This Class

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

2.2 The Scrödinger Equation

The Particle in a Box, Quantum Numbers, The Aufbau Principle and Shielding

2.3 Periodic Properties

mass # neutrons + # protons

$^{10}_{6}C$ $^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C$

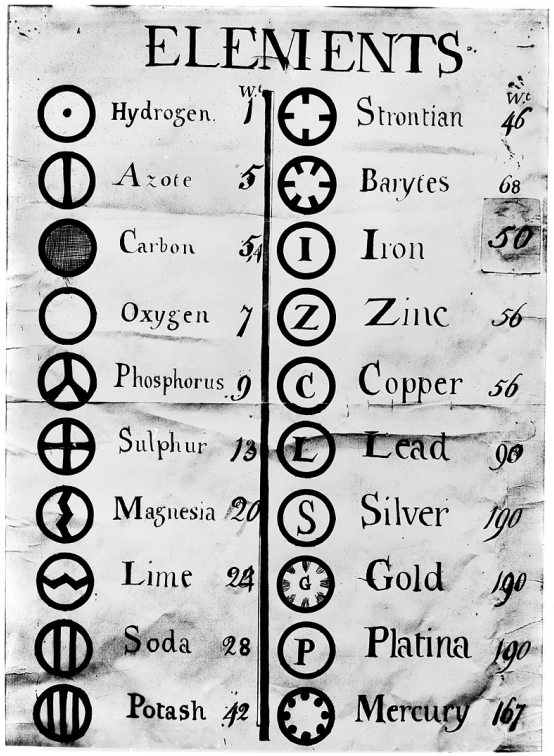
Dalton's Theory

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"

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



[1]

Döberiner's Triads

chlorine	35,470	calcium (Kalk/lime)	356,019	sulfur	32,	lithium
bromine	78,383 (80,470)	strontium (Strontianerde/ Strontian earth)	647,285	selenium	79,263 (80,741)	sodium (Natron/ baking soda)
iodine	126.479	barium (Baryterde/barite earth)	956,880	tellurium	12	potasium

https://babel.hathitrust.org/cgi/pt?id=mdp.39015065410634&view=1up&seq=317&skin=2021

[1] 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^1O	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

Periodic Table

2.1

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 elements with correct densities & formulas for O containing compounds & three densities

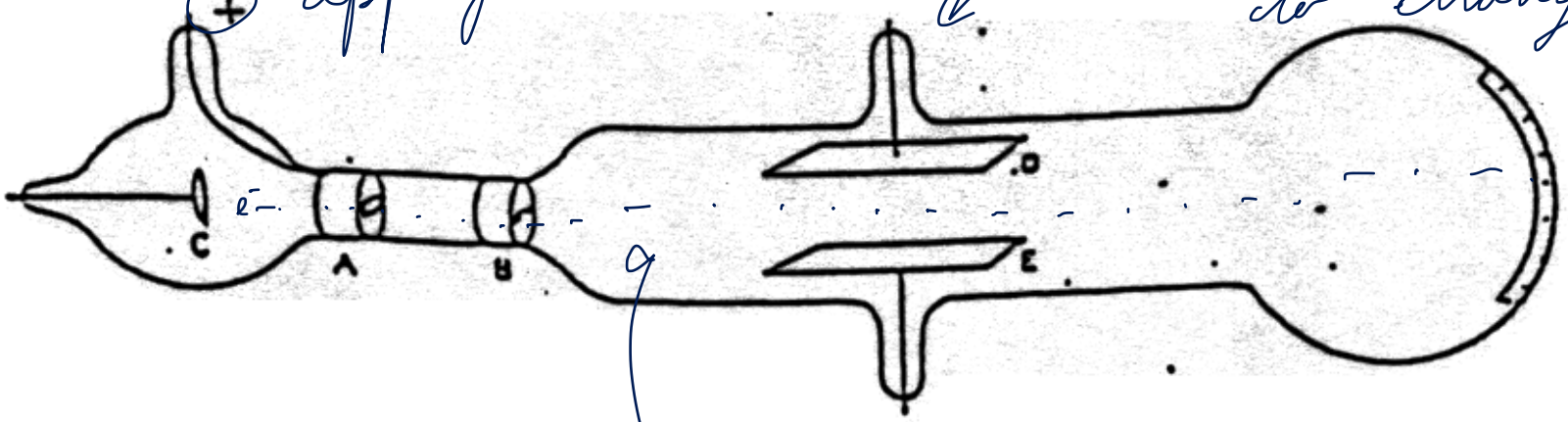
Periodic Table of the Elements

	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 told us that we could "see" what elements atoms were made of

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



apply voltage

plates or use electric field to change path

charge to mass ratio for the e⁻

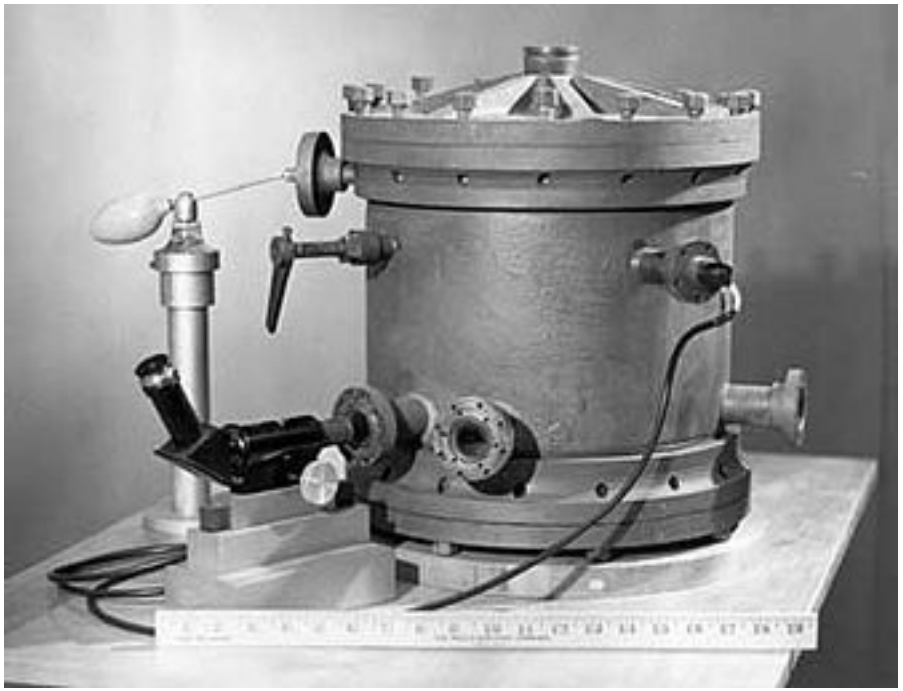
a beam of particles
- charged particles ⊖
- same regardless of gas in tube or cathode material
- relative size ~ $\frac{1}{1000}$ size H atom

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

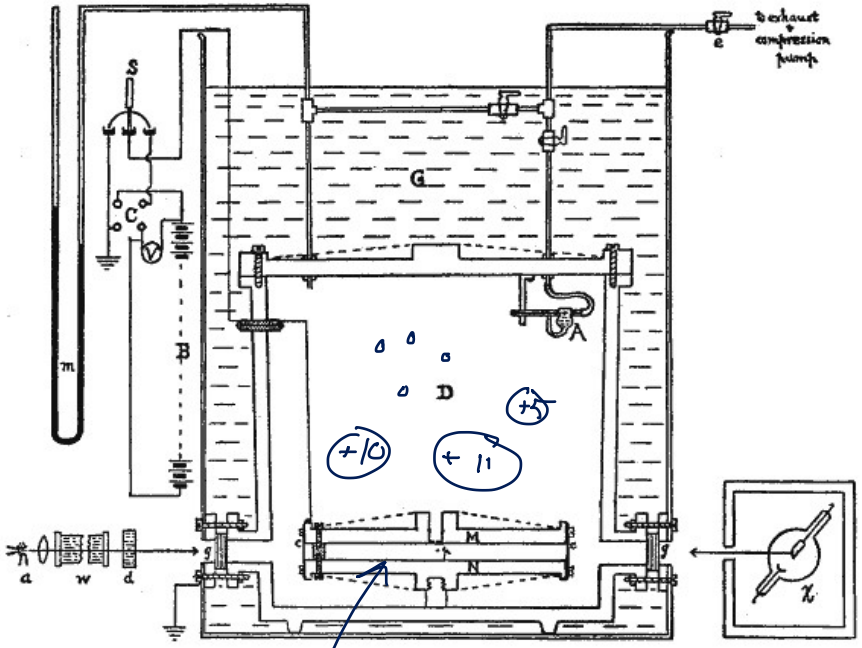
Oil Drop Experiments (RA Millikan)

determine the charge of an e⁻

1.



2



the charge on every oil drop has to be a multiple of the charge of the e⁻ and with JJ's work we now had the mass

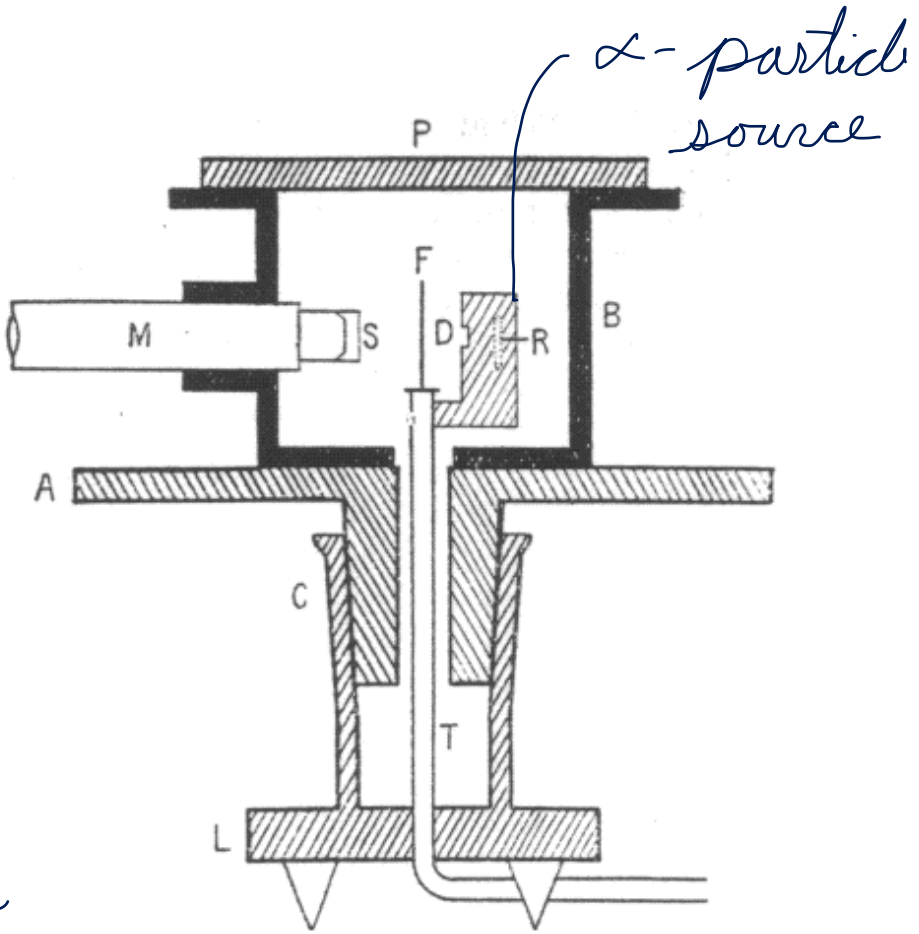
make oil drops hover through electric field

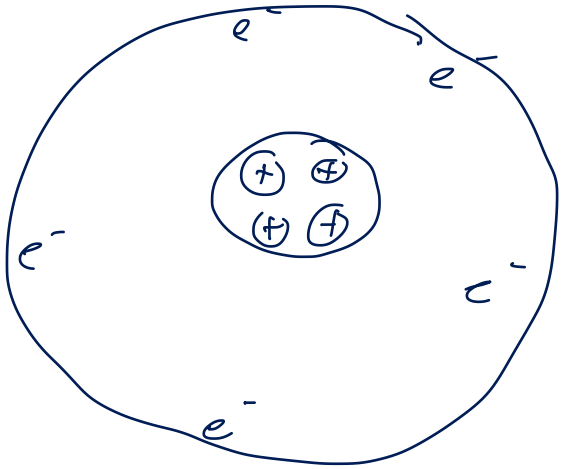
1. https://en.wikipedia.org/wiki/Oil_drop_experiment#/media/File:Millikan's_oil-drop_apparatus_1.jpg

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

"[…] 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."

$^{4}_{2}He^{2+}$ most would go straight through, some would be deflected, and a few would be bounced back toward the source.





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.

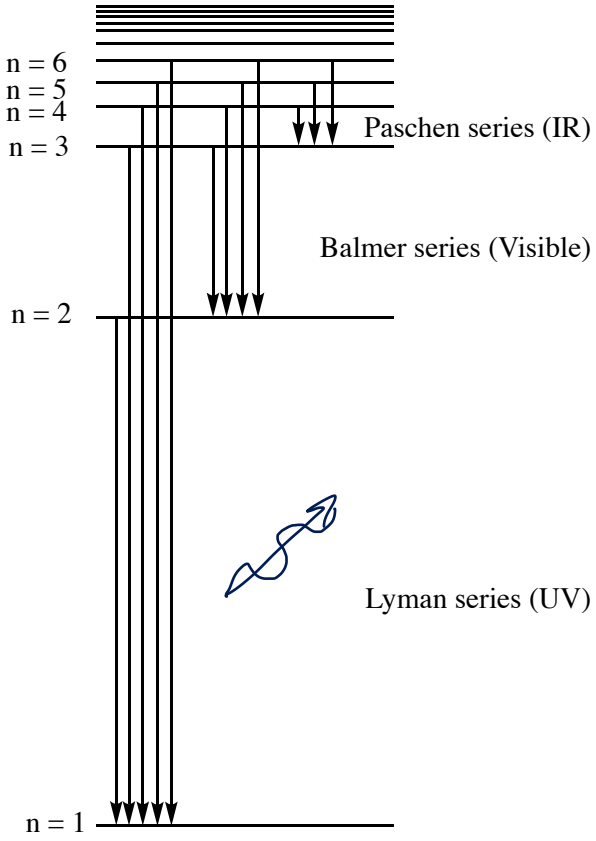
$$\nu = A \cdot (Z - b)^2$$"

"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."

empirically found
ν depended on atomic #
and hypothesize that was
the nuclear charge

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

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



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

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

this is telling us that e⁻'s are confined to specific energy levels... energy of an e⁻ in an atom is quantized

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 $\mu = \frac{m_{nucleus} + m_{electron}}{m_{nucleus} m_{electron}}$