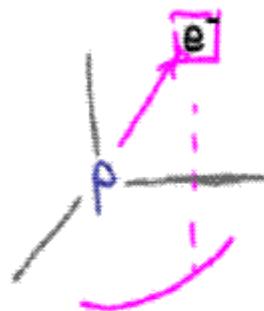


Physics 100 - October 17, 2007

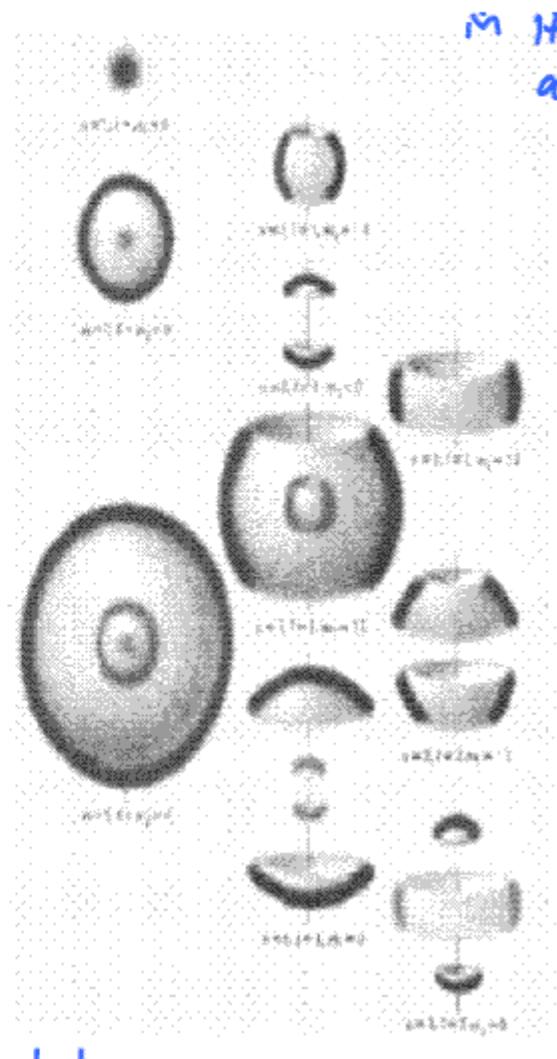
- Exams graded ... but data still needs to be recorded
- Will put in box outside my office for you to pick up (B+L 203 E)
- Will POST solutions, grade distribution online
- Please look over your papers + solns carefully
regrade policy on web
- Presentation groups
 - 7 Asteroids/extinctions
 - 6 GPS
 - 7 Nuclear Terrorism
 - 8 Nuclear Bombs
 - 6 Life + Times of X
 - 5 Cosmic Microwave Bkgnd
 - 5 Music
- Next week — class in your jammies

Quantum Mechanical treatment of H atoms (Schrödinger's equation) (single e^-)



only particular STATES
of existence for
electron allowed

STATES vary by
energy + shape

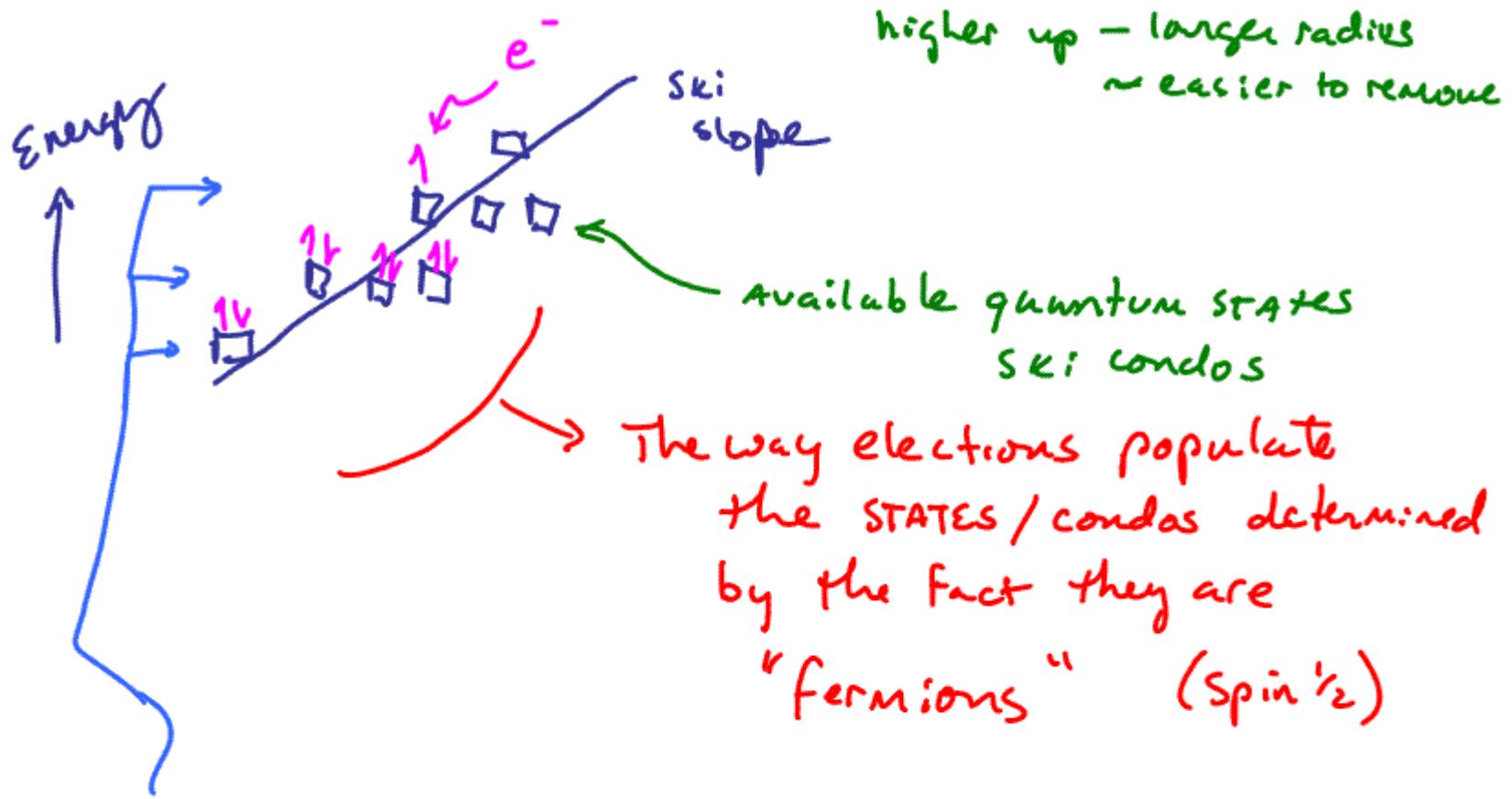


For multi-electron atoms - Electrons fill lowest available energy STATE, then next higher available STATE, etc



Chemical characteristics of atom determined by how electrons populate the Available quantum STATES

For example — "ionization energy"
energy to remove e^- from atom



Periodic structure in how e^- populate
Available houses
 \Rightarrow periodic structure in
Atomic characteristics

As $Z = \# \text{protons increases} \rightarrow \# \text{electrons increase}$
 \rightarrow determines type of atom/element

Periodic Table of the elements

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



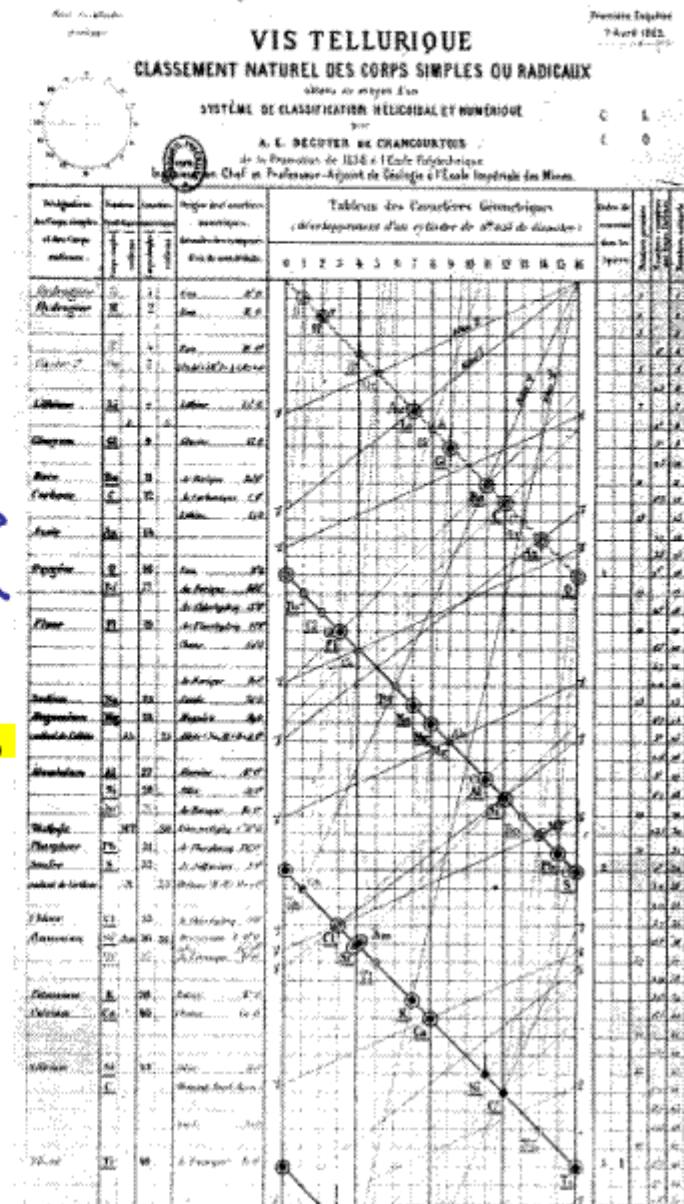
guillotined during French Revolution



Alexandre-Emile
 Béguier de Chancourtois
 France (1820-1886)

Antoine Lavoisier
 France (1743-1794)

"Father of Modern
 Chemistry"
 QUANTITATIVE ANALYSIS





Dmitri Mendeleev
Russian (1834-1907)

The Elements	Their Properties in the Free-state				The Composition of the Hydrogen and Organometallic Compounds		Symbolic 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_n or R_2CH_m	<i>R</i>		H_2O_x	$(\frac{d}{2} + \frac{n}{2})$	$\frac{d}{2}$		
Hydrogen	< 200°	—	< 0.03	29	m = 1	H	1	1 = n	(7)	0.917	19.0 < -10	
Lithium	180°	—	0.59	12	Li	7	17	—	2.9	15	-9	
Beryllium	100°	—	1.61	9.5	Be	9	—	—	3.96	16.8	+ 26	
Boron	(150°)	—	2.5	4.2	B	11	—	3	—	1.9	20	
Carbon	> 200°	—	< 0.0	> 6	4	—	C	12	—	> 1.9	< 18	
Nitrogen	< 200°	—	< 0.7	20	3	—	N	14	1 = 3* — 5*	1.94	66 < 6	
Oxygen	< 200°	—	< 1.0	> 16	2	—	O	16	—	—	—	
Fluorine	—	—	—	—	—	1	F	19	—	—	—	
Sodium	80°	0.71	0.98	22	Na	23	17	—	—	Na ₂ O	2.8	16
Magnesium	200°	0.97	1.74	14	Mg	24	21	—	3.8	22	—	
Aluminum	100°	0.51	2.0	11	Al	27	—	—	Al ₂ O ₃	4.9	23	
Silicon	(100°)	0.68	0.9	10	4	—	Si	28	—	2.95	17	
Phosphorus	41°	1.09	2.2	14	P	31	1	—	2.99	19	6.2	
Sulfur	214°	0.67	2.02	20	2	—	S	32	—	1.94	62	
Chlorine	75°	—	1.5	37	Cl	35	—	—	—	—	—	
Potassium	58°	0.94	0.87	45	K	39	21	—	2.7	35	-25	
Calcium	(80°)	—	1.6	20	Ca	40	21	—	3.15	30	7	
Sodium	—	—	—	—	Se	44	21	—	—	—	—	
Titanium	(200°)	—	0.11	(94)	Ti	45	—	4	—	—	—	
Vanadium	(200°)	—	0.1	9.8	V	51	—	—	4.2	29	(+ 5)	
Chromium	(200°)	—	0.5	8.9	Cr	52	—	—	3.49	23	6.7	
Manganese	(150°)	—	0.5	7.2	Mn	55	—	—	2.74	78	9.5	
Iron	100°	0.02	7.8	7.2	Fe	56	—	—	—	—	—	
Cobalt	(140°)	0.03	9.8	6.9	Co	59	—	—	—	—	—	
Nickel	130°	0.17	9.7	6.8	Ni	60	—	—	—	—	—	
Copper	163°	0.09	9.8	7.2	Cu	63	21	—	—	—	—	
Zinc	130°	—	7.2	9.2	Zn	65	21	—	—	—	—	
Gallium	30°	—	5.98	12	3	—	Ga	67	—	5.1	25	
Germanium	90°	—	5.47	15	4	—	Ge	72	—	4.7	44	
Arsenic	90°	—	5.47	15	3	—	As	73	—	4.7	46	
Antimony	200°	0.04	15	15	5	—	Sb	75	—	4.7	56	
Bismuth	417°	—	4.9	16	2	—	Bi	80	—	—	—	
Tharsis	7°	—	0.7	90	1	—	—	—	—	—	—	
Ruthenium	20°	—	1.5	57	Ru	85	21	—	—	—	—	
Rhenium	(100°)	—	0.5	35	Re	87	21	—	—	—	—	
Yttrium	—	—	(34)	36	T	89	21	—	4.9	48	-21	
Zirconium	(120°)	—	4.1	22	Zr	90	—	—	5.95	45	(+ 2)	
Nickel	—	—	7.4	18	Nb	94	—	—	5.7	45	-27	
Molybdenum	—	—	8.6	12	Mo	96	—	—	4.7	57	8.8	
Ruthenium	(200°)	0.10	19.2	8.4	(2)	—	—	—	—	—	—	
Rhenium	(180°)	0.08	12.1	8.6	Re	103	—	—	—	—	—	
Palladium	(200°)	0.12	11.4	8.2	Rh	104	—	—	—	—	—	
Silver	365°	0.19	10.5	19	Pd	105	21	—	—	—	—	
Cadmium	220°	0.02	9.6	18	Ag	108	21	—	Ag ₂ O	7.9	81	
Indium	115°	0.05	7.3	14	Cd	112	—	—	—	—	—	
Tin	200°	0.03	7.2	14	In	115	—	3	In ₂ O ₃	7.10	38	
Antimony	432°	0.12	6.7	18	Sn	118	—	—	—	—	—	
Tellurium	455°	0.17	9.3	30	5	—	Sn	120	—	6.3	49	
Iodine	114°	—	4.9	26	Te	123	—	—	Te ₂ O ₃	2.1	68	
Cosmium	217°	—	1.99	21	I	127	—	—	—	—	—	
Boron	—	—	3.75	36	Cs	133	17	—	—	—	—	
Santhium	(600°)	—	6.1	22	Br	137	—	—	—	—	—	
Cerium	(500°)	—	6.6	21	La	138	—	—	—	—	—	
Dolymens	(500°)	—	6.5	22	Lu	139	—	—	—	—	—	
Yttrium	—	—	(19)	(25)	Y	176	—	3	—	9.18	48	
Tantalum	—	—	10.4	18	Ta	189	—	—	5	7.3	39	
Tungsten	(1500°)	—	12.1	9.6	W	184	—	—	—	6.9	67	
Osmium	(2500°)	0.07	22.2	8.5	(1)	—	—	—	—	—	—	
Iridium	(2000°)	0.07	22.4	8.6	Os	191	—	—	—	—	—	
Platinum	1772°	0.05	21.2	9.2	Ir	193	—	—	—	—	—	
Gold	1045°	0.14	19.8	10	Pt	196	—	2	—	—	—	
Mercury	—	—	10.8	15	As	198	—	—	—	—	—	
Thallium	204°	0.01	11.8	17	Hg	200	17	27	Tl ₂ O ₃	11.1	39	
Lead	230°	0.09	11.8	18	Tl	204	—	—	—	—	—	
Bismuth	208°	0.14	9.9	21	Pb	206	—	21	—	8.9	53	
Thorium	—	—	21.2	9.1	Bi	208	—	3	—	—	—	
Uranium	(600°)	—	18.7	13	(1)	—	—	—	—	(7.2)	(80)	

when elements arranged by mass - See a certain periodicity in their chemical properties.

1A
H Hydrogen 1.008

Los Alamos National Laboratory Chemistry Division

2A
Be $[\text{He}]^2$ beryllium 9.012

11
Na $[\text{He}]^1$ sodium 22.99

12

Mg

Periodic Table of the Elements

3A	4A	5A	6A	7A
5 B $[\text{He}]^2 \text{[Li]}^1$ boron 10.81	6 C $[\text{He}]^2 \text{[Be]}^1$ carbon 12.01	7 N $[\text{He}]^2 \text{[N]}^1$ nitrogen 14.01	8 O $[\text{He}]^2 \text{[O]}^1$ oxygen 16.00	9 F $[\text{He}]^2 \text{[F]}^1$ fluorine 19.00
13 Al $[\text{He}]^2 \text{[Al]}^1$ aluminum 26.98	14 Si $[\text{He}]^2 \text{[Si]}^1$ silicon 28.09	15 P $[\text{He}]^2 \text{[P]}^1$ phosphorus 30.97	16 S $[\text{He}]^2 \text{[S]}^1$ sulfur 32.07	17 Cl $[\text{He}]^2 \text{[Cl]}^1$ chlorine 35.45
19 K $[\text{He}]^1$ potassium 39.10	20 Ca $[\text{He}]^2$ calcium 40.08	21 Sc $[\text{He}]^2 \text{[Sc]}^1$ scandium 44.96	22 Ti $[\text{He}]^2 \text{[Ti]}^1$ titanium 47.88	23 V $[\text{He}]^2 \text{[V]}^1$ vanadium 50.94
24 Cr $[\text{He}]^2 \text{[Cr]}^1$ chromium 52.00	25 Mn $[\text{He}]^2 \text{[Mn]}^1$ manganese 54.94	26 Fe $[\text{He}]^2 \text{[Fe]}^1$ iron 55.85	27 Co $[\text{He}]^2 \text{[Co]}^1$ cobalt 58.93	28 Ni $[\text{He}]^2 \text{[Ni]}^1$ nickel 58.69
29 Cu $[\text{He}]^2 \text{[Cu]}^1$ copper 63.55	30 Zn $[\text{He}]^2 \text{[Zn]}^1$ zinc 65.39	31 Ga $[\text{He}]^2 \text{[Ga]}^1$ gallium 69.72	32 Ge $[\text{He}]^2 \text{[Ge]}^1$ germanium 72.56	33 As $[\text{He}]^2 \text{[As]}^1$ arsenic 74.92
34 Se $[\text{He}]^2 \text{[Se]}^1$ selenium 78.96	35 Br $[\text{He}]^2 \text{[Br]}^1$ bromine 80.30	36 Kr $[\text{He}]^2 \text{[Kr]}^1$ krypton 83.80		
37 Rb $[\text{He}]^1$ rubidium 85.47	38 Sr $[\text{He}]^2$ strontium 87.62	39 Y $[\text{He}]^2 \text{[Y]}^1$ yttrium 88.91	40 Zr $[\text{He}]^2 \text{[Zr]}^1$ zirconium 91.22	41 Nb $[\text{He}]^2 \text{[Nb]}^1$ niobium 92.91
42 Mo $[\text{He}]^2 \text{[Mo]}^1$ molybdenum 95.94	43 Tc $[\text{He}]^2 \text{[Tc]}^1$ technetium 98.1	44 Ru $[\text{He}]^2 \text{[Ru]}^1$ ruthenium 101.1	45 Rh $[\text{He}]^2 \text{[Rh]}^1$ rhodium 102.9	46 Pd $[\text{He}]^2 \text{[Pd]}^1$ palladium 106.4
47 Ag $[\text{He}]^2 \text{[Ag]}^1$ silver 107.9	48 Cd $[\text{He}]^2 \text{[Cd]}^1$ cadmium 112.4	49 In $[\text{He}]^2 \text{[In]}^1$ indium 114.8	50 Sn $[\text{He}]^2 \text{[Sn]}^1$ tin 115.7	51 Sb $[\text{He}]^2 \text{[Sb]}^1$ antimony 121.8
52 Te $[\text{He}]^2 \text{[Te]}^1$ tellurium 127.6	53 I $[\text{He}]^2 \text{[I]}^1$ iodine 127.0			
55 Cs $[\text{He}]^1$ cesium 132.9	56 Ba $[\text{He}]^2$ barium 137.3	57 La* $[\text{He}]^2 \text{[La]}^1$ lanthanum 138.9	72 Hf $[\text{He}]^2 \text{[Hf]}^1$ hafnium 178.5	73 Ta $[\text{He}]^2 \text{[Ta]}^1$ tantalum 180.9
74 W $[\text{He}]^2 \text{[W]}^1$ tungsten 183.9	75 Re $[\text{He}]^2 \text{[Re]}^1$ rhenium 186.2	76 Os $[\text{He}]^2 \text{[Os]}^1$ osmium 190.2	77 Ir $[\text{He}]^2 \text{[Ir]}^1$ iridium 190.2	78 Pt $[\text{He}]^2 \text{[Pt]}^1$ platinum 195.1
79 Au $[\text{He}]^2 \text{[Au]}^1$ gold 197.0	80 Hg $[\text{He}]^2 \text{[Hg]}^1$ mercury 200.5	81 Tl $[\text{He}]^2 \text{[Tl]}^1$ thallium 204.4	82 Pb $[\text{He}]^2 \text{[Pb]}^1$ lead 207.2	83 Bi $[\text{He}]^2 \text{[Bi]}^1$ bismuth 209.9
84 Po $[\text{He}]^2 \text{[Po]}^1$ polonium (209)	85 At $[\text{He}]^2 \text{[At]}^1$ astatine (210)	86 Rn $[\text{He}]^2 \text{[Rn]}^1$ radon (222)	116 Uuh (290)	118 Uuo (?)

87 Fr $[\text{He}]^1$ francium (223)

88

Ra $[\text{He}]^2$ radium (226)
--

89

Ac~ $[\text{He}]^2$ actinium (227)

104

Rf $[\text{He}]^2$ rutherfordium (267)

105

Db $[\text{He}]^2$ dubnium (268)

106

Sg $[\text{He}]^2$ sogdium (269)

107

Bh $[\text{He}]^2$ bohrium (260)

108

Hs $[\text{He}]^2$ hsilium (261)

109

Mt $[\text{He}]^2$ mendelevium (262)

110

Ds $[\text{He}]^2$ darmstadtium (263)
--

111

Uuu $[\text{He}]^2$ ununtrium (270)
--

112

Uub $[\text{He}]^2$ ununbium (271)

113

Uuo $[\text{He}]^2$ ununoctium (270)

114

Uup $[\text{He}]^2$ ununpentium (296)
--

115

Uuh $[\text{He}]^2$ ununhexium (296)

116

Uuo $[\text{He}]^2$ ununoctium (296)

117

Uus $[\text{He}]^2$ ununseptium (297)
--

118

Uuo $[\text{He}]^2$ ununoctium (297)

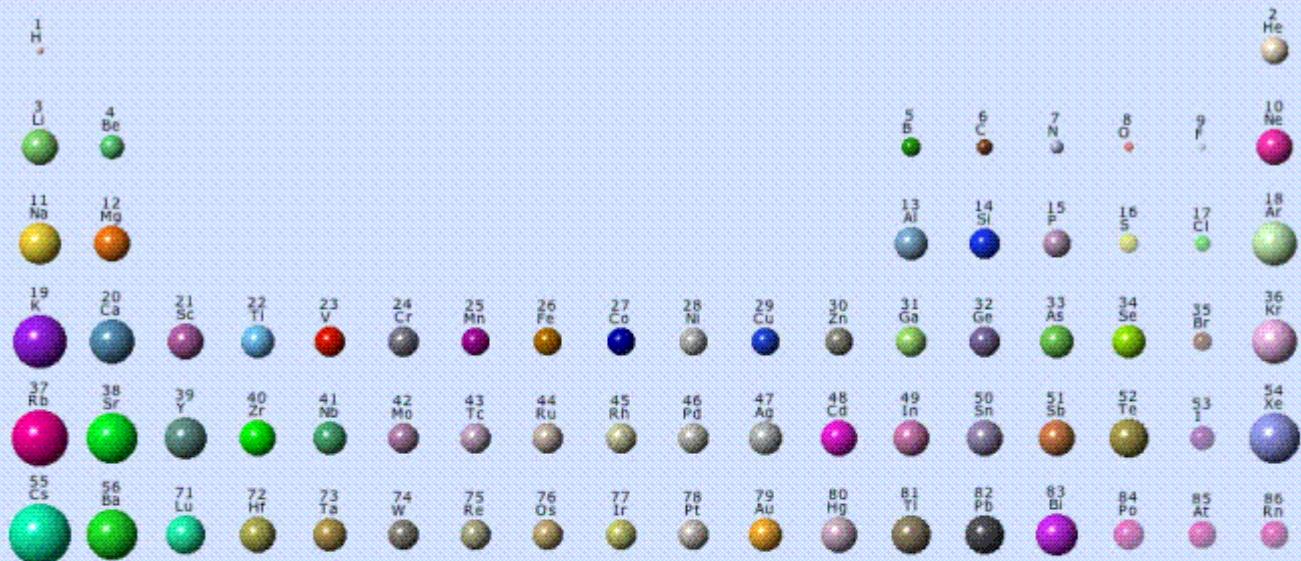
Lanthanide Series*

58 Ce $[\text{He}]^2$ cerium 140.1	59 Pr $[\text{He}]^2$ praseodymium 141.9	60 Nd $[\text{He}]^2$ neodymium 144.2	61 Pm $[\text{He}]^2$ promethium (147)	62 Sm $[\text{He}]^2$ samarium (150.0)	63 Eu $[\text{He}]^2$ europium 152.0	64 Gd $[\text{He}]^2$ gadolinium 157.4	65 Tb $[\text{He}]^2$ thulium 158.9	66 Dy $[\text{He}]^2$ dysprosium 162.5	67 Ho $[\text{He}]^2$ holmium 164.9	68 Er $[\text{He}]^2$ erbium 167.3	69 Tm $[\text{He}]^2$ thytium 169.9	70 Yb $[\text{He}]^2$ ytterbium 173.0	71 Lu $[\text{He}]^2$ lutetium 175.0
---	---	--	---	---	---	---	--	---	--	---	--	--	---

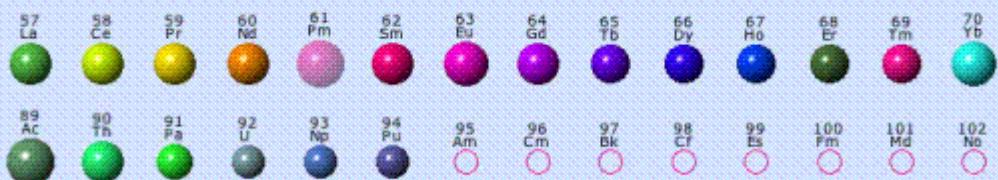
Actinide Series~

90 Th $[\text{He}]^2$ thorium 232.0	91 Pa $[\text{He}]^2$ protactinium (231)	92 U $[\text{He}]^2$ uranium (238)	93 Np $[\text{He}]^2$ neptunium (237)	94 Pu $[\text{He}]^2$ plutonium (243)	95 Am $[\text{He}]^2$ americium (243)	96 Cm $[\text{He}]^2$ curium (247)	97 Bk $[\text{He}]^2$ berkelium (247)	98 Cf $[\text{He}]^2$ californium (254)	99 Es $[\text{He}]^2$ eserrium (254)	100 Fm $[\text{He}]^2$ fermium (253)	101 Md $[\text{He}]^2$ mendelevium (256)	102 No $[\text{He}]^2$ nobelium (254)	103 Lr $[\text{He}]^2$ lawrencium (257)
--	---	---	--	--	--	---	--	--	---	---	---	--	--

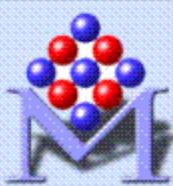
element names in blue are liquids at room temperature
 element names in red are gases at room temperature
 element names in black are solids at room temperature

VFI Atomic Radii

*Image generated by
CrystalMaker 6.3:
interactive crystal &
molecular structures
visualization
for Mac OS X*



Scale 10 Å



These data are based on interatomic distances in the structures of the elements. (Radii for metals correspond to coordination numbers of 12.) Where no radius value can be found for a particular element, its radius has been set to a default value of 1 Å and a circle is plotted instead of a rendered sphere. Data from Vainshtein et al., 1995; values for O, F, S, Cl, Br, I, At, Po, Pm, Rn have been taken from Clementi et al. 1963.

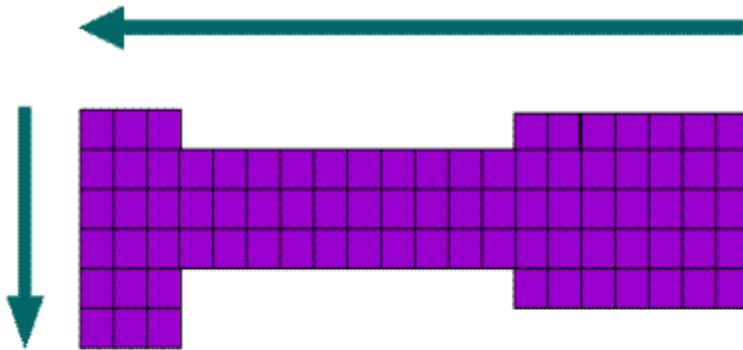
References: Vainshtein BK, Fridkin VM, Indenbom VL (1995) Structure of Crystals, 3rd Edition. Springer Verlag, Berlin.
Clementi E, Raimondi DL, Reinhardt WP (1963) Journal of Chemical Physics 38:2686



Figures from -

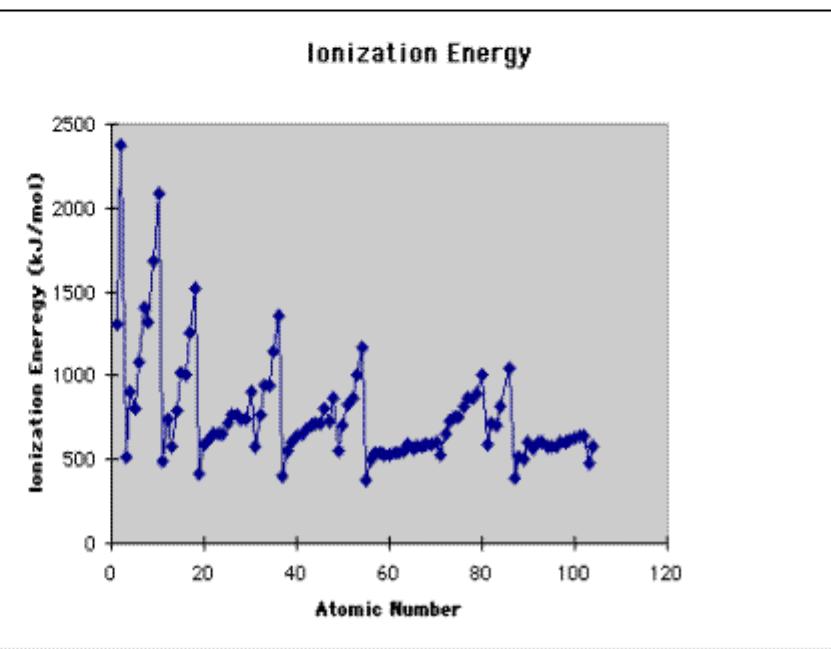
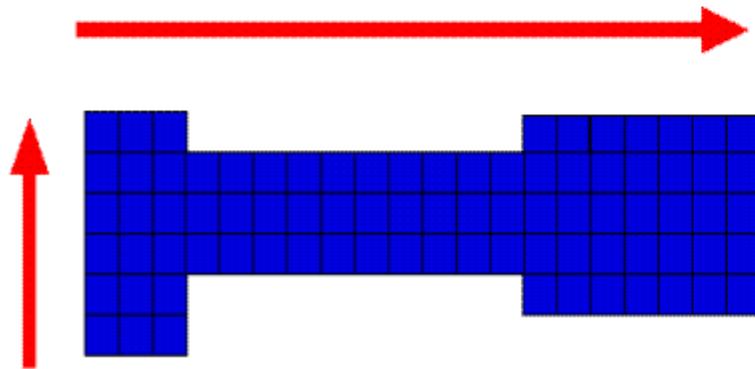
<http://www.shodor.org/chemviz/ionization/students/background.html>

Atomic Size Increases With Arrows

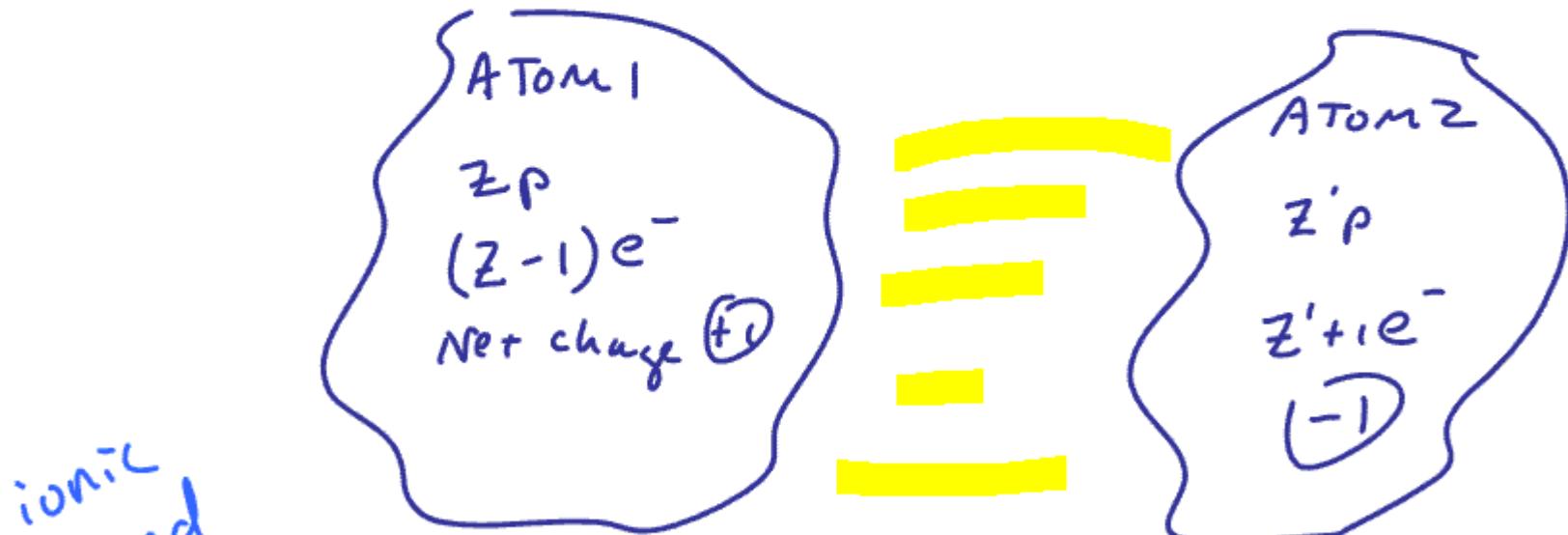
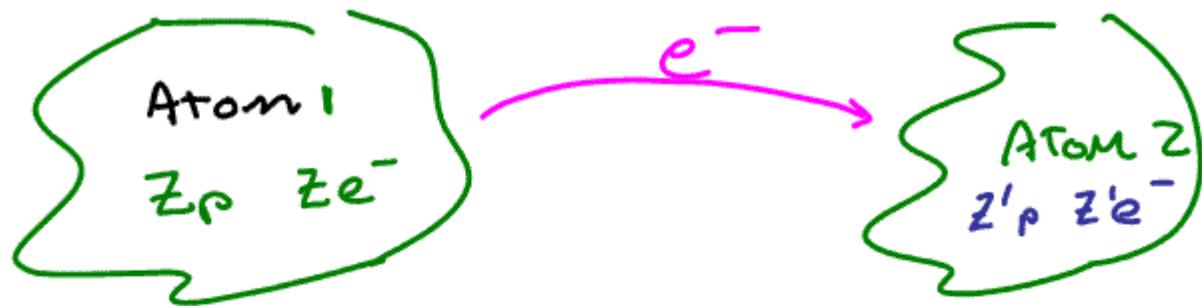


ionization Energy
energy to
remove an
electron

Ionization Energy Increases With Arrows



Chemistry

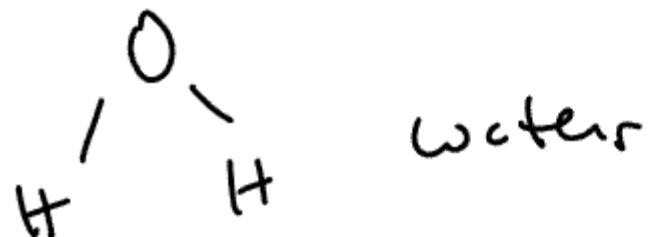


ionic
bond

$\text{Na}^+ \text{Cl}^-$
Sodium chloride (salt)

Attraction

Coulomb



Quantum Mechanics + Uncertainty

$$\frac{\hbar^2}{2m} \frac{d^2\psi(x)}{dx^2} + V\psi(x) = E\psi(x)$$

1927 Copenhagen Interpretation of QM

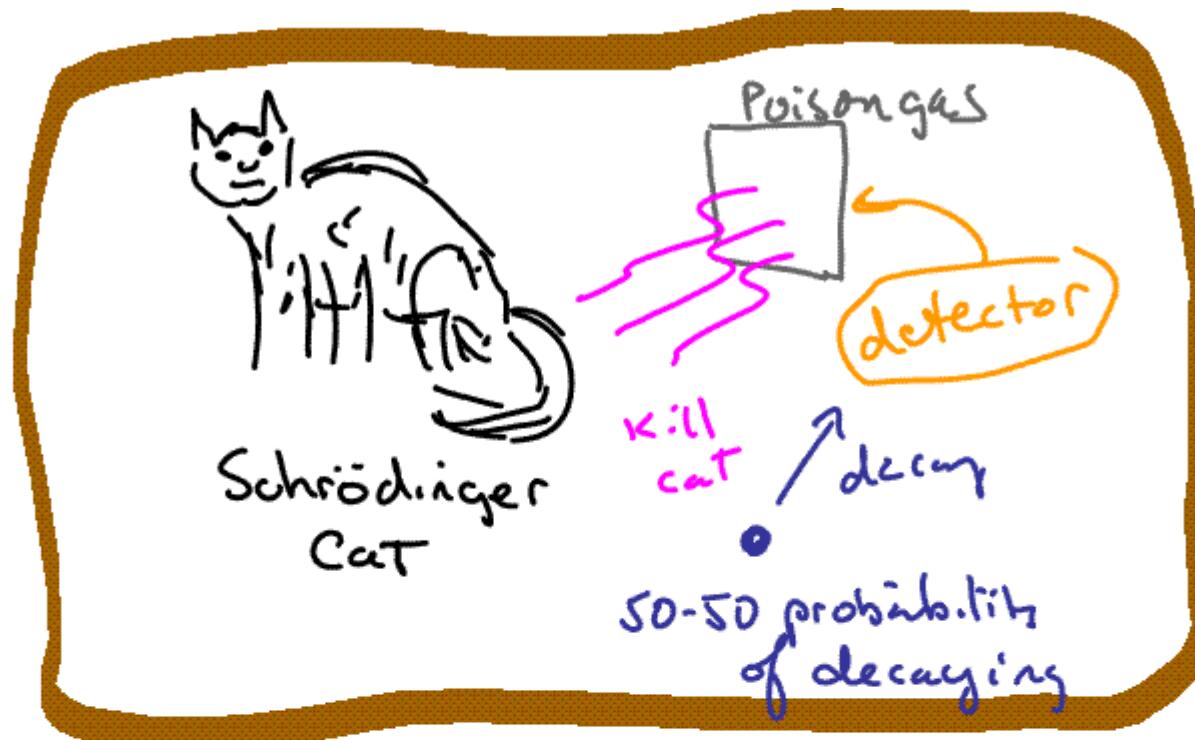
Bohr $\psi(x)$ not well defined \rightarrow tool for
Heisenberg \hookrightarrow wave function calculation
Born $\psi^2(x)$ is well defined

Measure of the probability of
finding the particle at position x

Probabilistic

q

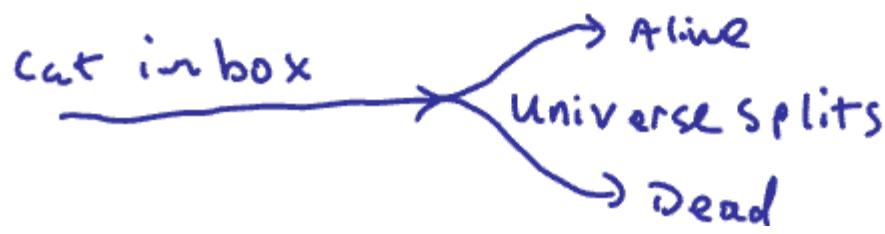
observer

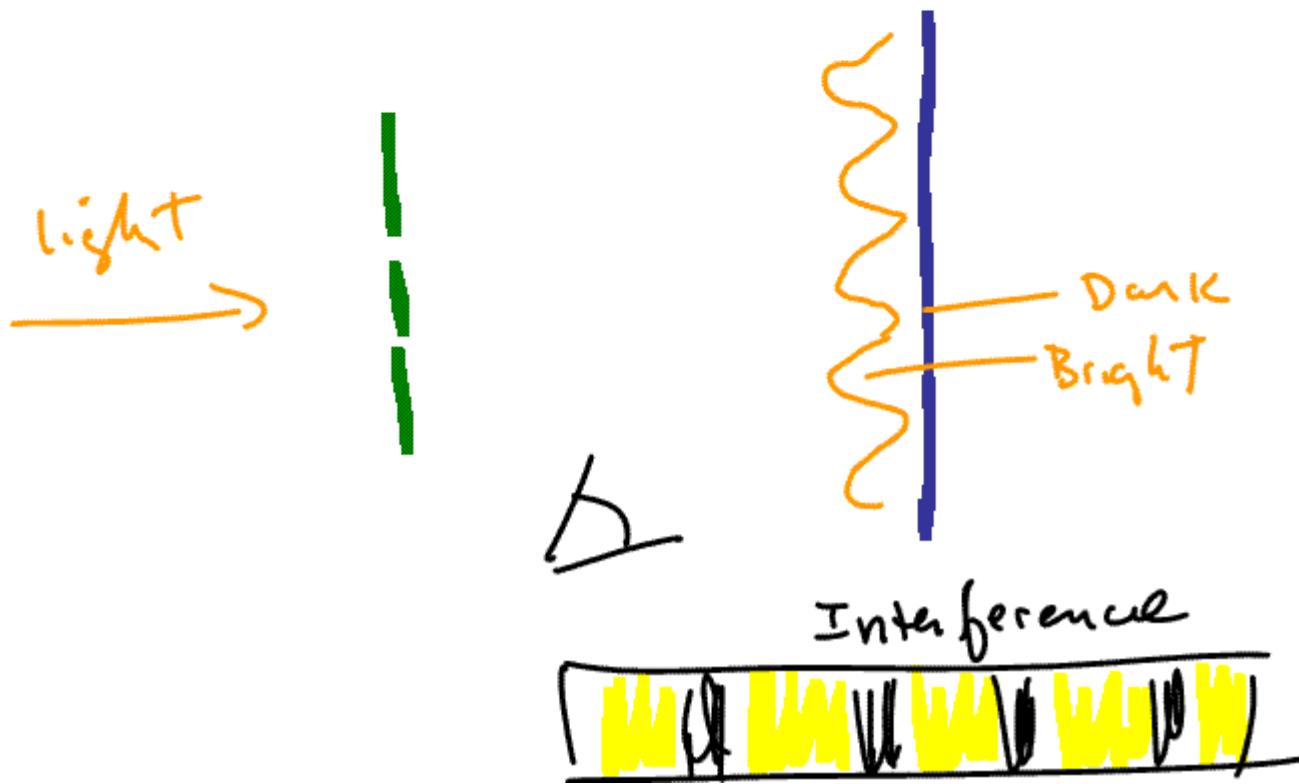
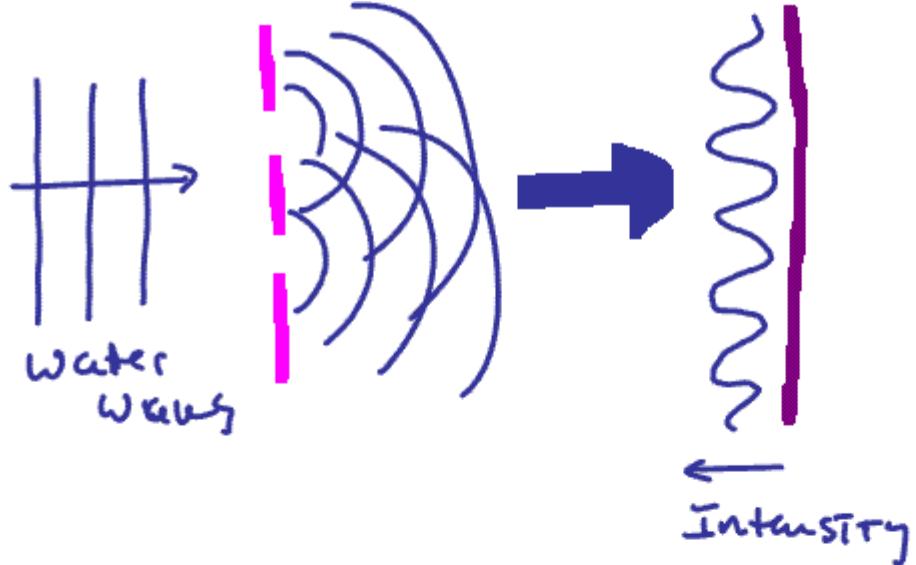


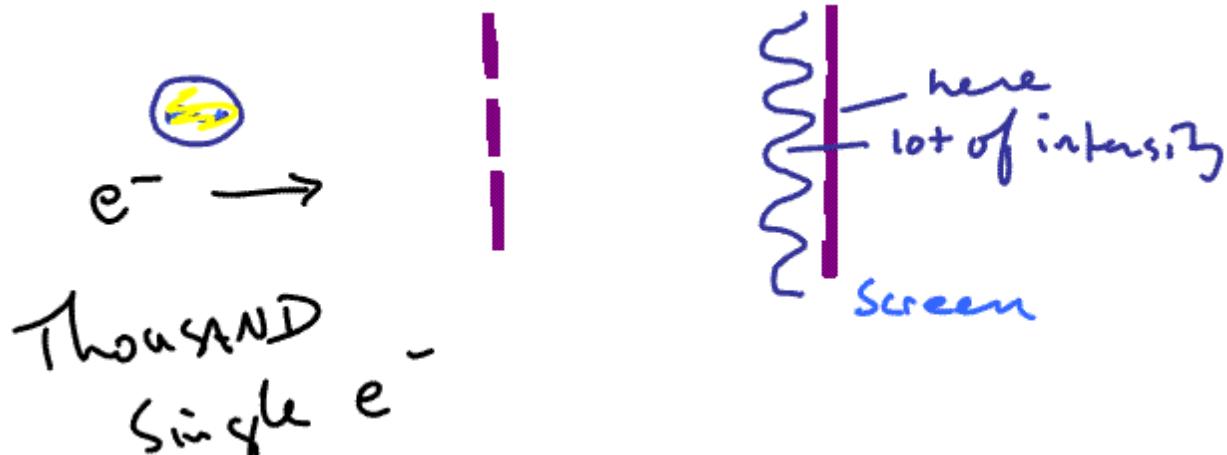
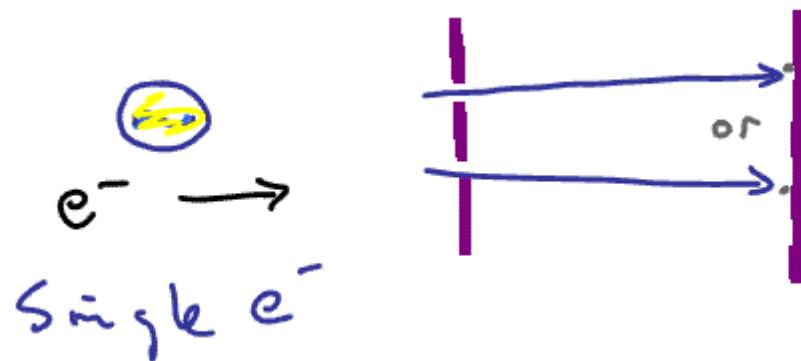
Is cat dead or alive?

Copenhagen Cat = $\frac{1}{2}(|\text{Dead}\rangle + |\text{Alive}\rangle)$

Many Worlds view of quantum Mechanics





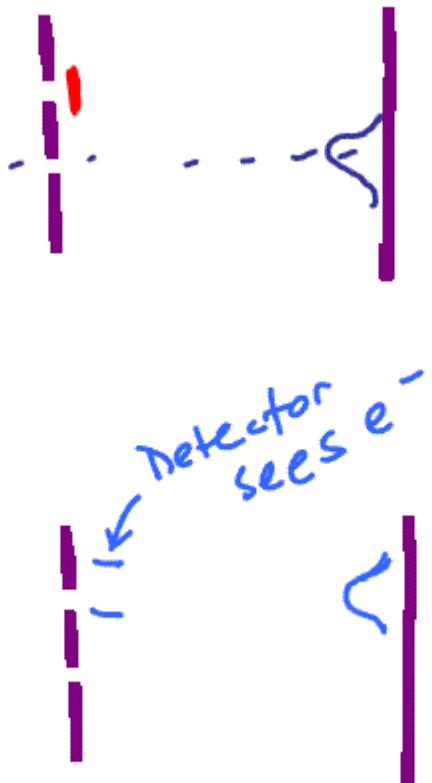


$e^- \rightarrow$

1000 Single

$e^- \rightarrow$

1000 Single



Observation
"Collapses"
Wavefunction
+
interference
pattern
disappears