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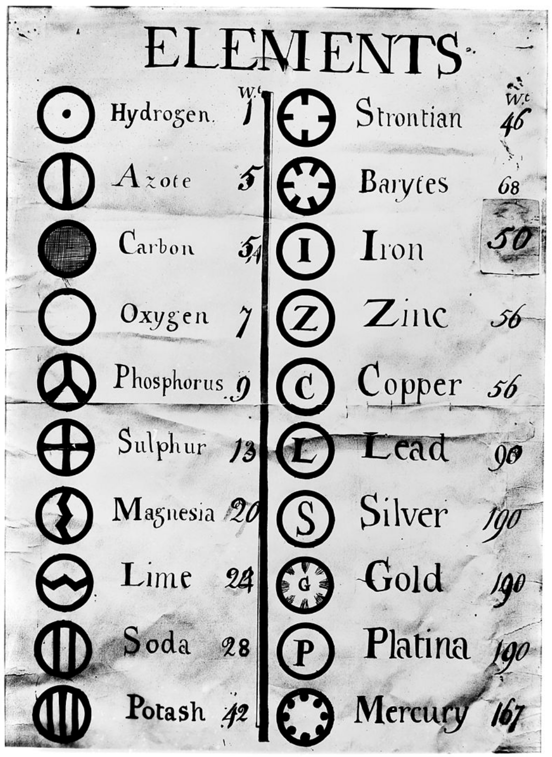
[1] As quoted in *Inorganic Chemistry* 5th Edition, Miessler, Fischer, and Tarr, Pearson (2014), p 9. referencing page 113 of John Daltons *A New System of Chemical Philosophy*, 1808 reprinted with an Introduction by Alexander Joseph, Perter Owen Limited, London, 1965.

[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	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe 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	—	— — — —

predicted density of oxide & chloride compounds of these elements

Periodic Table of the Elements

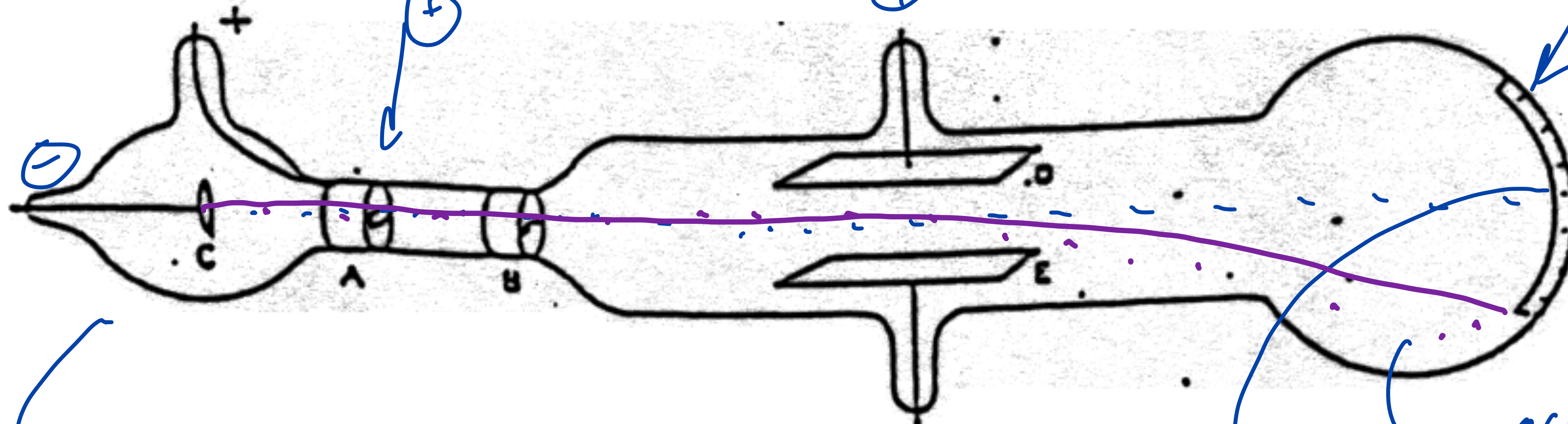
	1	2															3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
①	1 H																															2 He
②	3 Li	4 Be																									5 B	6 C	7 N	8 O	9 F	10 Ne
③	11 Na	12 Mg																									13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
④	19 K	20 Ca															21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	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 radioactivity shows that atoms can be broken apart into smaller particles

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

CRT

Cathode Ray Tubes (JJ Thomson)



particles were charged

all electrodes produced particles with the same properties

screen lights up when particles hit it

mass to charge ratio

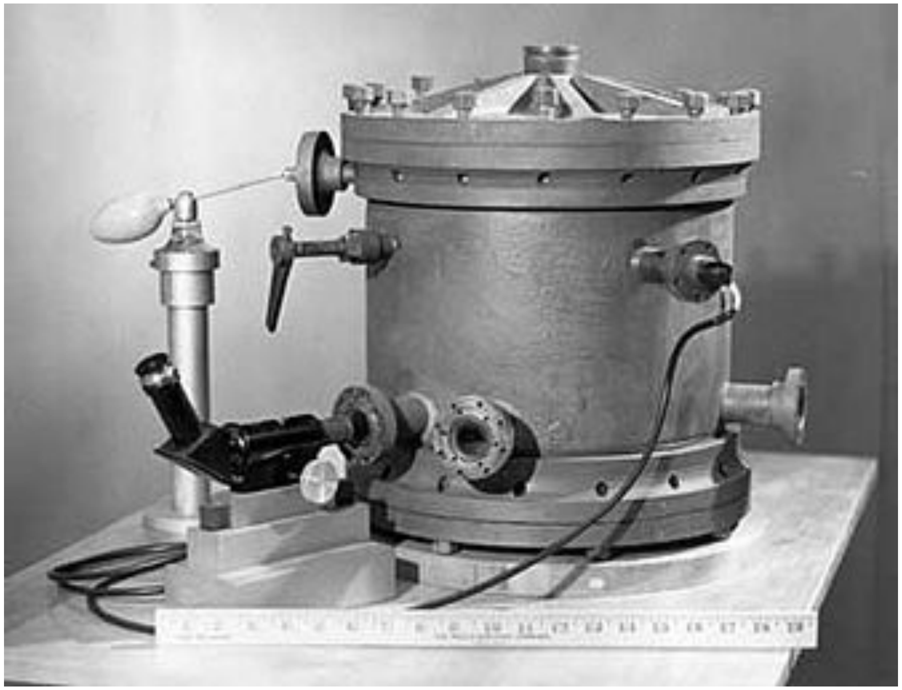
the amount that the path of the particles change depends on velocity, strength of electric field, length, mass of object + charge object

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

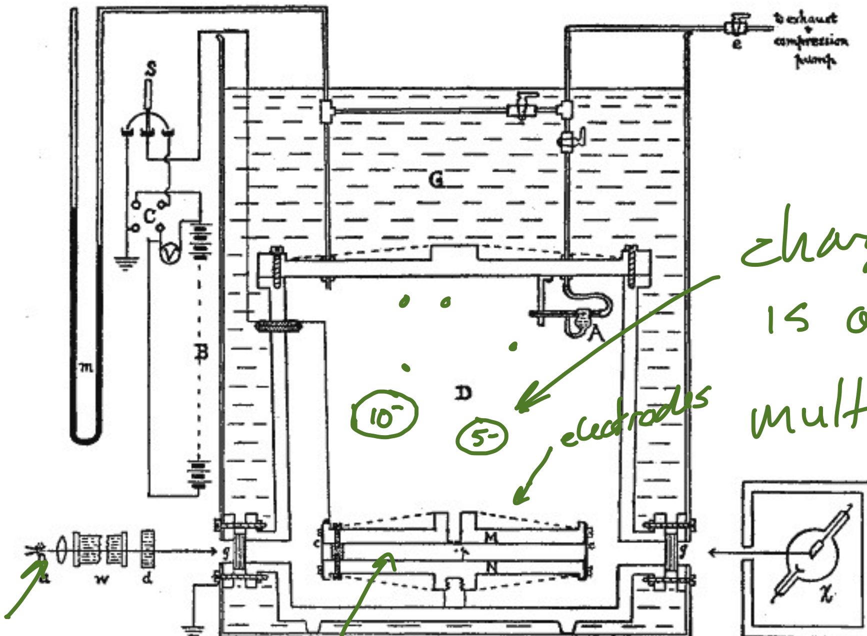
1. Found the charge of the e^-

2.

1.



2



charge is a multiple of the charge of an e^-

electric field exerts force that counteracts gravity

known known

levitate charged particles

electrodes

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

Gold Foil Experiment (E Rutherford)

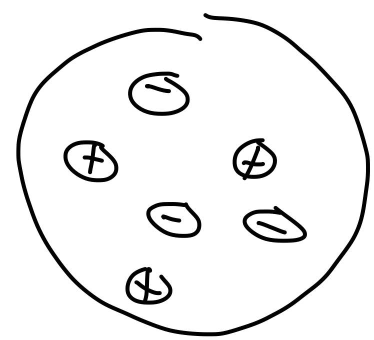
positive things (canal rays)

negative things (cathode ray tubes)

where are they

gold foil experiments

atom



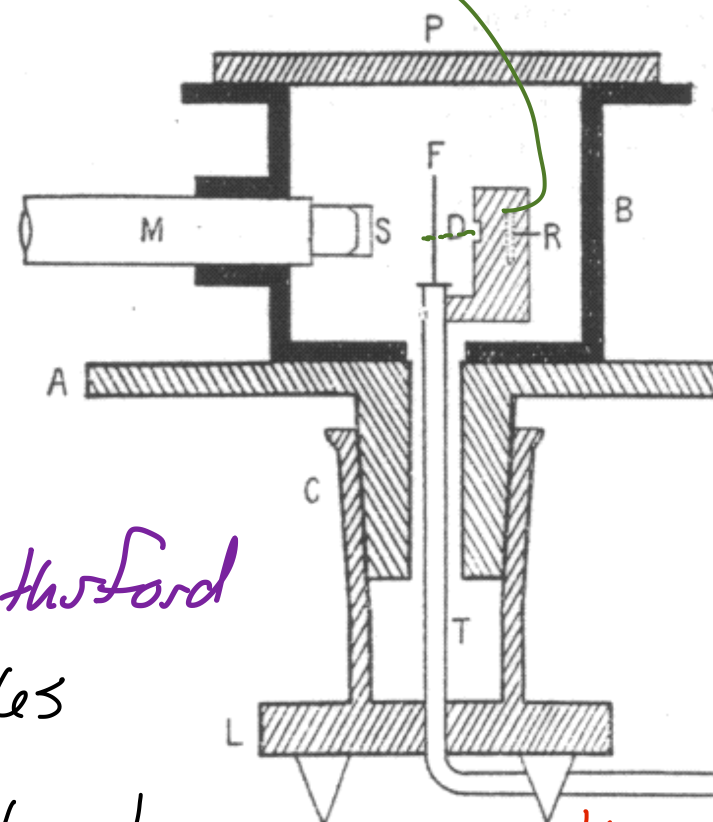
plum pudding model...

uniform density

Gold Foil Experiment (E Rutherford)

"[…] 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."

a source of alpha particles = ${}^{4}_{2}He^{2+}$



if the foil has uniform density it is either thick enough to stop the particles or it isn't

by moving the microscope Rutherford saw that most α-particles went straight through but not all … some were deflected … and some were reflected back towards the source

mostly empty space

so a part can be dense enough to reflect the particles

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 x-Ray photon is related to an atom's atomic number

"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."

e⁻'s are relaxing to their ground state on releasing a photon

high E to low E .... E of electrons is related to

$$E \propto \frac{q_1 q_2}{r}$$

charge of E

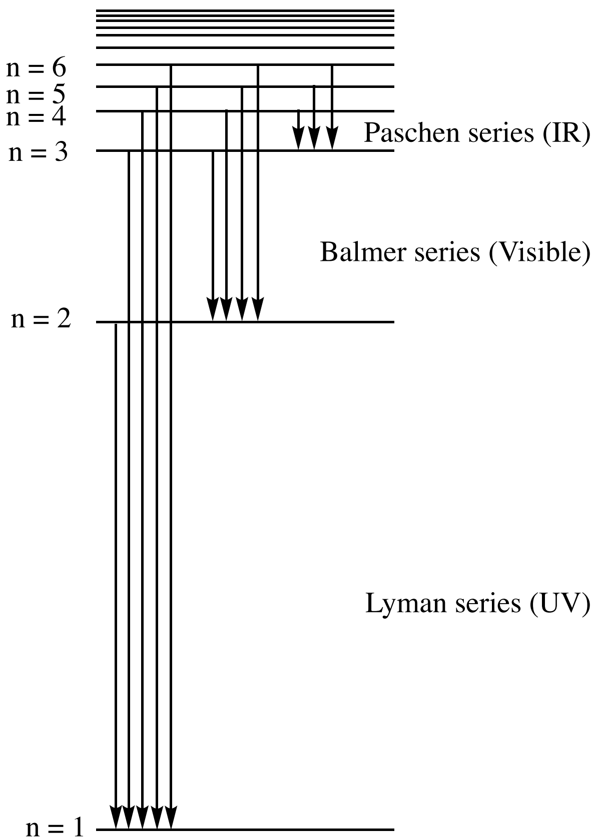
charge of nucleus

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

Hydrogen Line Spectra (Lyman, Balmer, Paschen and others)

Section 2.1.2

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



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

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

how do you explain that e^-'s can only have specific energy values

Energy

$E = KE + PE$

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

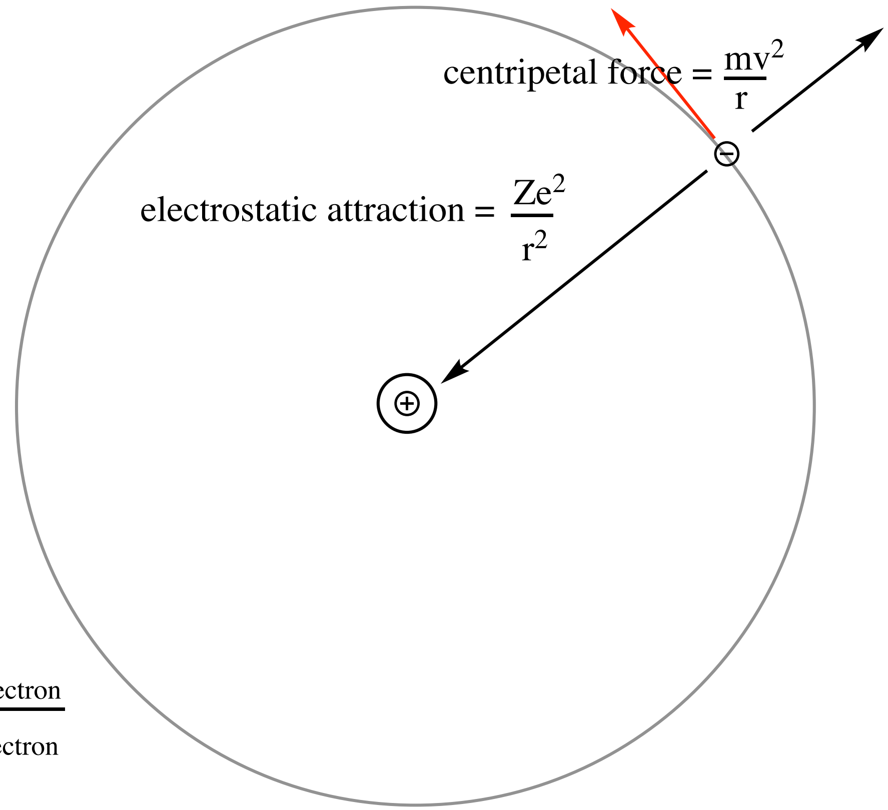
Angular Momentum is quantized

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

algebra …

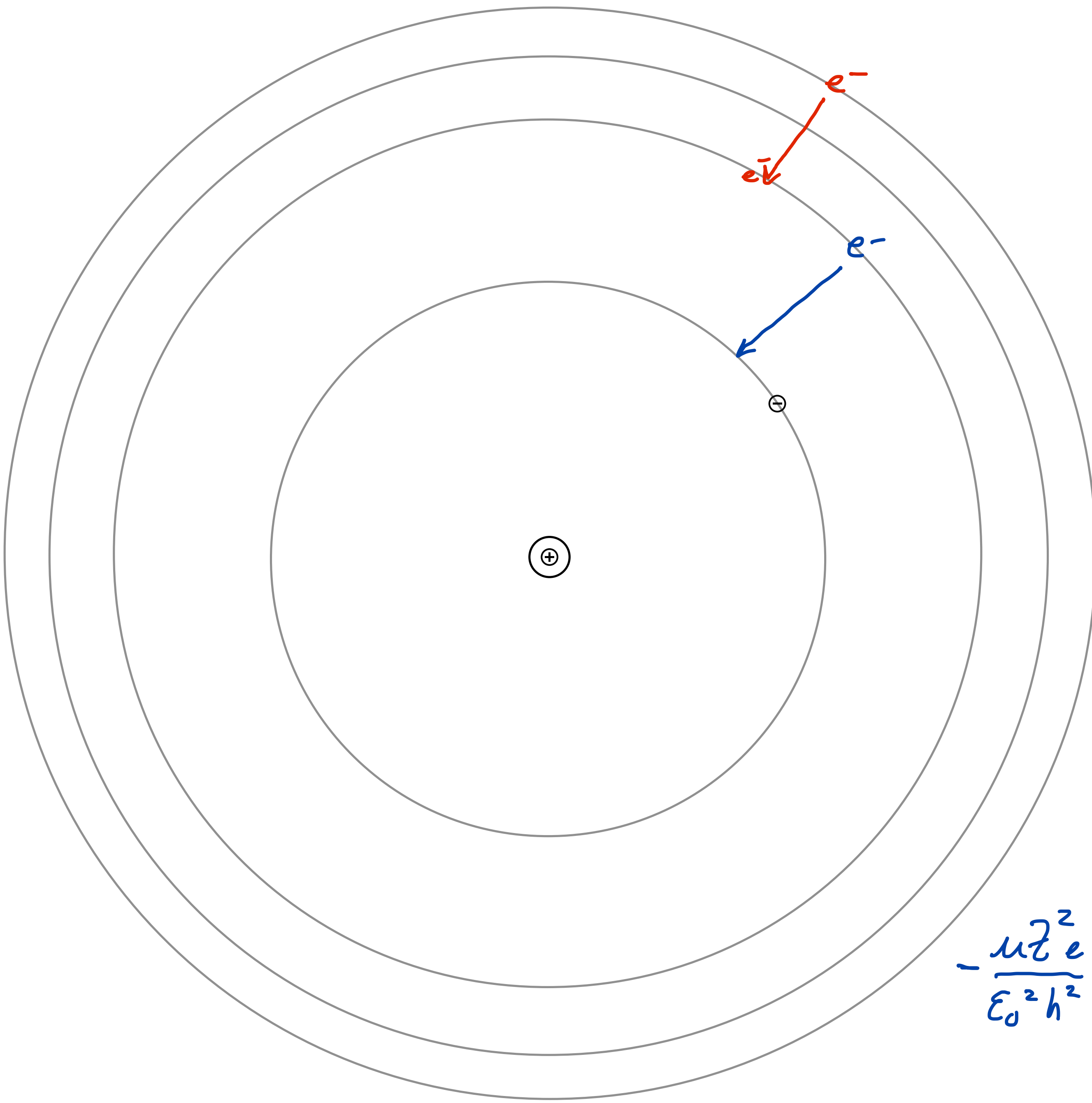
$$E_n = -\frac{\mu Z^2 e^4}{\varepsilon_0^2 h^2} \frac{1}{n^2}$$

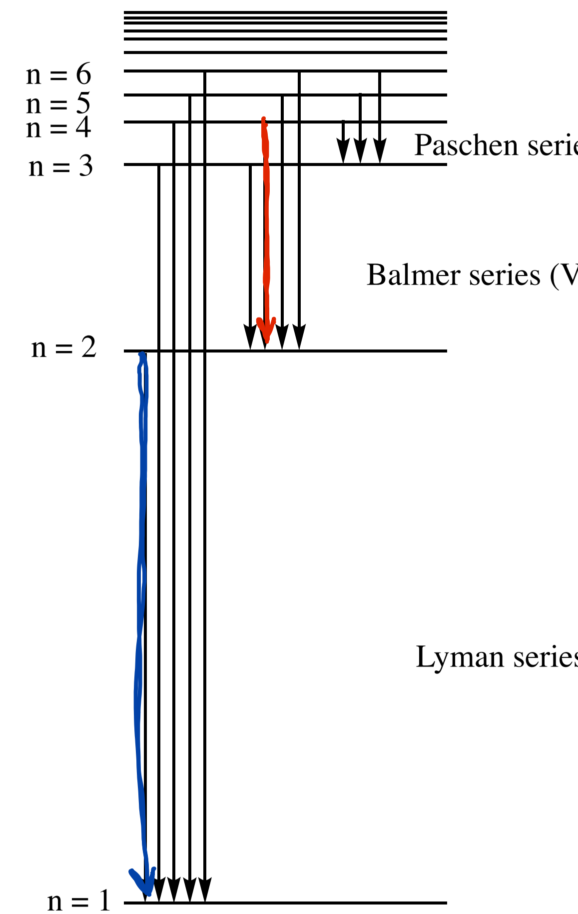
where the reduced mass $\mu = \dfrac{m_{nucleus} + m_{electron}}{m_{nucleus} m_{electron}}$



Bohr Atom

$$\Delta E_{e_{4\to 2}} = \frac{-\mu Z^2 e^4}{\varepsilon_0^2 h^2}\left(\frac{1}{2^2}-\frac{1}{4^2}\right)$$





$$-\frac{\mu Z^2 e^4}{\varepsilon_0^2 h^2}\left(\frac{1}{1^2}-\frac{1}{2^2}\right) = \Delta E_{e_{2\to 1}}$$

Are there other phenomena that have quantized energy levels?

Standing waves!