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?

Quantum Mechanics

Heisenberg

Wave equation for matter waves

Schrödinger

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

Plug in "potential" describing the physical situation

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

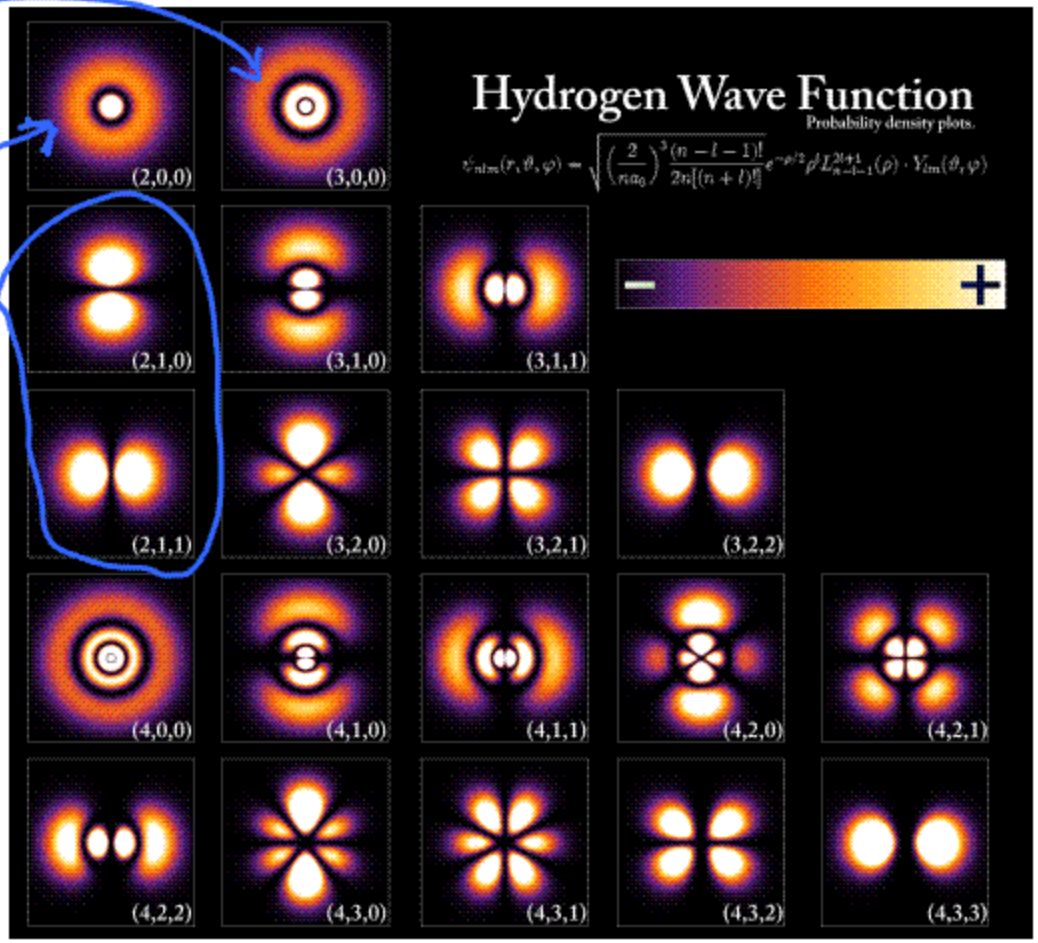
$\psi(x)$: Wave function

Put in e^- — p

+ Coulomb

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

Only discrete energies and spatial STATES allowed for the electron to occupy → orbital



Higher energy

low energy

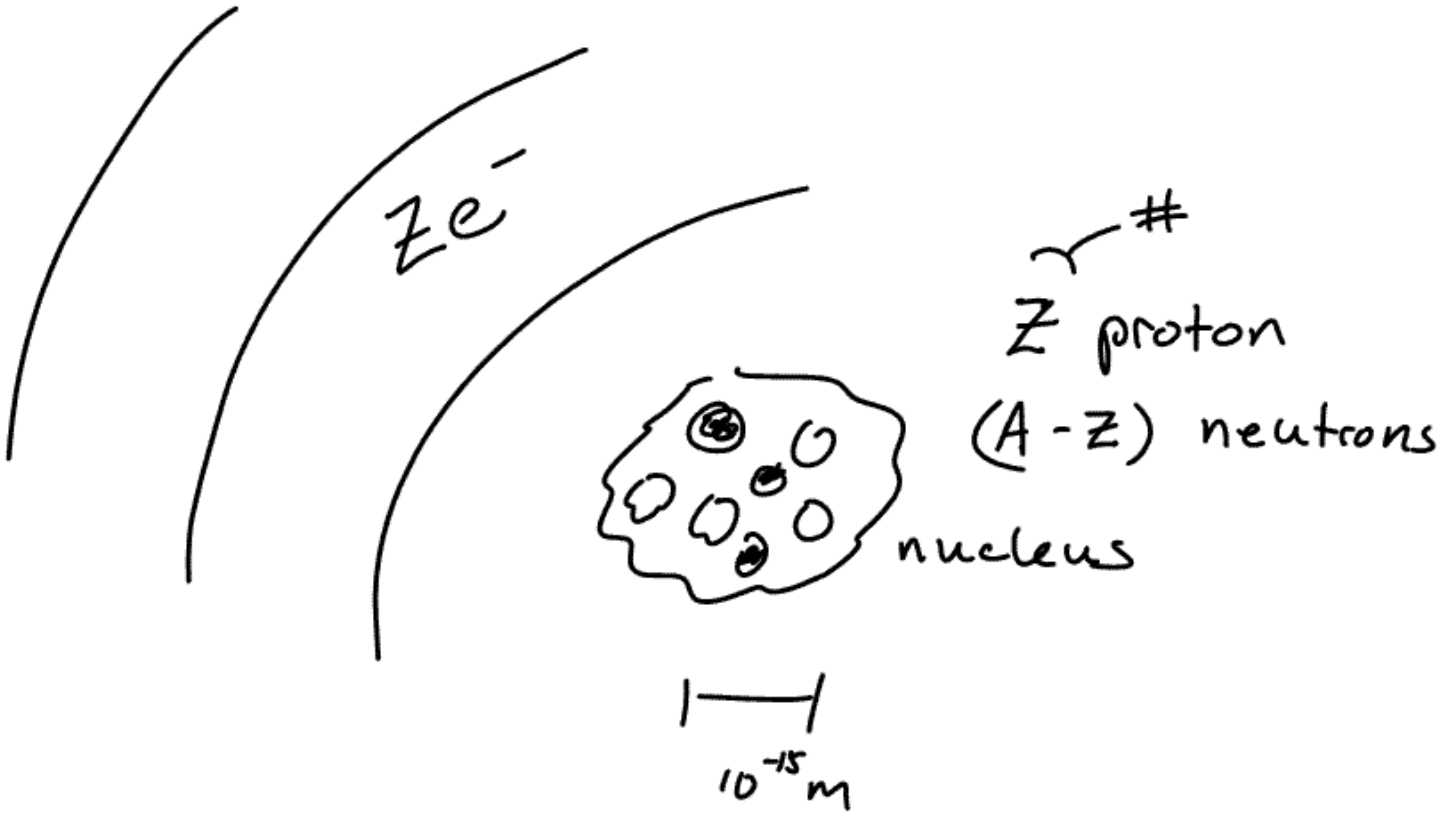
"degenerate" + slightly higher energy

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

Atomic orbital = ski condo analogy

Figure 20

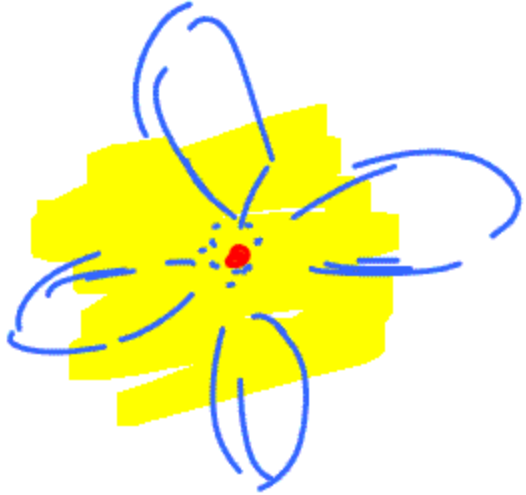
Solve Schr. eqn w/ spherical geometry + electrostatic force ... discover that electron can only exist in particular discrete states ... sort of like a person can live in one condo out of a few possibilities in a ski resort.



A ≡ 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 → # electrons increase

↑

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

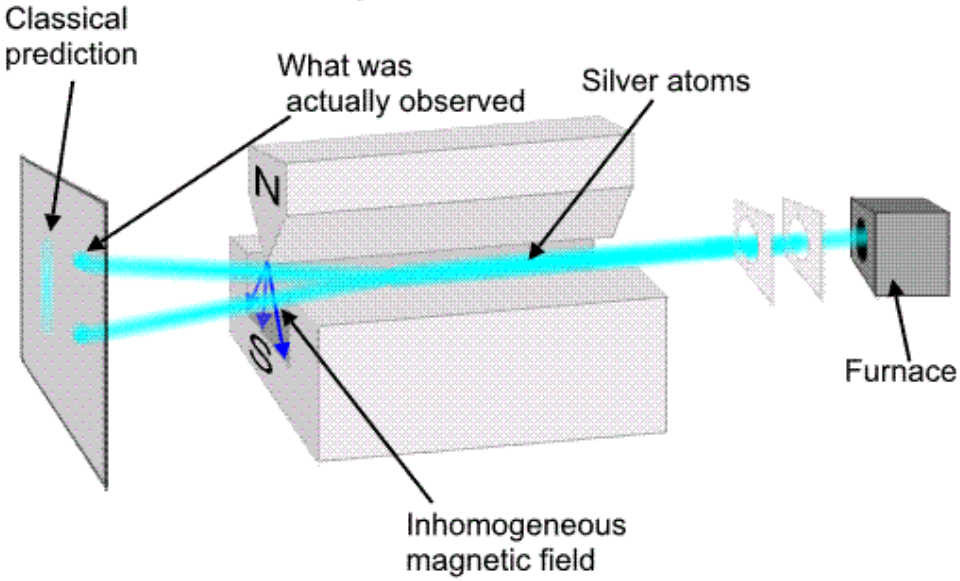


Diagram from Wikipedia

Otto Stern

-wikipedia

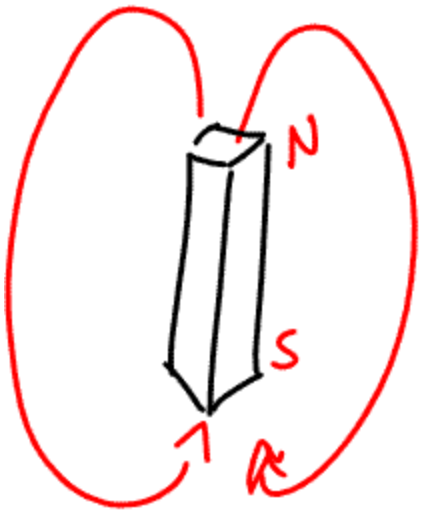
"If this nonsense from Bohr will prove to be right we will quit physics."
(Stern vowed in 1913)

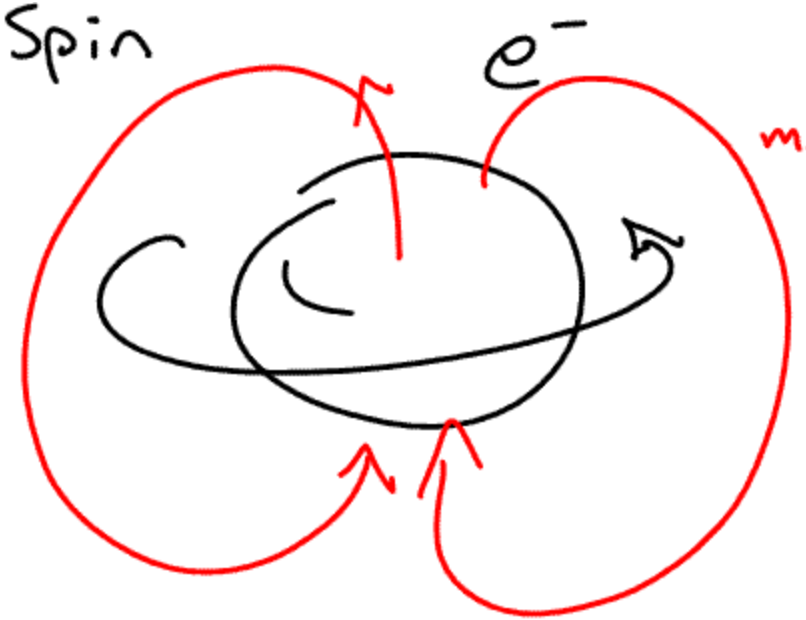
asquoted in Phys. Today Dec 03

Walther Gerlach

from phys Today article (Dec. 03)

Intrinsic Spin





magnetic field

Magnetic field looks like a bar magnet

Spin is quantized → only discrete values allowed

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

relative spin (or magnetic field strength)

Particles have little magnetic fields like bar magnets

Think of as spinning charge distribution

integer spin $0, 1, 2 \cdots$ Bosons

half integer $\frac{1}{2}, \frac{3}{2}, \frac{5}{2} \cdots$ Fermions

Particle Promiscuity

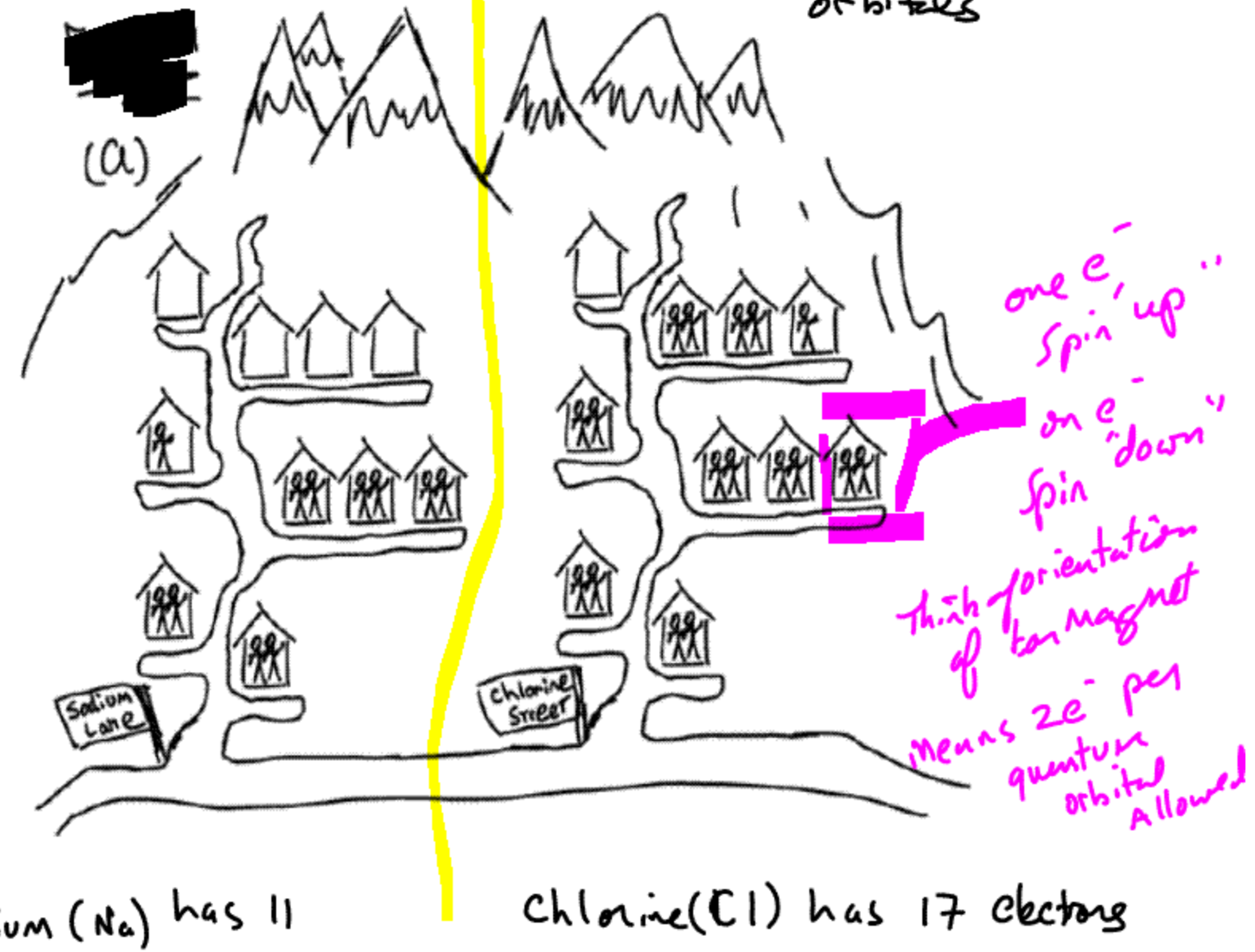
MANY per quantum STATE Allowed

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 Z (#protons) / mass / #electrons

Notice periodicity of chemical properties and physical characteristics

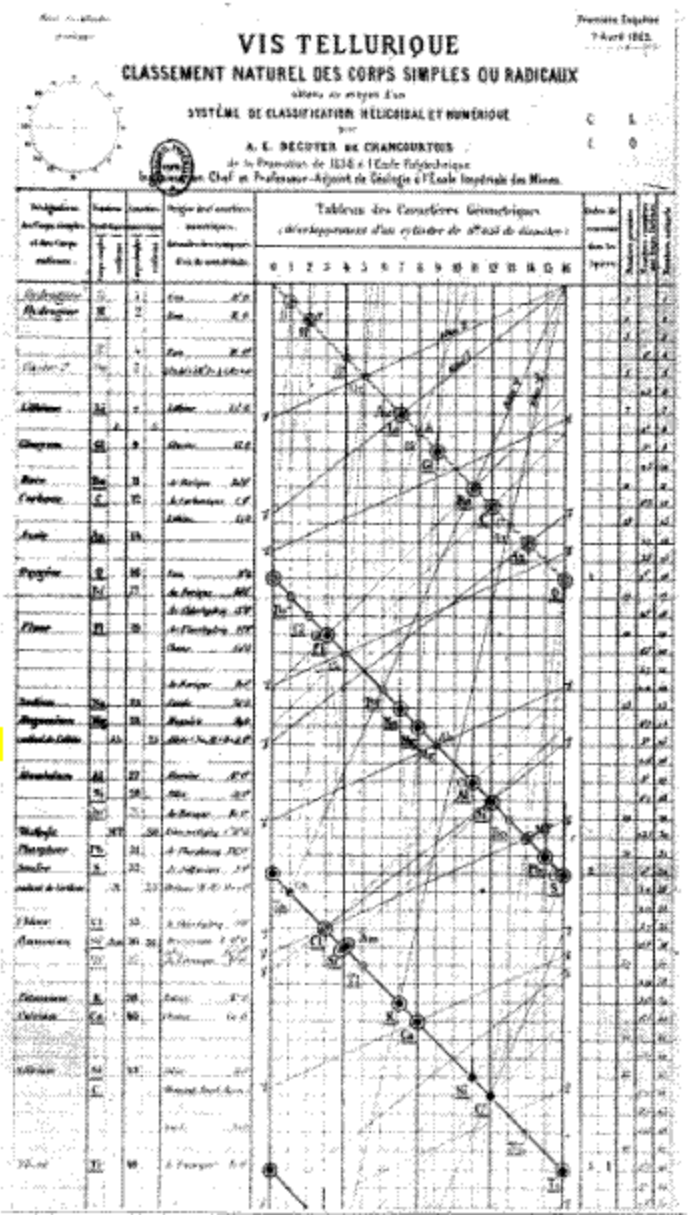
Periodic Table of the elements

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-Emile Béguyer de Chancourtios
France (1820-1886)



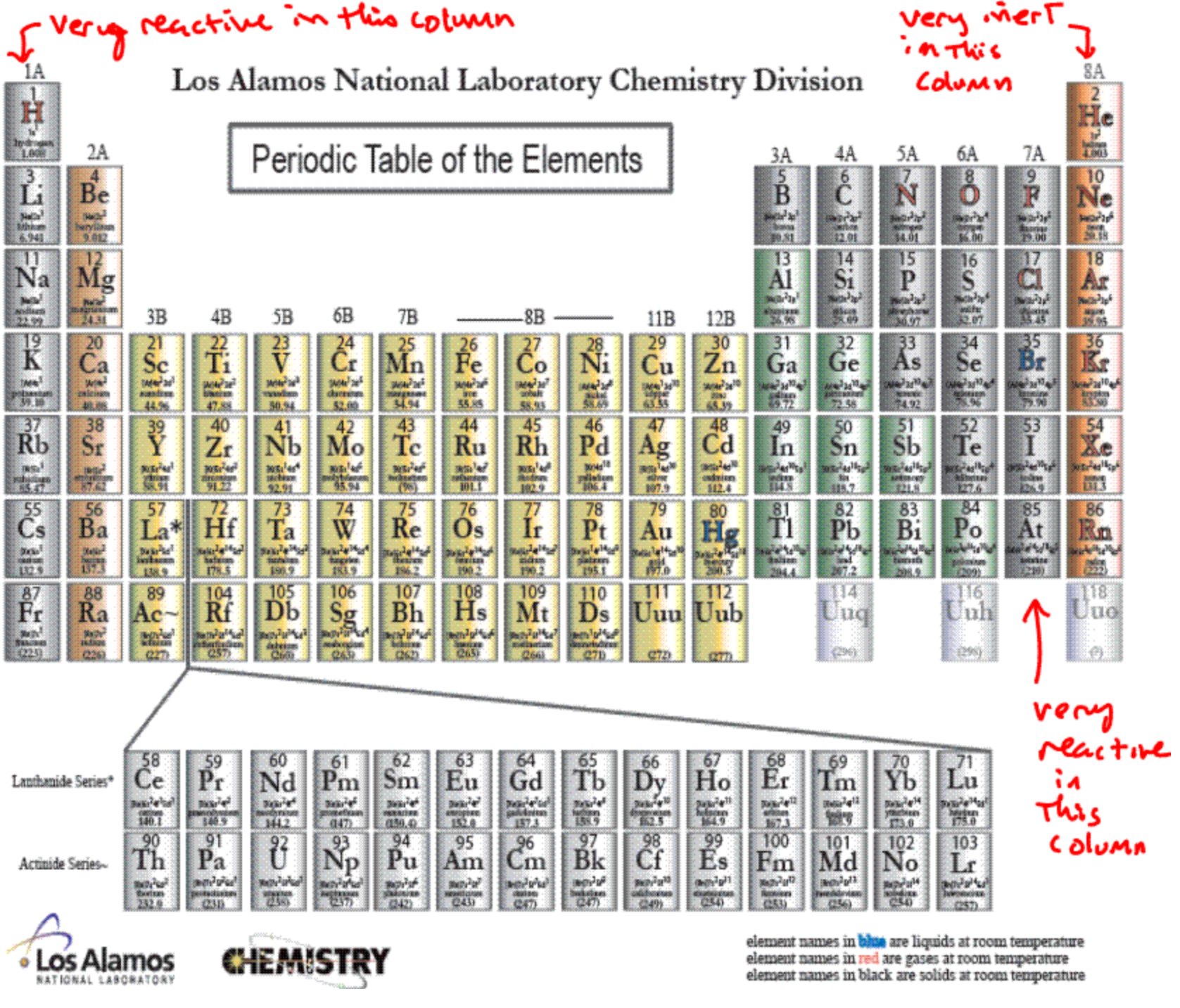
Dmitri Mendeleev

Russian (1834-1907)

THE PERIODICITY OF THE ELEMENTS

The Elements	Their Properties in the Free State				The Composition of the Hydrogen and Organo-metallic Compounds	Symbols and Atomic Weights		The Composition of the Saline Oxides	The Properties of the Saline Oxides			Small Periods or Series
	t	v	d	$\frac{A}{d}$	RH_m or $R(CH_3)_n$	R	A	R_2O_n	$\frac{(2A+n\cdot 16)^2}{d}$ V			
	[1]	[2]	[3]	[4]	[5]	[6]		[7]	[8]	[9]	[10]	[11]
Hydrogen	<−200°	—	<0·07>	29		H	1	1 —n	0·217	1·9	<−20	1
Lithium	180°	—	0·59	12		Li	7	1†	2·9	15	− 9	2
Beryllium	(900°)	—	1·64	5·5		Be	9	— 2	3·96	16·8	+ 2·6	
Boron	(1200°)	—	2·5	4·4	3 — —	B	11	— — 3	1·9	39	10	
Carbon	>(3500°)	—	<3·0	> 6	4 — —	C	12	— — — 4	>1·0	<38	<19	
Nitrogen	−203°	—	<0·7	> 30	3 — —	N	14	1 — 3* — 5*	1·64	66	< 6	
Oxygen	<−200°	—	<1·0	> 16	2 — —	O	16	— — — —	—	—	—	
Fluorine	—	—	—	—	1	F	19	— — — —	—	—	—	
Sodium	90°	0·71	0·98	23	1	Na	23	1† — — —	Na$_2$O 2·6	24	−22	3
Magnesium	500°	0·27	1·74	14	2 — —	Mg	24	— 2† — —	3·6	22	− 3	
Aluminium	600°	0·13	2·6	11	3 — —	Al	27	— — 3 —	Al$_2$O$_3$ 4·9	26	+ 2·2	
Silicon	(1200°)	0·08	2·3	10	4 — —	Si	28	— — 3 4	2·63	45	3·2	
Phosphorus	44°	1·20	2·2	14	3 — —	P	31	1 — 3* 4* 5*	2·30	59	6·2	
Sulphur	114°	0·87	2·07	15	2 — —	S	32	— 2 — 4* 5* 6*	1·90	62	9·7	
Chlorine	−75°	—	1·3	27	1	Cl	35·5	1 — — 3 — 5* — 7*	—	—	—	
Potassium	58°	0·84	0·87	45		K	39	1† — — — —	2·7	35	−35	4
Calcium	(800°)	—	1·6	25		Ca	40	— 2† — — —	2·13	36	− 7	
Scandium	—	—	(2·5)	(18)		Sc	44	— — 3† — —	2·96	35	(0)	
Titanium	(1500°)	—	(5·1)	(9·4)		Ti	48	— — 3 4 —	4·2	38	(+5)	
Vanadium	(2000°)	—	6·1	9·2		V	51	— — 3 4 5	3·49	51	6·7	
Chromium	(2000°)	—	5·5	8·9		Cr	52	— 2 3 — — 6*	2·74	73	9·5	
Manganese	(1500°)	—	7·4	7·3		Mn	55	— 2† 3 4 — 6* 7*	—	—	—	
Iron	1400°	0·13	7·8	7·2		Fe	56	— 2† 3 — — 6*	—	—	—	
Cobalt	(1400°)	0·13	8·6	6·5		Co	58½	— 2† 3 4	—	—	—	
Nickel	1350°	0·17	8·7	6·6		Ni	59	— 2† 3 —	—	—	—	
Copper	1054°	0·29	8·8	7·2		Cu	63	1† 2† — —	Cu$_2$O 5·9	24	9·5	5
Zinc	435°	—	7·1	9·2	2 — —	Zn	65	— 2† — —	3·7	28	4·7	
Gallium	30°	—	5·96	12	3 — —	Ga	70	— — 3 —	Ga$_2$O$_3$ (5·1)	(38)	(4·6)	
Germanium	900°	—	5·47	13	4 — — —	Ge	72	— 2 — 4 —	4·7	44	4·5	
Arsenic	500°	900	5·7	13	3 — — —	As	75	— — 3 — 5* —	4·1	56	6·0	
Selenium	217°	—	4·8	16	2 — —	Se	79	— — — 4 — 6* —	—	—	—	
Bromine	−7°	—	3·7	22	1	Br	80	1 — — — 5* — 7*	—	—	—	
Rubidium	39°	—	1·5	87		Rb	85	1† — — — — —	—	—	—	6
Strontium	(800°)	—	2·5	35		Sr	87	— 2† — — — —	4·3	48	−1·1	
Yttrium	—	—	(3·5)	(26)		Y	89	— — 3† — — —	5·95	45	(−2)	
Zirconium	(1500°)	—	4·1	22		Zr	90	— — — 4 — —	6·7	42	−0·2	
Niobium	—	—	7·1	13		Nb	94	— — 3 — 5* —	4·7	37	+0·2	
Molybdenum	—	—	8·6	12		Mo	96	— 2 3 4 — 6* —	4·4	65	2·8	
						(1)						
Ruthenium	(2000°)	0·10	12·2	8·4		Ru	103	— 2 3 4 — 6 — 8	—	—	—	
Rhodium	(1800°)	0·08	12·1	8·6		Rh	104	— 2 3 4 — 6 —	—	—	—	
Palladium	1500°	0·12	11·4	8·8		Pd	106	1† 2 — 4 — —	—	—	—	
Silver	950°	0·19	10·5	10		Ag	108	1† — — — — —	Ag$_2$O 7·2	31	11	7
Cadmium	320°	0·31	8·6	13	2 — —	Cd	112	— 2† — — — —	8·13	31	2·5	
Indium	176°	0·45	7·4	14	3 — — —	In	113	— — 3 — — —	In$_2$O$_3$ 7·18	38	2·7	
Tin	230°	0·29	7·3	16	4 — — —	Sn	118	— — 3 4 — —	6·85	42	3·9	
Antimony	450°	0·13	6·7	18	3 — — —	Sb	120	— — 3 4 5 —	6·5	49	2·6	8
Tellurium	450°	0·17	6·4	20	2 — —	Te	125	— — — 4 — 6* —	5·1	69	4·7	
Iodine	114°	—	4·9	26	1	I	127	1 — — 3 — 5* — 7*	—	—	—	
Caesium	27°	—	1·88	71		Cs	133	1† — — — — — —	—	—	—	
Barium	—	—	3·73	36		Ba	137	— 2† — — — — —	5·1	69	6·9	
Lanthanum	(900°)	—	6·1	23		La	138	— — 3† — — — —	6·5	59	+1·2	
Cerium	(700°)	—	6·6	21		Ce	140	— — 3 4 — — —	6·74	56	2·9	
Didymium	(800°)	—	6·5	22		Di	142	— — 3 — 5 — —	—	—	—	
						(14)						
Ytterbium	—	—	(6·9)	(25)		Yb	173	— — 3 — — — —	9·18	43	(−2)	10
						(1)						
Tantalum	—	—	10·4	18		Ta	182	— — — — 5 — —	7·5	39	4·6	
Tungsten	(1500°)	—	17·1	9·6		W	184	— — — 4 — 6 —	6·9	62	9	
						(1)						
Osmium	(2500°)	0·07	22·3	8·5		Os	191	— — 3 4 — 6 — 8	—	—	—	
Iridium	2000°	0·07	22·4	8·6		Ir	193	— — 3 4 — 6 —	—	—	—	
Platinum	1775°	0·05	21·2	9·2		Pt	196	— 2 — 4 — — —	—	—	—	
Gold	1045°	0·14	19·3	10		Au	198	1 — 3 — — — —	Au$_2$O (12·5)	(60)	(15)	11
Mercury	−39°	—	13·6	15	2 — —	Hg	200	1† 2† — — — —	11·1	59	4·5	
Thallium	294°	0·13	11·8	17	3 — — —	Tl	204	1† — 3 — — —	Tl_2O_3 (9·7)	(47)	(4·3)	
Lead	326°	0·20	11·3	18	4 — — —	Pb	206	— 2† — 4 — —	8·9	50	4·3	
Bismuth	269°	0·14	9·9	21	3 — —	Bi	208	— — 3 — 5 — —	—	—	—	
						(5)						
Thorium	—	—	11·1	21		Th	232	— — — 4 — — —	9·86	54	2·9	12
						(1)						
Uranium	(800°)	—	18·7	12		U	240	— — — 4 — 6 —	(7·2)	(60)	(0)	

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
1A
2A
3B
4B
5B
6B
7B
8B
11B
12B
3A
4A
5A
6A
7A
8A
Lanthanide Series*
Actinide Series~
very reactive in this column
Los Alamos NATIONAL LABORATORY
CHEMISTRY
element names in blue are liquids at room temperature
element names in red are gases at room temperature
element names in black are solids at room temperature