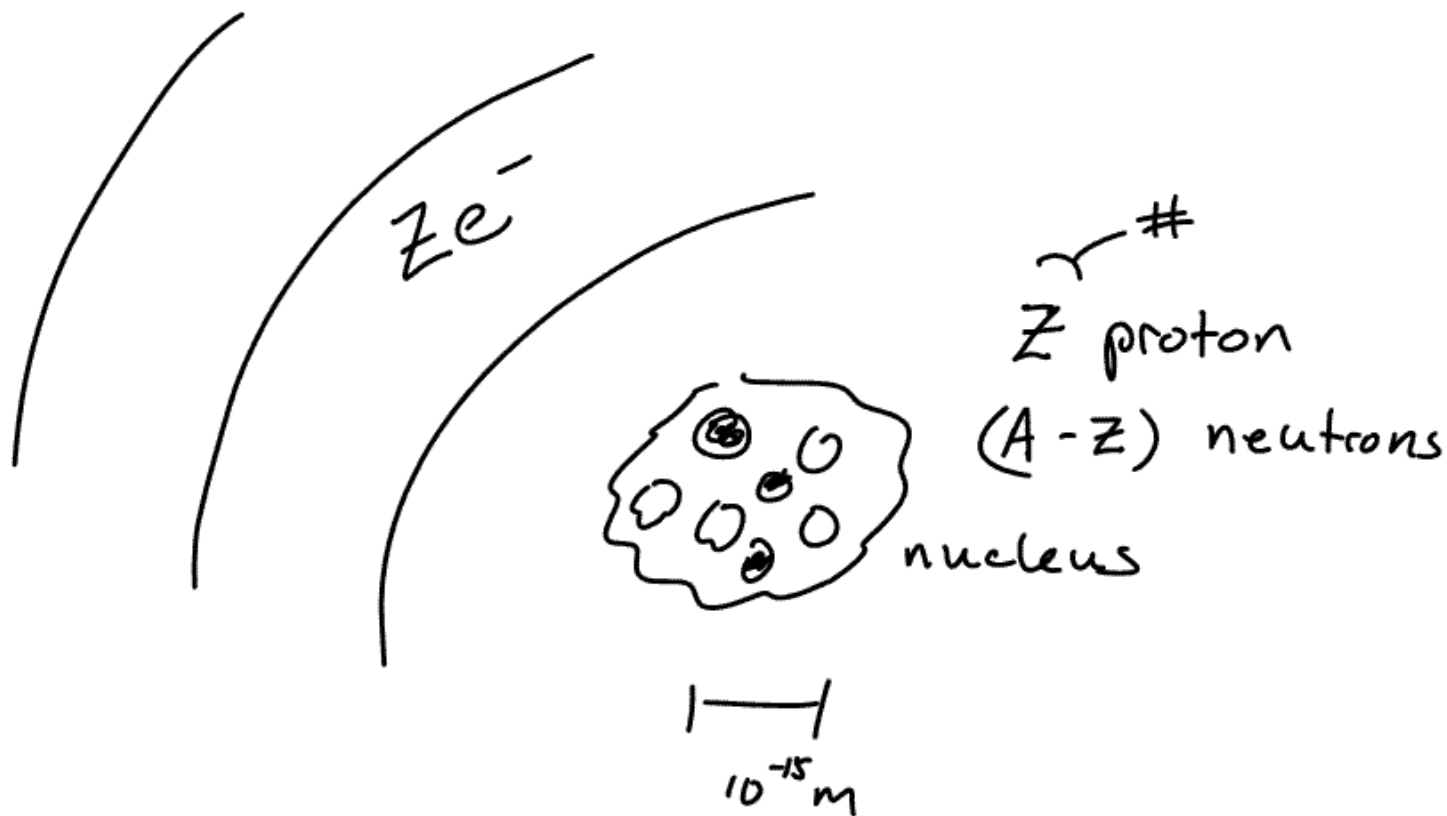


figure from http://en.wikipedia.org/wiki/File:Hydrogen_Density_Plots.png

Atomic orbital - SK: condo analogy



Solve Schr. eqn w/ spherical geometry + electrostatic force ...
discover that electron can only exist in particular discrete
states ... Sort of like a person can live in one condo
out of a few possibilities in a ski resort.

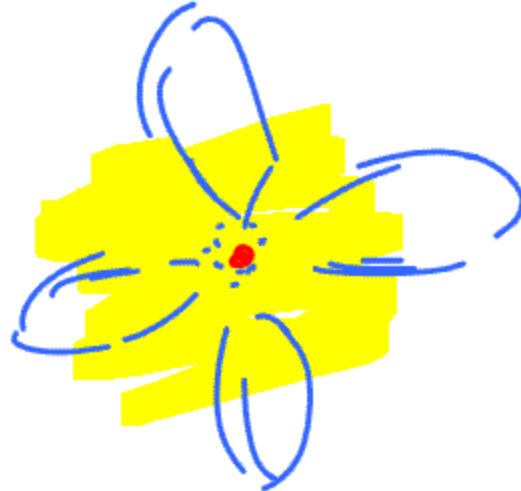


$A \equiv$ Atomic mass

Hydrogen has $Z=1$
Helium has $Z=2$
Lithium has $Z=3$

⋮
up to slightly over 100

known as elements



as Z increases $\rightarrow$ # electrons increase
 $\uparrow$
#protons in nucleus

How do these electrons populate the available orbitals?

To answer this we need to investigate

Particle Promiscuity

Stern-Gerlach experiment - 1922

→ Discovery that electrons have spin

Spin

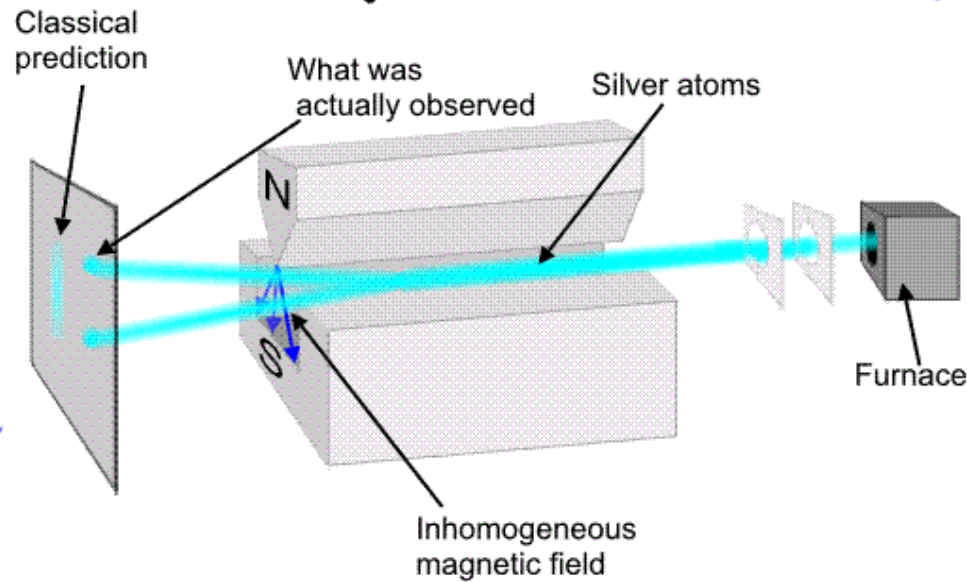


Diagram from
Wikipedia

OTTO STERN



"If this nonsense from Bohr will
prove to be right we will quit physics."
(Stern vowed in 1913)

-Wikipedia

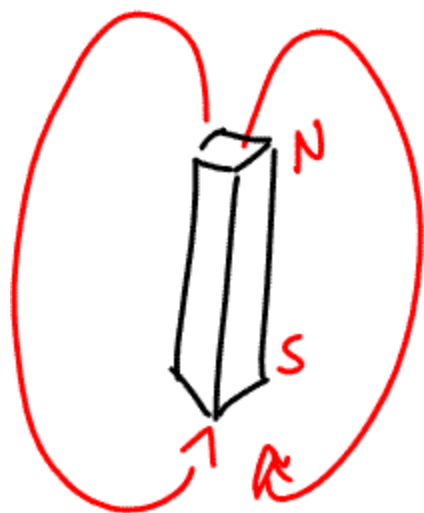
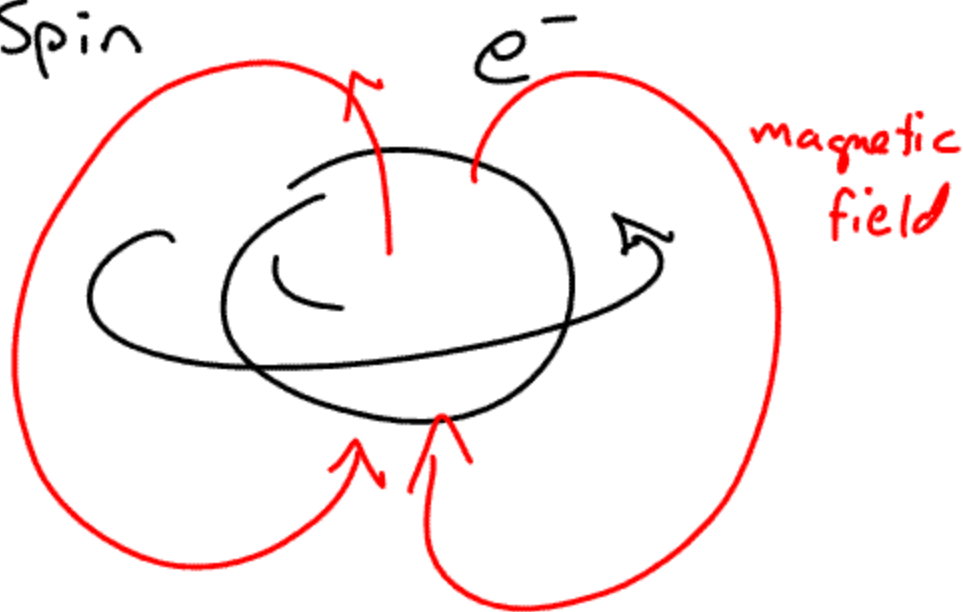
as quoted in Phys. Today Dec 03

Walther Gerlach



from phys Today article
(Dec. 03)

Intrinsic Spin



magnetic field
looks like a bar
magnet

Spin is quantized → only discrete values allowed

$0, \frac{1}{2}, 1, \frac{3}{2}, 2, \dots$

relative spin
(or magnetic field strength)

Particles have little
magnetic fields like
bar magnets
Think of as spinning charge
distribution

integer spin

0, 1, 2, ... Bosons

half integers

$\frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \dots$ Fermions

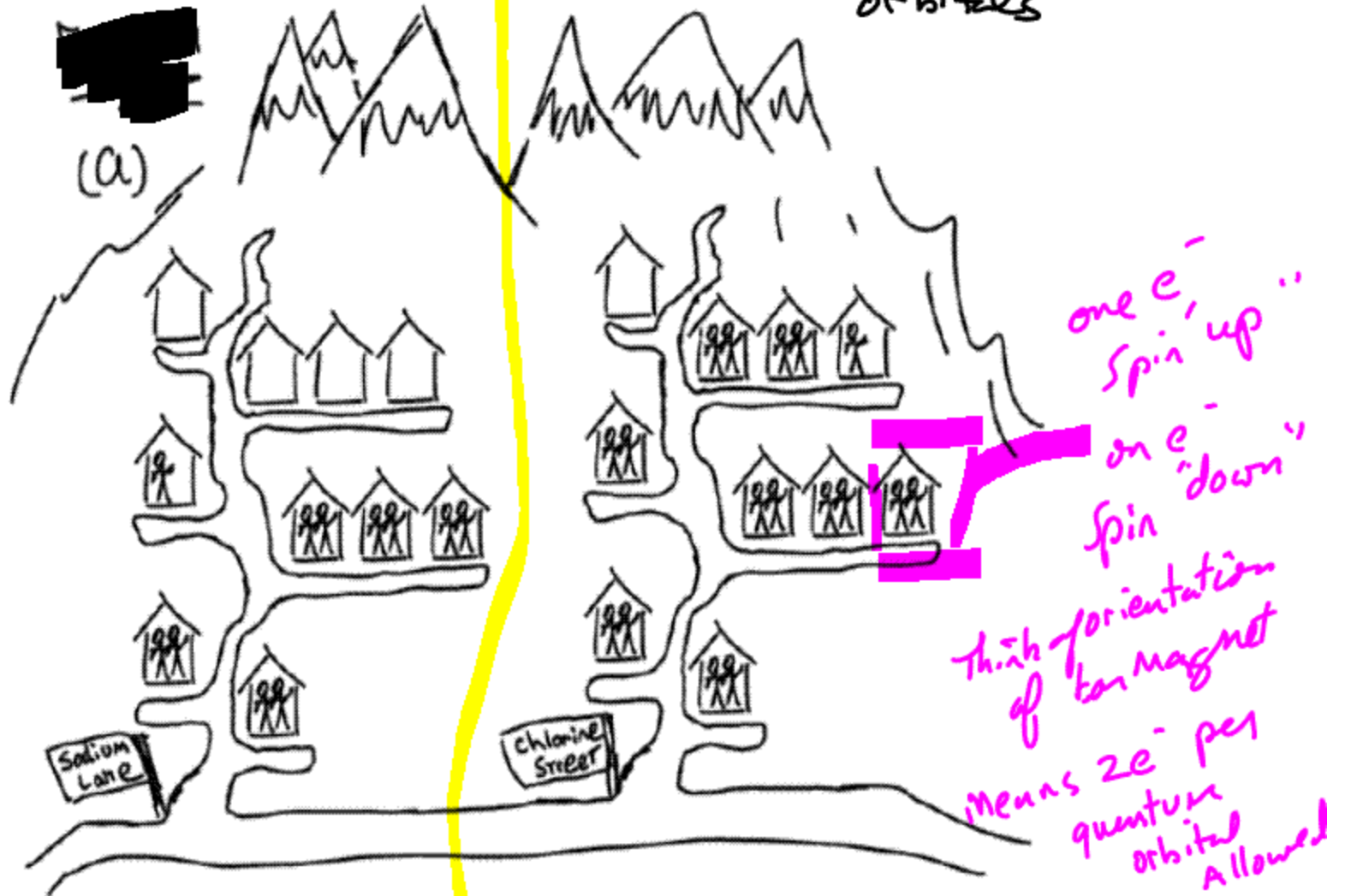
Particle Promiscuity

MANY
per quantum
STATE
Allowed

only 1
per
quantum
STATE
allowed

electrons are fermions
This governs how multiple electrons
fill available quantum orbitals

How different # of electrons populate the orbitals



Sodium (Na) has 11 electrons

Chlorine (Cl) has 17 electrons

When atoms interact by exchanging and/or sharing electrons, it is known as a chemical reaction

So, chemical reactivity / characteristics

depends on details of the available quantum states in the atom and how the electrons populate these states

If you arrange atoms in $\overset{\text{\# protons}}{\downarrow} Z / \text{mass} / \text{\# electrons}$

Notice periodicity of chemical properties and physical characteristics

Periodic Table of the elements

John Newlands - English analytical chemist
(1837-1898) ... Arranged table of elements
by ATOMIC Masses



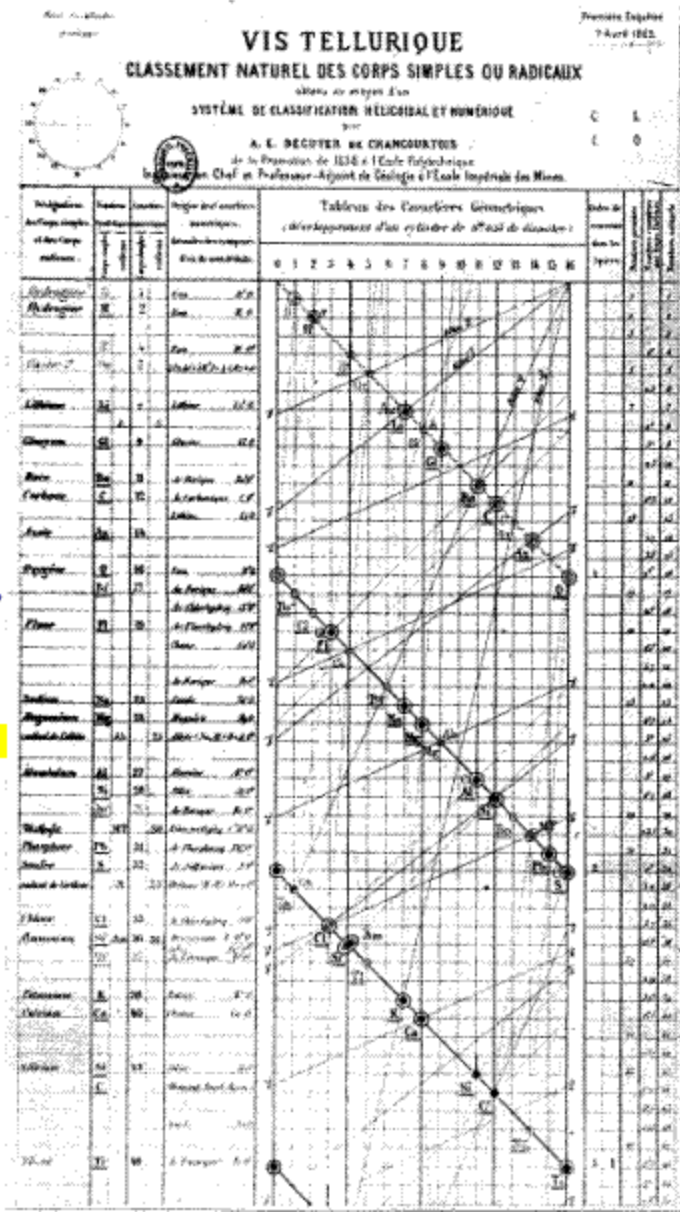
Antoine Lavoisier
France (1743-1794)

"Father of Modern
Chemistry"
QUANTITATIVE ANALYSIS

guillotined during French Revolution



**Alexandre-Émile
Béguyer de Chancourtios**
France (1820-1886)





Dmitri Mendeleev
Russian (1834-1907)

THE PERIODICITY OF THE ELEMENTS														
The Elements	Their Properties in the Free State				The Composition of the Hydrides and Organo-metallic Compounds	Symbols and Atomic Weights		The Composition of the Saline Oxides	The Properties of the Saline Oxides				Small Periods or Series	
	<i>t</i>	<i>a</i>	<i>d</i>	<i>A</i>		RH ₂ or R(CH ₃) ₃ _n	R		A	R ₂ O _x	$\frac{2(A + n'16)}{x}$	$\frac{2(A + n'16)}{x}$		V
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]		
Hydrogen	<-200°	—	<0.002	20	1	H	1	1	—	0.917	19.9	<-30	1	
Lithium	180°	—	0.50	12	—	Li	7	1†	—	29	12	-3	2	
Beryllium	(900°)	—	1.64	9.5	—	Be	9	—	2	396	16.8	+26	—	
Boron	(1600°)	—	2.5	10.8	—	B	11	—	3	15	10	10	—	
Carbon	>(3500°)	—	<29	12	—	C	12	—	4	>19	<68	<19	—	
Nitrogen	900°	—	<0.7	14	—	N	14	1	3*—5*	164	66	<5	—	
Oxygen	<-200°	—	<1.0	16	—	O	16	—	—	—	—	—	—	
Fluorine	—	—	—	—	—	F	19	—	—	—	—	—	—	
Sodium	90°	0.71	0.96	23	—	Na	23	1†	—	Na ₂ O	28	24	-22	3
Magnesium	500°	0.92	1.74	24	—	Mg	24	—	2†	36	22	-2	—	
Aluminium	900°	0.25	2.6	27	—	Al	27	—	3	Al ₂ O ₃	49	36	+12	—
Silicon	(1800°)	0.08	2.5	28	—	Si	28	—	4	—	—	—	—	
Phosphorus	44°	1.29	2.5	31	—	P	31	1	3*—4*—5*	230	59	62	—	
Sulphur	114°	0.87	2.01	32	—	S	32	2	4*—5*—6*	190	62	67	—	
Chlorine	-70°	—	1.5	35.5	—	Cl	35.5	1	3—5*—7*	—	—	—	—	
Potassium	58°	0.84	0.82	39	—	K	39	1†	—	27	35	-25	4	
Calcium	(900°)	—	1.6	40	—	Ca	40	—	2†	215	36	-7	—	
Scandium	—	—	—	—	—	Sc	44	—	3†	—	—	—	—	
Titanium	(2500°)	—	5.1	(39.4)	—	Ti	48	—	3—4—5	42	39	(+5)	—	
Vanadium	(2000°)	—	5.5	51	—	V	51	—	3—4—5	249	58	67	—	
Chromium	(2000°)	—	5.5	52	—	Cr	52	—	3—4—5—6*	274	70	9.5	—	
Manganese	(1500°)	—	7.5	55	—	Mn	55	—	3—4—5—6*	—	—	—	—	
Iron	1500°	0.12	7.8	56	—	Fe	56	—	3—4—5*	—	—	—	—	
Cobalt	(1800°)	0.12	8.6	59	—	Co	59	—	3—4—5*	—	—	—	—	
Nickel	1510°	0.17	8.7	58.7	—	Ni	58.7	—	3—4—5*	—	—	—	—	
Copper	1084°	0.89	8.8	63.5	—	Cu	63.5	1†	2†	Cu ₂ O	5.9	64	9.6	5
Zinc	920°	—	7.2	65.4	—	Zn	65.4	—	2†	—	—	—	—	
Gallium	30°	—	5.96	70	—	Ga	70	—	3	Ga ₂ O ₃	(51)	(36)	(40)	—
Germanium	900°	—	5.47	72.6	—	Ge	72.6	—	3—4—5*	47	44	43	—	
Arsenic	800°	0.06	5.7	75	—	As	75	—	3—4—5*	41	56	60	—	
Selenium	817°	—	4.9	79	—	Se	79	—	4—5*	—	—	—	—	
Bromine	-7°	—	0.1	80	—	Br	80	1	—	—	—	—	—	
Krypton	—	—	—	—	—	Kr	83.8	—	—	—	—	—	—	
Rubidium	39°	—	1.5	85.4	—	Rb	85.4	1†	—	—	—	—	—	
Strontium	(900°)	—	2.5	87.6	—	Sr	87.6	—	2†	45	48	-11	—	
Yttrium	—	—	—	—	—	Y	89	—	3†	505	45	(-2)	—	
Zirconium	(1500°)	—	3.4	91.2	—	Zr	91.2	—	3—4—5*	37	45	-24	—	
Niobium	—	—	7.1	92.9	—	Nb	92.9	—	3—4—5*	47	57	+6.3	—	
Molybdenum	—	—	8.6	95.9	—	Mo	95.9	—	3—4—5*	44	65	68	—	
(1)														
Rhenium	(2000°)	0.10	19.2	84.9	—	Re	186.2	—	3—4—5—6—7	—	—	—	—	
Rhodium	(1800°)	0.08	12.1	86.1	—	Rh	186.2	—	3—4—5—6—7	—	—	—	—	
Palladium	1300°	0.12	11.4	89.1	—	Pd	106.4	—	3—4—5—6—7	—	—	—	—	
Silver	1500°	0.19	10.5	107.9	—	Ag	107.9	1†	—	Ag ₂ O	7.5	61	11	7
Cadmium	320°	0.61	8.6	112.4	—	Cd	112.4	—	2†	813	51	25	—	
Indium	176°	0.46	7.4	114.8	—	In	114.8	—	3	In ₂ O ₃	7.18	38	27	—
Tin	226°	0.99	7.2	118.7	—	Sn	118.7	—	3—4—5*	695	43	28	—	
Antimony	452°	0.12	6.7	121.8	—	Sb	121.8	—	3—4—5*	62	49	26	8	
Tellurium	451°	0.17	9.4	127.6	—	Te	127.6	—	3—4—5*	51	66	47	—	
Iodine	114°	—	4.9	126.9	—	I	126.9	1	—	—	—	—	—	
Cesium	29°	—	1.88	132.9	—	Cs	132.9	1†	—	—	—	—	—	
Barium	—	—	3.75	137.3	—	Ba	137.3	—	2†	31	60	-60	—	
Lanthanum	(900°)	—	6.1	138.9	—	La	138.9	—	3†	65	50	+12	—	
Cerium	(700°)	—	6.6	140.1	—	Ce	140.1	—	3—4	674	50	29	—	
Praseodymium	(500°)	—	6.5	140.9	—	Pr	140.9	—	3—4	—	—	—	—	
(1)														
Thorium	—	—	10.9	232	—	Th	232	—	3	918	43	(-2)	10	
Tantalum	—	—	10.4	181	—	Ta	181	—	5	73	39	46	—	
Tungsten	(1500°)	—	19.1	183.8	—	W	183.8	—	4—6	69	67	8	—	
(1)														
Osmium	(2500°)	0.07	23.5	192	—	Os	192	—	3—4—5—6—7	—	—	—	—	
Iridium	2000°	0.07	22.4	192.2	—	Ir	192.2	—	3—4—5—6—7	—	—	—	—	
Platinum	1772°	0.05	21.5	195.1	—	Pt	195.1	—	3—4	—	—	—	—	
Gold	1063°	0.14	19.3	197.0	—	Au	197.0	1	—	Au ₂ O	12.5	(30)	(13)	11
Mercury	-39°	—	19.0	200.6	—	Hg	200.6	1†	2†	111	39	45	—	
Thallium	294°	0.51	11.8	204.4	—	Tl	204.4	1†	3	Tl ₂ O ₃	89	54	43	—
Lead	327°	0.29	11.8	207.2	—	Pb	207.2	—	3—4	—	—	—	—	
Bismuth	268°	0.14	9.8	208.9	—	Bi	208.9	—	3—4	—	—	—	—	
(5)														
Thallium	—	—	11.3	210	—	Tl	210	—	4	986	54	26	12	
(1)														
Uranium	(900°)	—	18.7	238	—	U	238	—	4—6	(72)	(80)	(9)	—	

when elements arranged by mass — see a certain periodicity in their chemical properties.

Very reactive in this column

Very inert in this column

Los Alamos National Laboratory Chemistry Division

Periodic Table of the Elements

Los Alamos National Laboratory Chemistry Division																Column v			
Periodic Table of the Elements																			
1A 1 H Hydrogen 1.008	2A												3A 5 B Boron 10.81	4A 6 C Carbon 12.01	5A 7 N Nitrogen 14.01	6A 8 O Oxygen 16.00	7A 9 F Fluorine 19.00	8A 10 Ne Neon 20.18	
3 Li Lithium 6.941	4 Be Beryllium 9.012																		
11 Na Sodium 22.99	12 Mg Magnesium 24.31	3B	4B	5B	6B	7B	8B		11B	12B	13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95			
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.58	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80		
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3		
55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La* Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.5	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 208.9	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)		
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac~ Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (264)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (271)	111 Uuu Ununundium (272)	112 Uub Unbibium (277)	114 Uuq Ununquadium (294)	116 Uuh Unhexium (296)	118 Uuo Ununoctium (?)					

Lanthanide Series*

58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (147)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
90 Th Thorium 232.0	91 Pa Protactinium (231)	92 U Uranium (238)	93 Np Neptunium (237)	94 Pu Plutonium (242)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (249)	99 Es Einsteinium (254)	100 Fm Fermium (253)	101 Md Mendelevium (256)	102 No Nobelium (254)	103 Lr Lawrencium (257)

very reactive in this column