Today (2)

2.1 Historical Development of Atomic Theory

2.1.1 The Periodic Table

2.1.2 Discovery of Subatomic Particles and The Bohr Atom

Next Class (3)

2.2 The Schrödinger Equation

2.2.1: The Particle in a Box

2.2.2 Quantum Numbers and Atomic Wave Functions

2.2.3 The Aufbau Principle and Shielding

Second Class from Today (4)

2.2.2 Quantum Numbers and Atomic Wave Functions

2.2.3 The Aufbau Principle and Shielding

2.3 Periodic Properties

Third Class from Today (5)

2.3 Periodic Properties

Dalton’s Theory

1. All matter is composed of atoms.
2. All atoms of a given element are alike and all atoms of a given element are different than the atoms of another element.
3. Compounds are formed when atoms combine in fixed proportions.
4. A chemical reaction involves the rearrangement of atoms. No atoms are broken apart or destroyed in a chemical reaction.

“…the ultimate particles of all homogeneous bodies are perfectly alike in weight, figure, etc. In other words, every particle of water is like every other particle of water […]”[1]

“[…] most probable […] that there are the same number of particles in two measure of hydrogen as in one measure of oxygen”[2]

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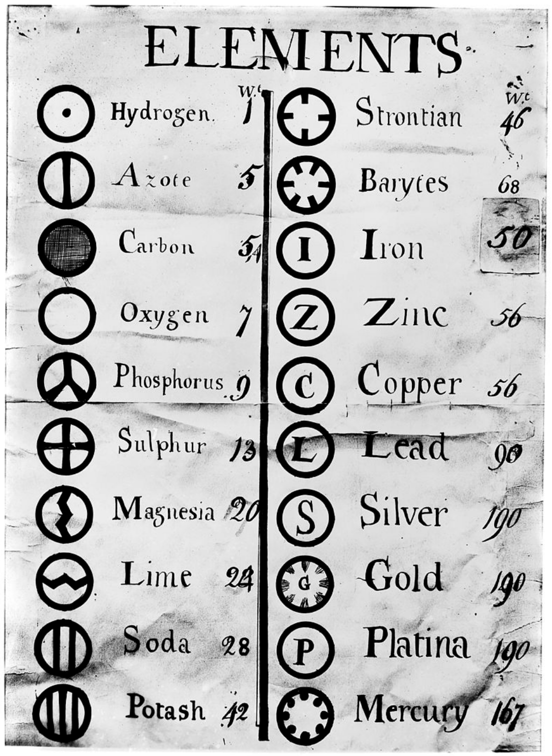
[1] As quoted in *Inorganic Chemistry* 5th Edition, Miessler, Fischer, and Tarr, Pearson (2014), p 9. referencing page 113 of John Daltons *A New System of Chemical Philosophy*, 1808 reprinted with an Introduction by Alexander Joseph, Perter Owen Limited, London, 1965.

[2] Ibid. referencing page 133 of John Daltons *A New System of Chemical Philosophy*, 1808 reprinted with an Introduction by Alexander Joseph, Perter Owen Limited, London, 1965.

"A **chemical element** is a chemical substance that cannot be broken down into other substances."[1]



Dalton's Symbols for the Elements[3]

Döberiner's Triads[2]

chlorine	35,470[2]	calcium (Kalk/lime)	356,019	sulfur	32,239
bromine	78,383[2] (80,470)	strontium (Strontianerde/ Strontian earth)	647,285	selenium	79,263 (80,741)
iodine	126.479[2]	barium (Baryterde/barite earth)	956,880	tellurium	129,243

[1] https://en.wikipedia.org/wiki/Chemical_element accessed September 7, 2023

[2] Annalen der Physik. ser.2 v.15 (1829) pp. 301-307 via https://babel.hathitrust.org/cgi/pt?id=mdp.39015065410634&view=1up&seq=317&skin=2021

[3] https://en.wikipedia.org/wiki/History_of_the_periodic_table#/media/File:Dalton's_symbols_of_the_elements._1806_Wellcome_M0004592.jpg which references https://wellcomeimages.org/indexplus/obf_images/0f/17/3e7d575111fcdad60b4fe0e9a466.jpg

Reihen	Gruppo I. — R^2O	Gruppo II. — RO	Gruppo III. — R^2O^3	Gruppo IV. RH^4 RO^2	Gruppo V. RH^3 R^2O^5	Gruppo VI. RH^2 RO^3	Gruppo VII. RH R^2O^7	Gruppo VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

https://en.wikipedia.org/wiki/History_of_the_periodic_table#/media/File:Mendelejevs_periodiska_system_1871.png
https://en.wikipedia.org/wiki/Periodic_table

Mendeleev (1871)

series	Group I R_2O	Group II RO	Group III R_2O_3	Group IV RH_4 RO_2	Group V RH_3 R_2O_5	Group VI RH_2 RO_3	Group VII RH R_2O_7	Group VIII RO_4
1	H = 1							
2	Li = 7	Be = 9,4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35,5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63
5	(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se =78	Br = 80	
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb =122	Te = 125	I = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au =199
11	(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Periodic Table of the Elements

	1	2															3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
①	1 H																															2 He
②	3 Li	4 Be																									5 B	6 C	7 N	8 O	9 F	10 Ne
③	11 Na	12 Mg																									13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
④	19 K	20 Ca															21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
⑤	37 Rb	38 Sr															39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
⑥	55 Cs	56 Ba	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
⑦	87 Fr	88 Ra	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

https://en.wikipedia.org/wiki/Periodic_table radio activity

β decay

e^-'s released from atom

⊖

α decay

⊕ He^{2+}

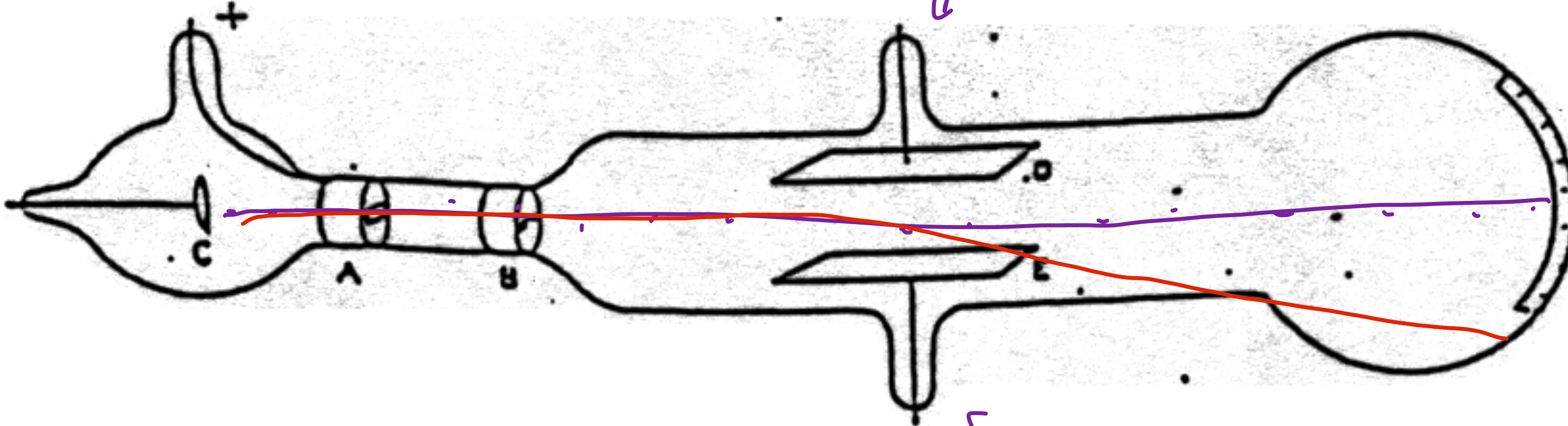
γ rays

no charge

https://en.wikipedia.org/wiki/Image:Becquerel_plate.jpg accessed 9/9/2021

Cathode Ray Tubes (JJ Thomson)

cathode is an electrode



rays emminating from the cathode are the same regardless of the material

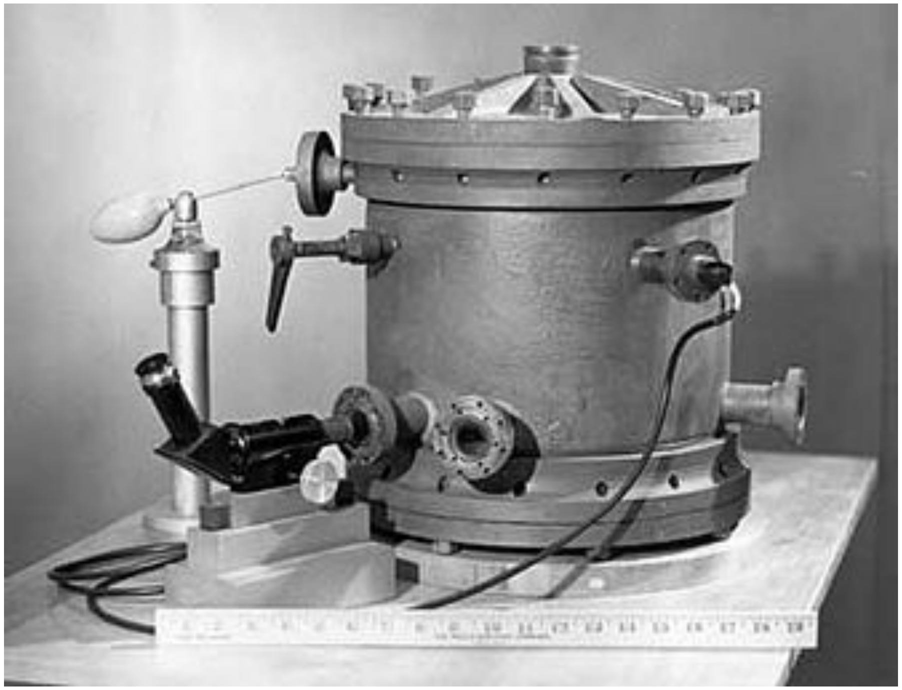
cathode ray tubes is where e⁻'s were discovered and their mass to charge ration was determine

https://en.wikipedia.org/wiki/J._J._Thomson#/media/File:JJ_Thomson_Cathode_Ray_2.png J.J. Thomson - Philosophical Magazine, 44, 293 (1897)

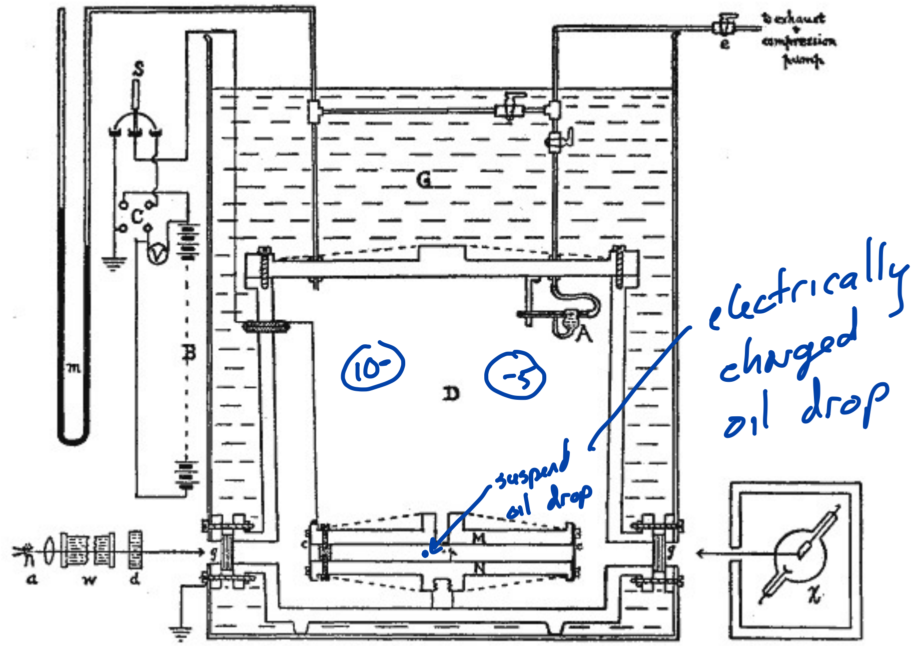
Charge to mass ratio for an electron found by JJ Thompson using cathode ray tubes.

But what is the charge?

What is the mass?



1.



2

determine the mass of the drop constant rate drag = gravity

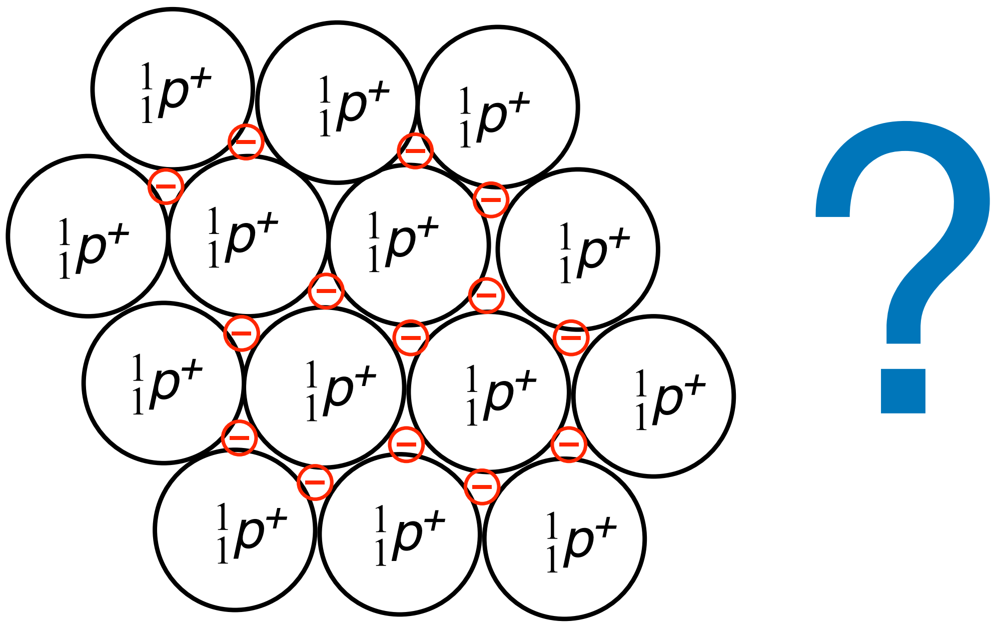
make drop hover between to electrically charged plates... to determine its charge

the charges of the drops are all multiples of the charge of an e^-

1. https://en.wikipedia.org/wiki/Oil_drop_experiment#/media/File:Millikan’s_oil-drop_apparatus_1.jpg

2. https://en.wikipedia.org/wiki/Oil_drop_experiment#/media/File:Scheme_of_Millikan’s_oil-drop_apparatus.jpg

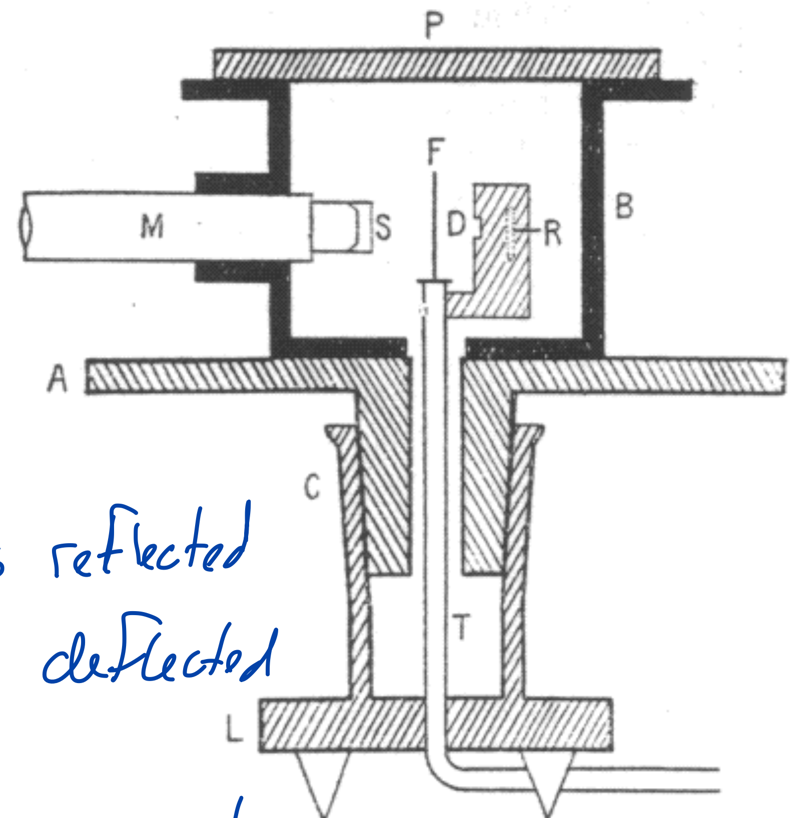
plum pudding model ... uniform distribution



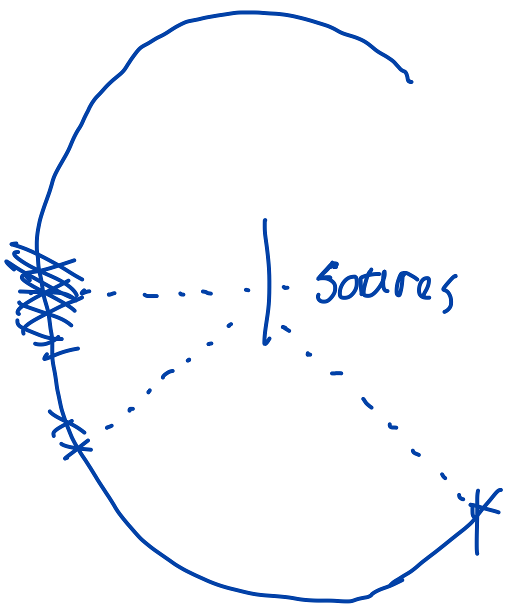
of ⊕ an ⊖ through out the atom

A certain thickness of metal is required to stop α-particles .... α particles should blast through a thin sheet of metal

"[…] metal foil (F). The microscope (M) and screen (S) were affixed to a rotating cylinder and could be moved a full circle around the foil so that they could count scintillations from every angle."



particles hit the screen when the microscope is not directly opposite the source



some α-particles reflected
some particles deflected

to reflect the α-particle the mass of the atom had to be concentrated into a tiny volume

nucleus

https://en.wikipedia.org/wiki/Geiger–Marsden_experiments#CITEREFGeigerMarsden1913

https://en.wikipedia.org/wiki/Geiger–Marsden_experiments#/media/File:Geiger-Marsden_diagram.gif

“Moseley found that the K_α lines (in Siegbahn notation) were indeed related to the atomic number, Z.

Following Bohr's lead, Moseley found that for the spectral lines, this relationship could be approximated by a simple formula, later called Moseley's Law.

$$\nu = A \cdot (Z-b)^2$$”

energy of the ejected electron is related to the charge of the nucleus

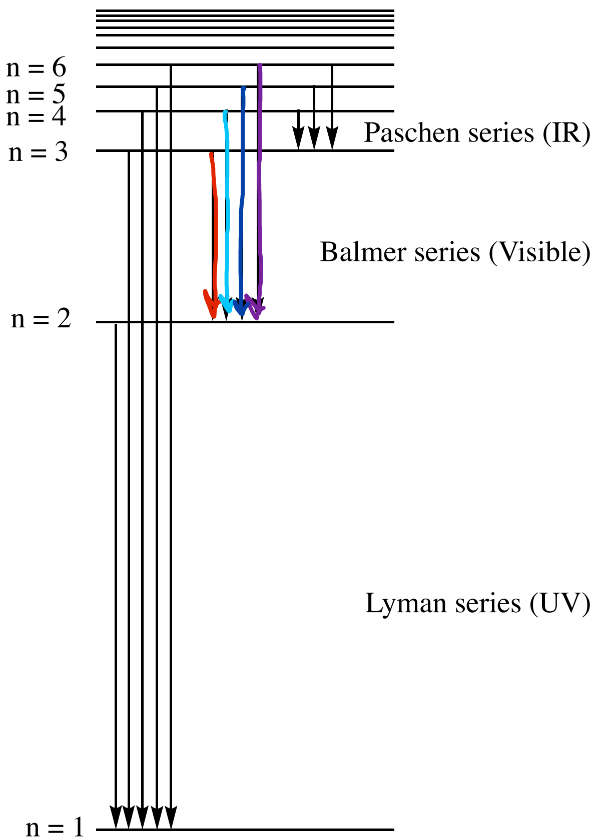
“Until Moseley's work, "atomic number" was merely an element's place in the periodic table and was not known to be associated with any measurable physical quantity.”

X-rays would hit atoms + eject e⁻'s from the atoms

https://en.wikipedia.org/wiki/Moseley%27s_law

https://en.wikipedia.org/wiki/Emission_spectrum1

line spectra are an indication the e^-'s can only exist in specific energy levels



$$E_{photon} = R_H\left(\frac{1}{4} - \frac{1}{n^2}\right)$$

$$E_{photon} = R_H\left(\frac{1}{n_l^2} - \frac{1}{n_h^2}\right)$$

Mathematical formulas found empercally

Energy

$$E = KE + PE$$

$$E = \frac{1}{2} mv^2 + \frac{Ze^2}{r}$$

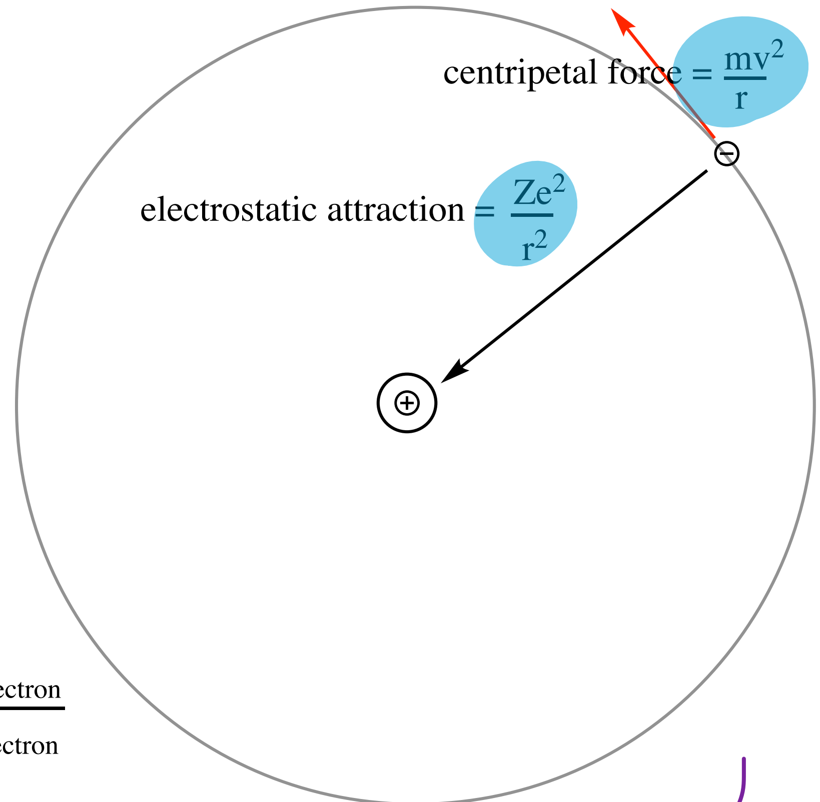
Angular Momentum is quantized

$$mvr = \mathbf{n}\frac{h}{2\pi}$$

algebra …

$$E_n = \frac{-\mu Z^2 e^4}{\varepsilon_0^2 h^2}\,\frac{1}{n^2}$$

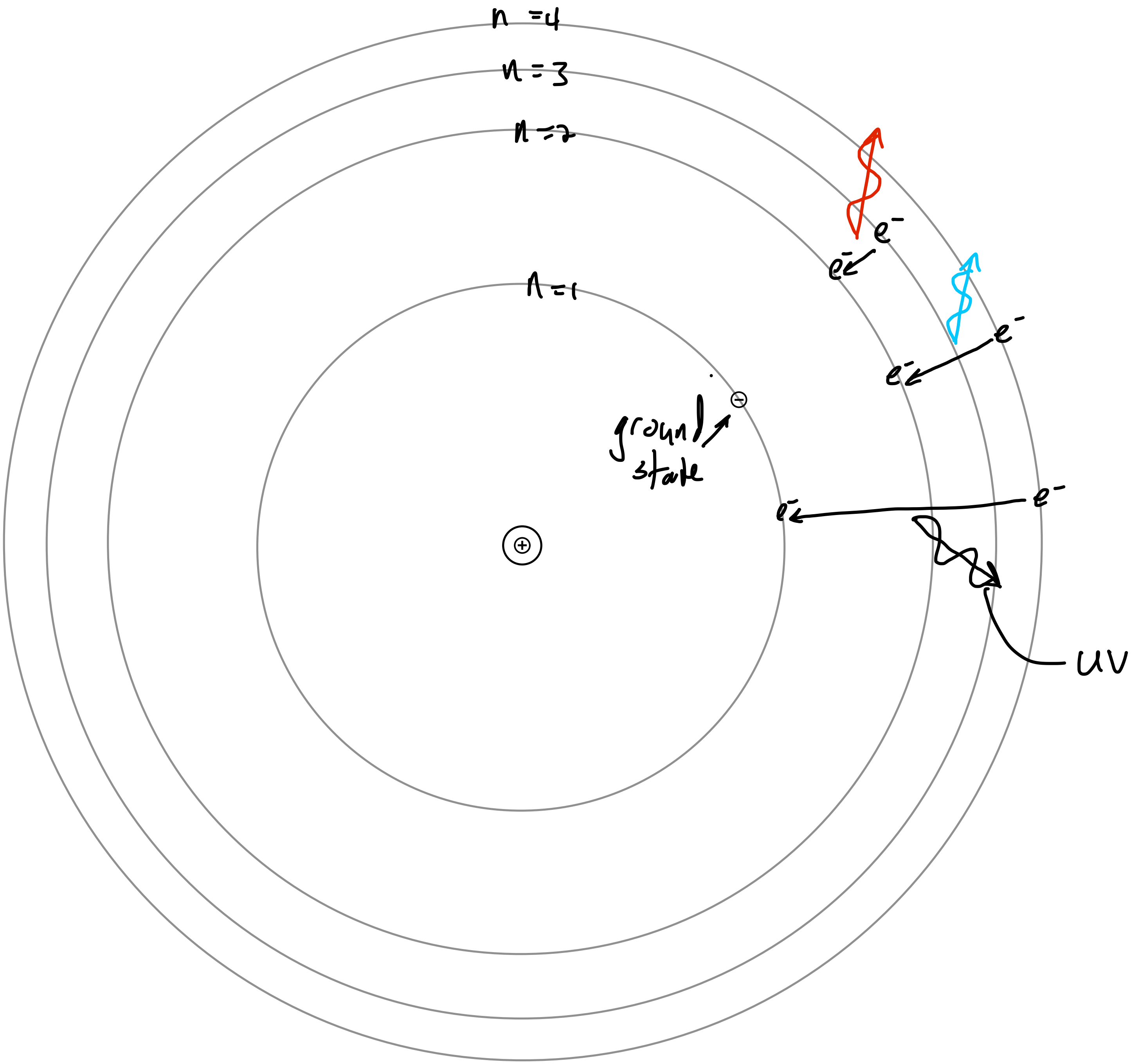
where the reduced mass $\mu = \dfrac{m_{nucleus} + m_{electron}}{m_{nucleus} m_{electron}}$

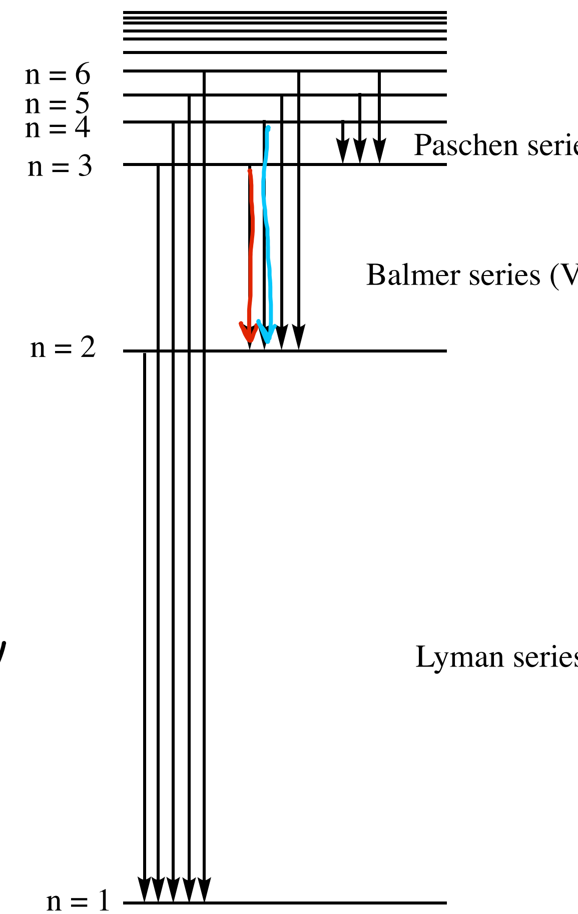


By only allowing the e⁻ to have angular momentum in steps of $\frac{h}{2\pi}$, Bohr quantized the energy of the e⁻

In order to keep the e⁻ in orbit, the electrostatic attraction has to be equal to the centripetal force.

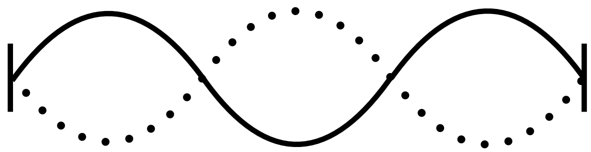
2 equations 2 unknowns (v + r) solve and find E!


n = 4
n = 3
n = 2
n = 1
ground state
e⁻
UV

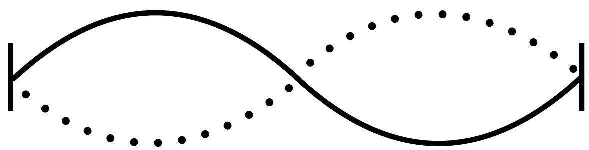

n = 6
n = 5
n = 4
n = 3
n = 2
n = 1
Paschen serie
Balmer series (V
Lyman series

Are there other phenomena that have quantized energy levels?

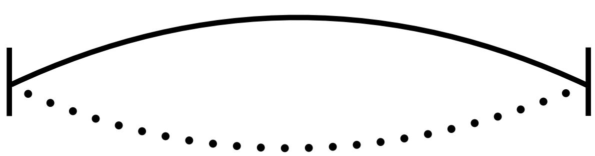
n = 3



n = 2



n = 1



e^- is a wave confined to an atom ... a standing wave.