

Physics 102 - October 12, 2009

- EXAM 1 Wednesday Hoyt
- Bring Calculator
- 3x5 index card w/ formulas, etc. allowed
- Q+A sessions

Today 6-7 pm Goergen 109

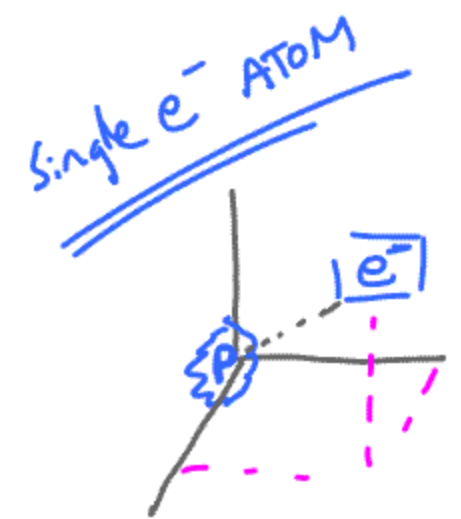
Tomorrow 4-5:30 pm B+L 208

Last Time

Electrons are Waves



Quantum mechanics



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

Spherical geometry

I hope this looks familiar!

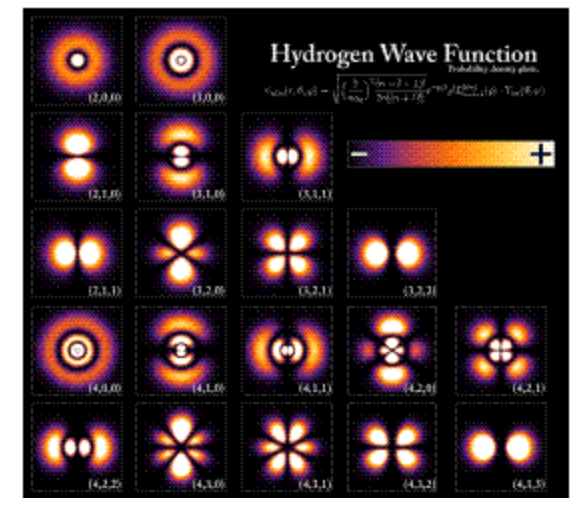
$$F = k \frac{q_1 q_2}{r^2}$$

"Coulombs law"

Quantized Spatial locations
Energies
...

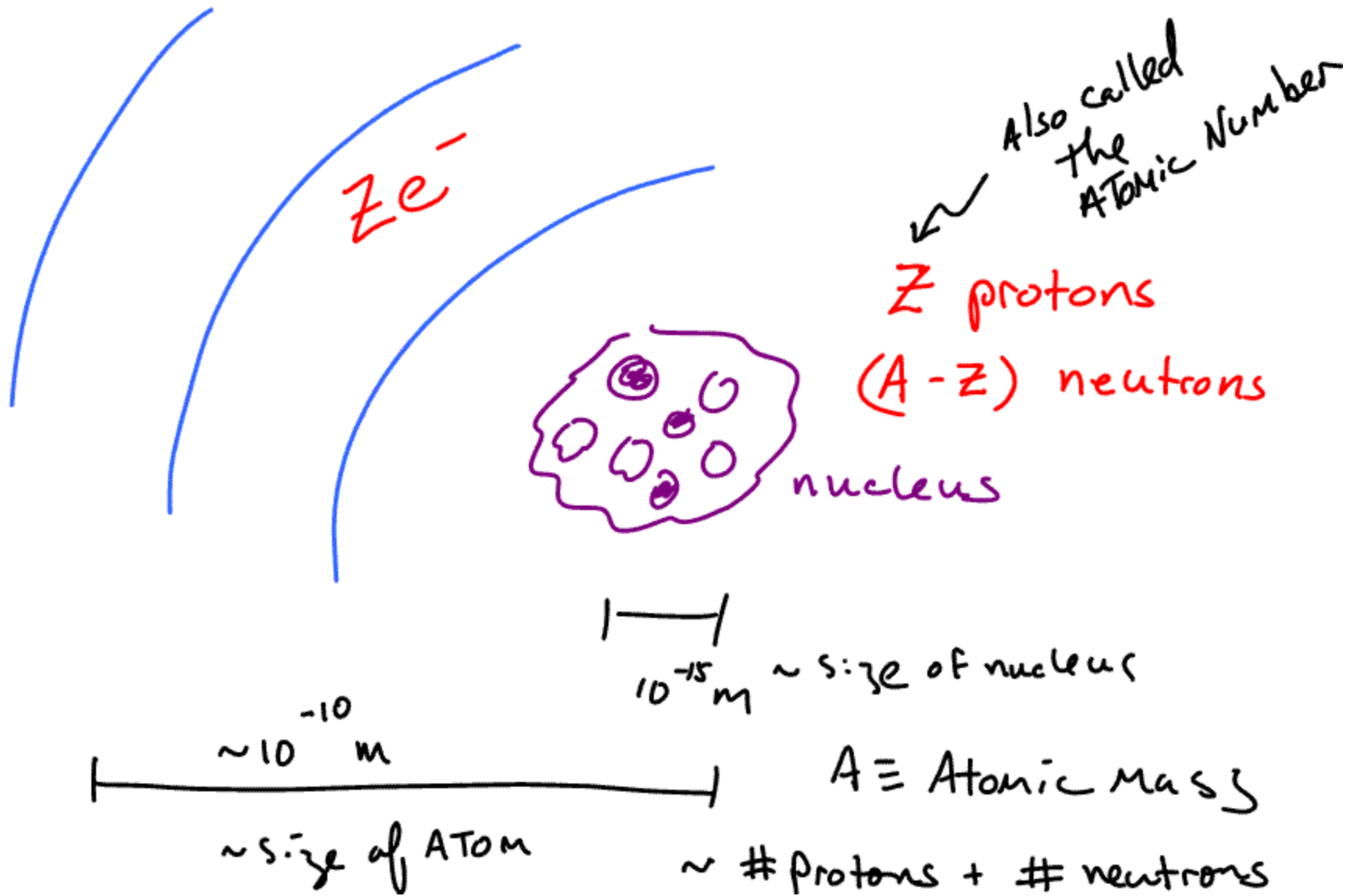


Quantized Atomic
"STATES"
or
"orbitals"



Explains single e^- ATOM Spectra

What about ATOMS with more than 1 e^- ?



Different $Z \rightarrow$ Different $\# e^-$
in neutral
ATOM

\rightarrow Different chemical
characteristics
+ MASS

"Elements"

Slightly over 100 elements in nature

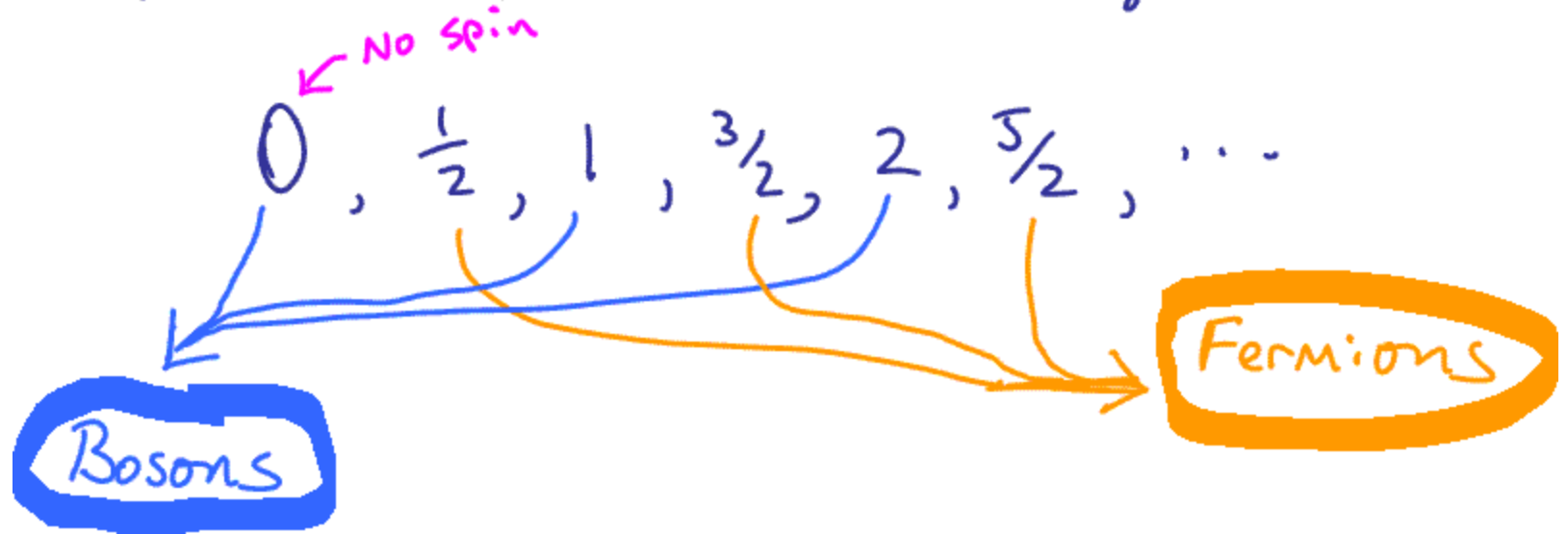
How do electrons fill the orbitals?
(or populate the condos?)

In 1922, particles discovered to have
intrinsic **Spin**

intrinsic "magnetic moments"

Think of as small bar magnets

particle spin is Quantized



Bosons - can share the same conds
or quantum STATE

fermions - only 1 to a STATE

↳ in each orbital or conds
can have 2 e⁻

one spin "up"

one spin "down"

With spin included
as part of quantum
STATE → have
only 1 e⁻ per
STATE

Figure 21
(a)

e^- energy



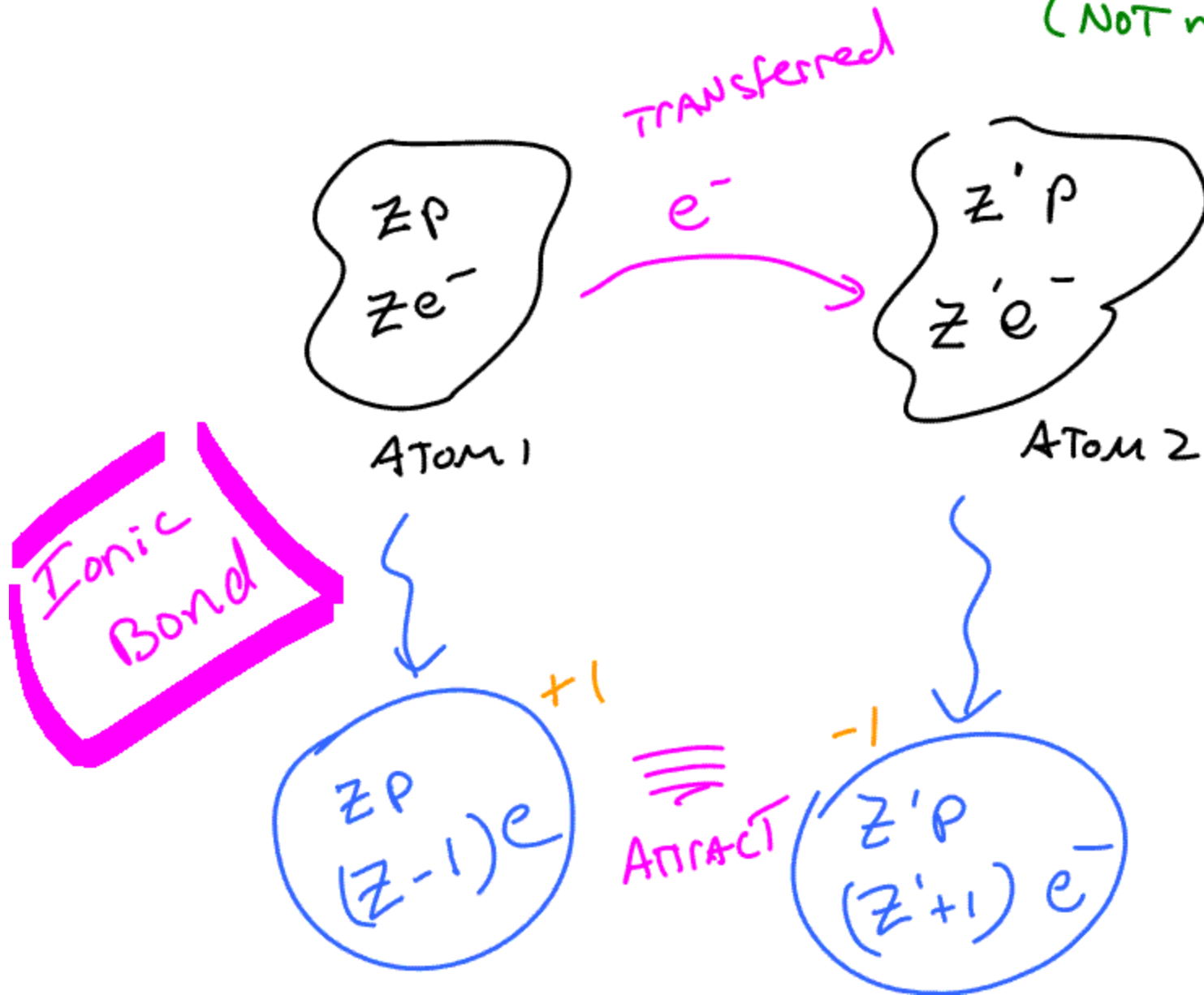
outer electrons

most important

in determining size + chemical characteristics of atom

Chemical Bonds

IONS \equiv ATOM w/ e^-
Added or removed
(NOT neutral)





Covalent Bond





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	Symbol and Atomic Weight	The Composition of the Saline Oxides		The Properties of the Saline Oxides			Small Periods or Series		
	t	a	d	A			R_2O_n or $R_2(CH_3)_n$	R	A	d	v		v	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]			
Hydrogen	< -200°	< 0°	> 20		H	1	1	1	1	0.017	1.008	< -30	1	
Lithium	180°	—	0.30	12	Li	7	1†	—	—	29	13	—	2	
Beryllium	(900°)	—	1.64	9.5	Be	9	—	2	—	9.06	16.9	+ 2.6	—	
Boron	(1800°)	—	2.5	11	B	11	—	3	—	17.8	10	—	—	
Carbon	> (3000°)	—	< 2.8	14	C	12	—	4	—	> 1.0	< 2.0	< 2.0	—	
Nitrogen	—	—	< 0.7	14	N	14	1	—	3*	1.04	0.6	< 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	34	-22	3
Magnesium	500°	0.97	1.74	24	Mg	24	—	2†	—	3.6	22	—	—	
Aluminium	900°	0.23	2.6	27	Al	27	—	3	—	4.8	26	+ 1.0	—	
Silicon	(1800°)	0.08	0.5	30	Si	28	—	4	—	9.65	25	—	—	
Phosphorus	44°	1.29	2.2	31	P	31	1	—	3*	2.30	29	0.2	—	
Sulphur	114°	0.67	2.01	32	S	32	—	—	—	1.96	0.2	0.7	—	
Chlorine	-75°	—	1.5	35.5	Cl	35.5	1	—	—	—	—	—	—	
Potassium	58°	0.84	0.92	39	K	39	1†	—	—	2.7	35	-25	4	
Calcium	(900°)	—	1.6	40	Ca	40	—	2†	—	4.2	30	—	—	
Scandium	—	—	2.0	(38)	Sc	44	—	3†	—	8.60	35	0.0	—	
Titanium	(2000°)	—	3.51	(44)	Ti	48	—	—	—	4.2	39	(+5)	—	
Vanadium	(3000°)	—	5.5	51	V	51	—	—	—	2.60	58	0.7	—	
Chromium	(3000°)	—	5.5	52	Cr	52	—	—	—	2.74	70	0.5	—	
Manganese	(1500°)	—	7.5	55	Mn	55	—	—	—	—	—	—	—	
Iron	(1800°)	0.22	7.8	56	Fe	56	—	—	—	—	—	—	—	
Cobalt	(1800°)	0.22	8.9	59	Co	59	—	—	—	—	—	—	—	
Nickel	1510°	0.17	9.2	58.7	Ni	58.7	—	—	—	—	—	—	—	
Copper	1084°	0.80	8.8	63.5	Cu	63.5	1†	—	—	Ca ₂ O	5.9	0.4	0.6	5
Zinc	420°	—	7.2	65.4	Zn	65.4	—	—	—	—	—	—	—	
Gallium	30°	—	5.96	70	Ga	70	—	—	—	Ga ₂ O ₃	(71)	(86)	(40)	—
Germanium	500°	—	5.47	72.6	Ge	72.6	—	—	—	4.7	44	4.5	—	
Arsenic	300°	0.01	5.7	75	As	75	—	—	—	4.1	56	0.0	—	
Selenium	317°	—	4.8	79	Se	79	—	—	—	—	—	—	—	
Bromine	-7°	—	0.1	80	Br	80	1	—	—	—	—	—	—	
Krypton	—	—	—	—	Kr	84	—	—	—	—	—	—	—	
Rubidium	30°	—	1.5	85.5	Rb	85.5	1†	—	—	—	—	—	—	
Strontium	(600°)	—	0.4	87.6	Sr	87.6	—	—	—	—	—	—	—	
Yttrium	—	—	3.0	(89)	Y	89	—	—	—	5.00	45	(-2)	—	
Zirconium	(1500°)	—	4.1	91.2	Zr	91.2	—	—	—	0.7	45	-0.0	—	
Niobium	—	—	7.1	93	Nb	93	—	—	—	4.7	27	+0.2	—	
Molybdenum	—	—	8.6	96	Mo	96	—	—	—	4.4	65	0.8	—	
Technetium	—	—	—	—	Tc	98	—	—	—	—	—	—	—	
Ruthenium	(2000°)	0.10	10.2	101	Ru	101	—	—	—	—	—	—	—	
Rhodium	(1800°)	0.08	12.1	103	Rh	103	—	—	—	—	—	—	—	
Palladium	1300°	0.12	11.4	106.4	Pd	106.4	—	—	—	—	—	—	—	
Silver	350°	0.10	10.5	108	Ag	108	1†	—	—	—	—	—	—	
Cadmium	320°	0.61	8.6	112.4	Cd	112.4	—	—	—	—	—	—	—	
Indium	176°	0.05	7.4	114.8	In	114.8	—	—	—	—	—	—	—	
Thallium	320°	0.20	7.3	118.7	Tl	118.7	—	—	—	—	—	—	—	
Antimony	452°	0.12	6.7	121.8	Sb	121.8	—	—	—	—	—	—	—	
Tellurium	451°	0.17	9.1	127.6	Te	127.6	—	—	—	—	—	—	—	
Iodine	114°	—	4.9	126.9	I	126.9	1	—	—	—	—	—	—	
Cesium	27°	—	1.88	132.9	Cs	132.9	1†	—	—	—	—	—	—	
Barium	—	—	3.75	137.3	Ba	137.3	—	—	—	—	—	—	—	
Lanthanum	(600°)	—	0.1	138.9	La	138.9	—	—	—	—	—	—	—	
Cerium	(700°)	—	0.6	140.1	Ce	140.1	—	—	—	—	—	—	—	
Dysprosium	(900°)	—	0.5	162.5	Dy	162.5	—	—	—	—	—	—	—	
Ytterbium	—	—	0.9	(163)	Yb	173	—	—	—	—	—	—	—	
Tantalum	—	—	10.4	181	Ta	181	—	—	—	—	—	—	—	
Tungsten	(1800°)	—	10.1	184	W	184	—	—	—	—	—	—	—	
Osmium	(2000°)	0.07	22.5	192	Os	192	—	—	—	—	—	—	—	
Iridium	2000°	0.07	22.4	194	Ir	194	—	—	—	—	—	—	—	
Platinum	1772°	0.05	21.5	195.1	Pt	195.1	—	—	—	—	—	—	—	
Gold	1063°	0.14	19.3	197	Au	197	1	—	—	—	—	—	—	
Mercury	-39°	—	10.5	200.6	Hg	200.6	1†	—	—	—	—	—	—	
Thallium	294°	0.11	11.8	204.4	Tl	204.4	—	—	—	—	—	—	—	
Lead	327°	0.20	11.2	207.2	Pb	207.2	—	—	—	—	—	—	—	
Bismuth	268°	0.14	9.8	209	Bi	209	—	—	—	—	—	—	—	
Polonium	—	—	—	—	Po	209	—	—	—	—	—	—	—	
Thorium	—	—	11.3	232	Th	232	—	—	—	—	—	—	—	
Uranium	(800°)	—	18.7	238	U	238	—	—	—	—	—	—	—	

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

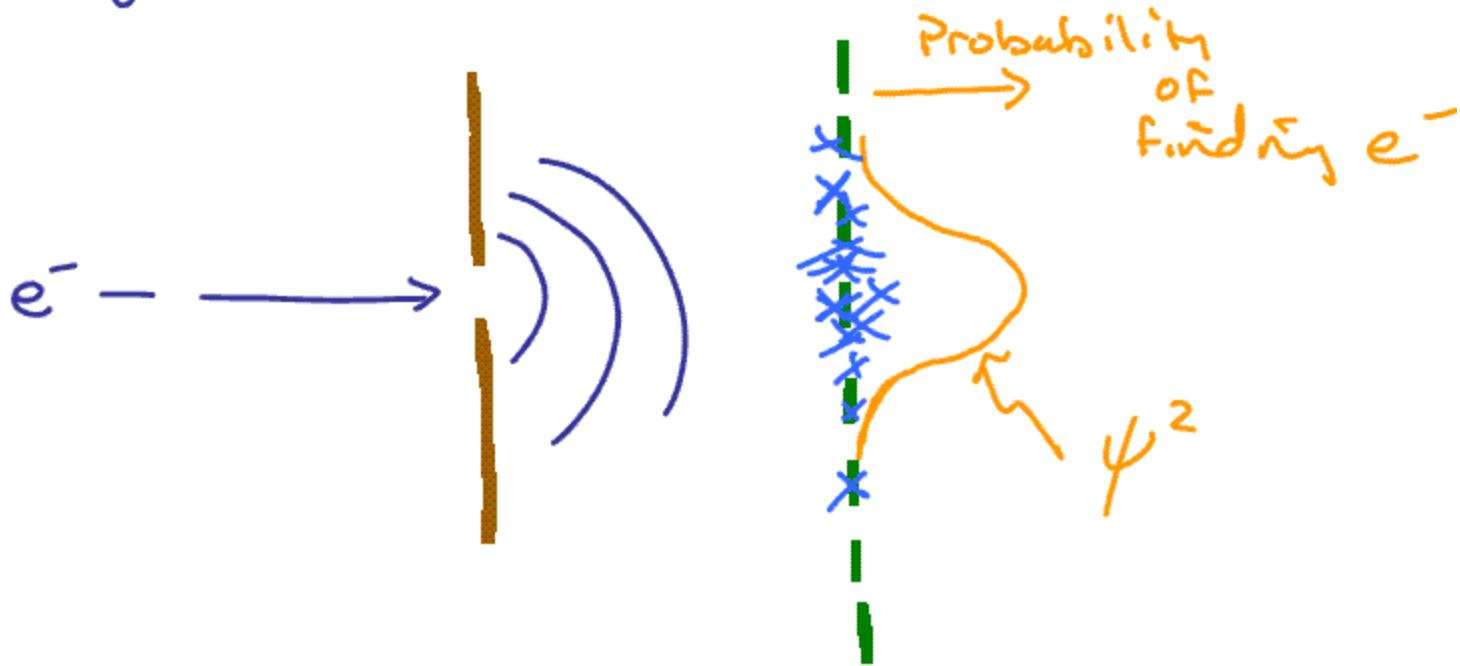
1A 1 H Hydrogen 1.008	2A 2 He Helium 4.003											3A 3 B Boron 10.81	4A 4 C Carbon 12.01	5A 5 N Nitrogen 14.01	6A 6 O Oxygen 16.00	7A 7 F Fluorine 19.00	8A 8 Ne Neon 20.18		
3 Li Lithium 6.941	4 Be Beryllium 9.012											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95		
11 Na Sodium 22.99	12 Mg Magnesium 24.31	3B 21 Sc Scandium 44.96	4B 22 Ti Titanium 47.88	5B 23 V Vanadium 50.94	6B 24 Cr Chromium 52.00	7B 25 Mn Manganese 54.94	8B 26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	11B 29 Cu Copper 63.55	12B 30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.56	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80		
19 K Potassium 39.10	20 Ca Calcium 40.08	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 190.2	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 Ununium (272)	112 Uub Unbium (277)	114 Uuq Unquadium (296)	116 Uuh Unhexium (296)	118 Uuo Unoctium (?)					

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

Imagine e^- passing thru thin slit. The electron wave is diffracted (spreads out). Where does the electron hit the film/detector? Quantum mechanics only provides us with a Probability Distribution of where the electron might hit.



$\psi(x)$ not well defined

$\psi^2(x)$ \rightarrow probability distribution

Max Born German (1882-1970)

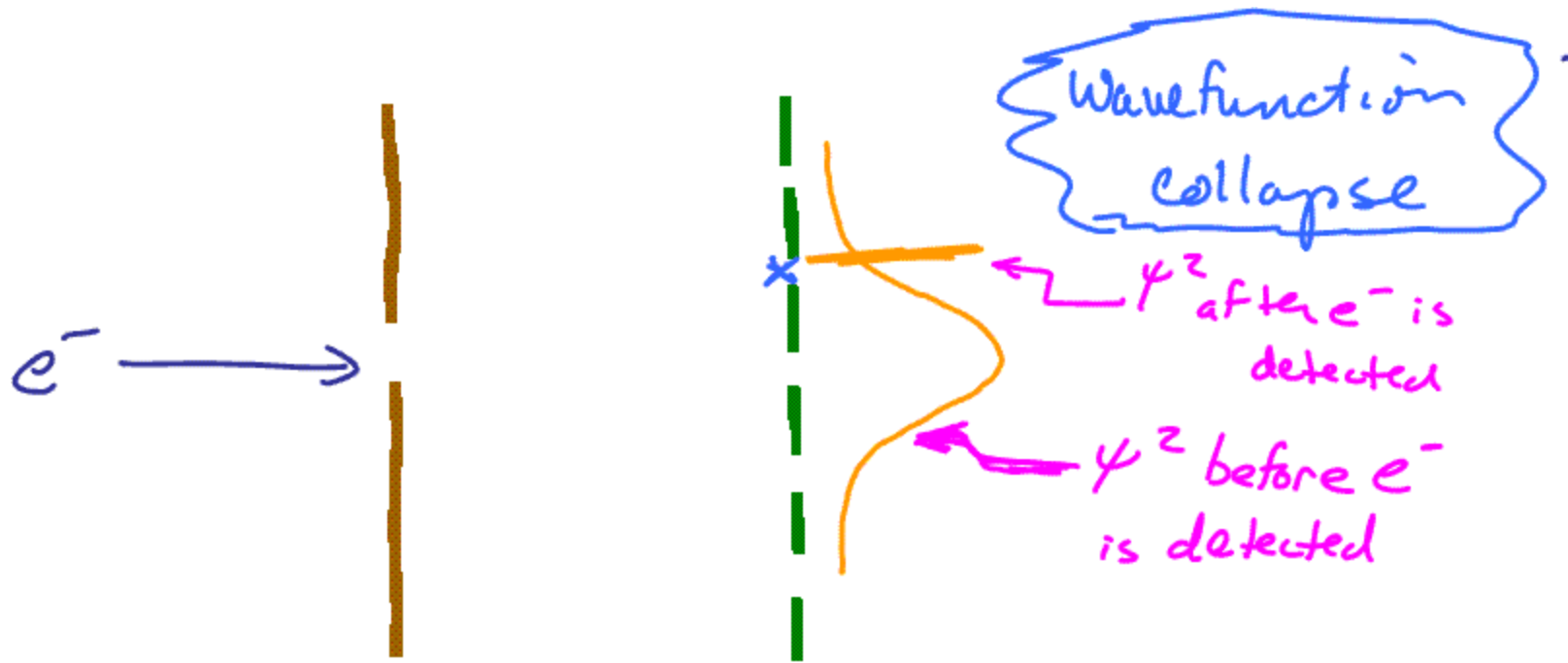


1954 Nobel Prize in physics

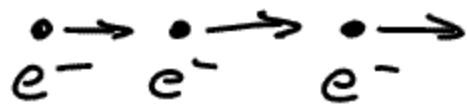
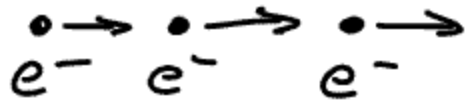
"For his fundamental research
in quantum mechanics,
especially for his statistical
interpretation of the
wavefunction"

$\psi(x)$ wave function

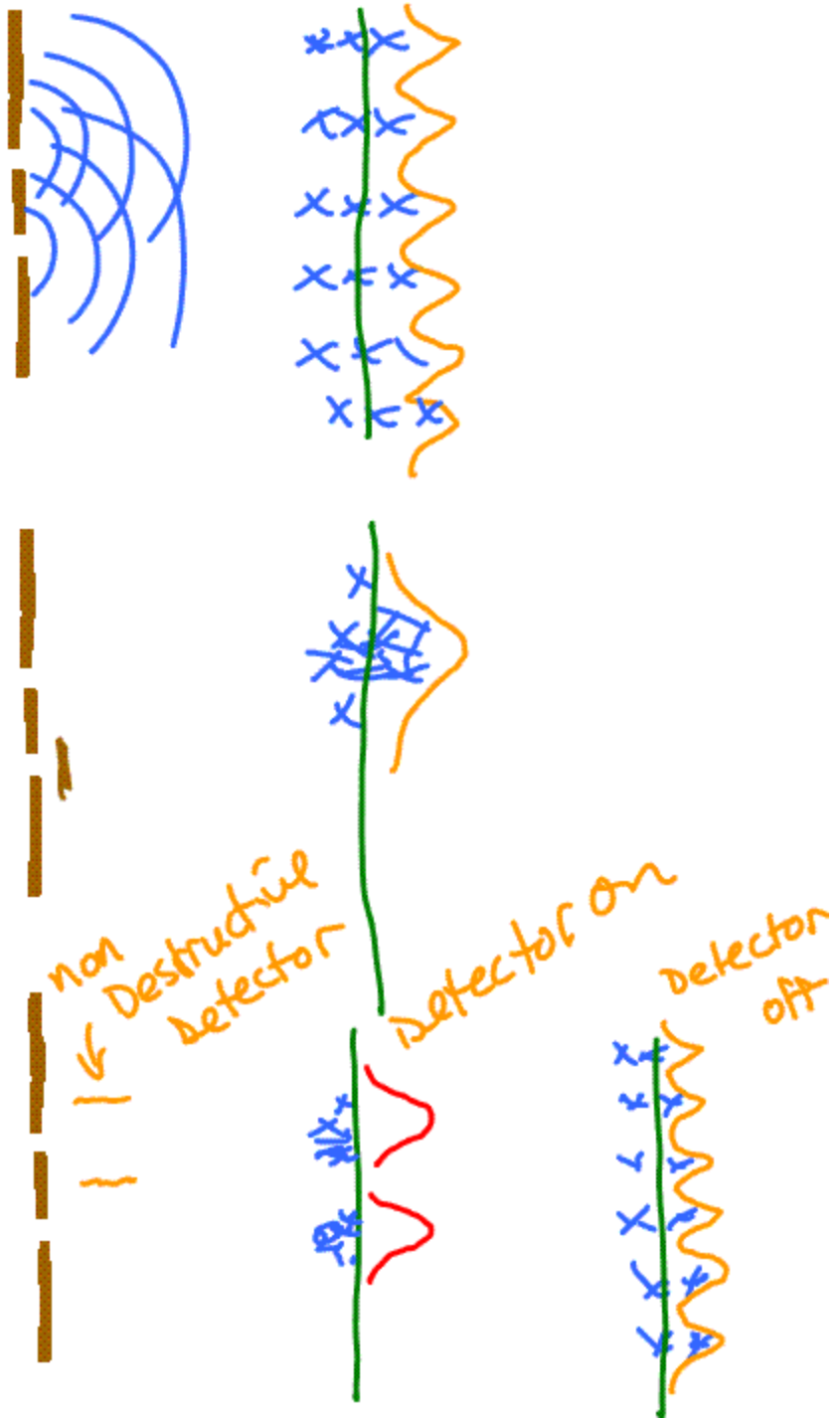
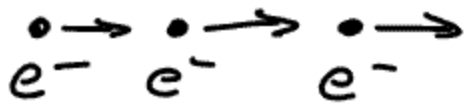
$\psi^2(x) \sim$ probability of finding particle
in region of space



Once electron hits the film/detector we know with 100% certainty where the electron hits
- So wavefunction has to "collapse"



just determining the slit that the e^- passes thru (even with non-destructive detector) is sufficient to collapse the wave function.



Schrödinger's Cat



Thought experiment
nucleus has
50:50 chance
of decaying +
killing the cat.
What is the
"state" of the
cat before box
opened?

Copenhagen
Interpretation

$$\text{nucleus quantum state} = \frac{1}{2}(\text{decayed}) + \frac{1}{2}(\text{not decayed})$$



$$\text{cat state} = \frac{1}{2}(\text{dead}) + \frac{1}{2}(\text{alive})$$





Hugh
Everett (1957)

Bryce DeWitt
1960's + 70's
↳ Many
Worlds
interpretation

Overall wavefunction does not collapse. IT evolves in time.
"Decoherence" forces wavefunction to evolve into different
streams that do NOT interact.