

Intro to Quantum Physics F3241

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Week 7

Recap Atomic Spectra

Different atoms, when excited, emit photons with different specific wavelengths. We have a formula for predicting the wavenumber (or wavelength) of photons absorbed/emitted by different atoms.

Key formulae:

Balmer's empirical formula: $\lambda_n = 364.6 \frac{n^2}{n^2 - 4} \text{ nm}$

Rydberg-Ritz formula: $\frac{1}{\lambda_{mn}} = R \left(\frac{1}{m^2} - \frac{1}{n^2} \right) \text{ for } n > m$

Rydberg's formula for Hydrogen

$$\frac{1}{\lambda} = R \left[\frac{1}{m^2} - \frac{1}{n^2} \right] \text{ for } n > m$$

Rydberg's constant $R_{\infty} = 1.0974 \times 10^7 \text{ m}^{-1}$

For Hydrogen, $R_H = 1.0968 \times 10^7 \text{ m}^{-1}$

Hydrogen is different than all other atoms:

Rydberg's formula in general

The complete form: $\frac{1}{\lambda_{mn}} = ZR \left(\frac{1}{m^2} - \frac{1}{n^2} \right)$ for $n > m$
 Z is the *atomic number*, which is 1 for Hydrogen

Group	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	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	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
				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	
				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	

Collisions / scattering

Elastic Scattering:

Inelastic Scattering:

Why do atoms 'prefer' to be in their ground state?

An excited atom will always return to its ground state via emission of a photon with a specific wavelength. Why?

Rutherford Scattering

Key formulae:

Coulomb potential: $V = -\frac{kZe^2}{r}$

Centripetal force: $F = \frac{kZe^2}{r^2} = \frac{mv^2}{r}$

Total energy: $E = \frac{1}{2}mv^2 + \left(-\frac{kZe^2}{r}\right) \sim -\frac{1}{r}$

A whirlwind intro to electrodynamics

Coulomb's Law: $F = k \frac{q_1 q_2}{r^2}$

1. Opposites attract.
2. The electric force follows an inverse square law.
3. The electric force is different depending on the medium in which the charges are placed.

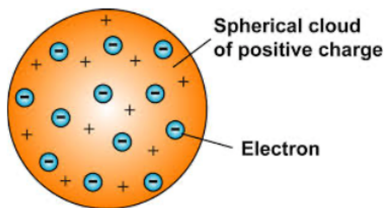
Coulomb's constant $k = \frac{1}{4\pi\epsilon_0} = 1.44e^{-2} \text{ MeV fm}$

A whirlwind intro to electrodynamics

Coulomb's Law: $F = k \frac{q_1 q_2}{r^2}$

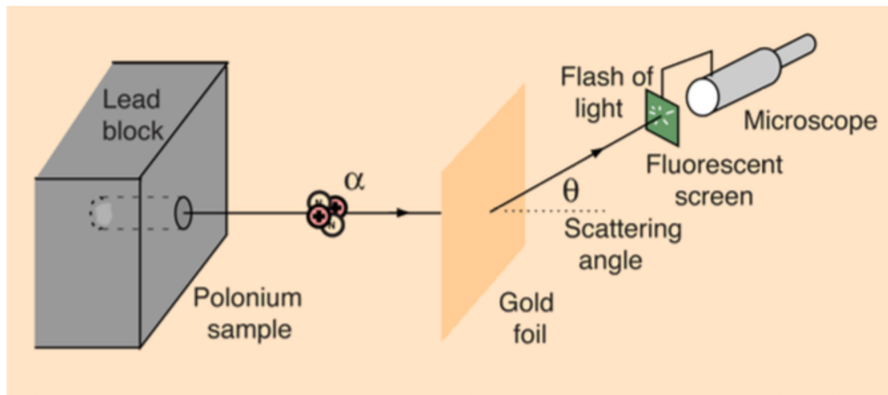
What is the potential energy associated with this force?

Thomson's Atom



Rutherford: let's test this model by smashing charged particles into an atom!

Rutherford's Experiment



Rutherford observed some particles being back-scattered.

Conservation of momentum and KE (2-body)

Momentum is always conserved:

Kinetic energy is only conserved in elastic collisions:

Conservation of total Energy

$$(KE + PE)_i = (KE + PE)_f$$

Initially:

Finally:

Rutherford's Formula

$$N(\theta) = \frac{N_i n L Z^2 k^2 e^4}{4r^2 KE^2 \sin^4(\theta/2)}$$

N_i = number of incident alpha particles

n = atoms per unit volume in target

L = thickness of target

Z = atomic number of target

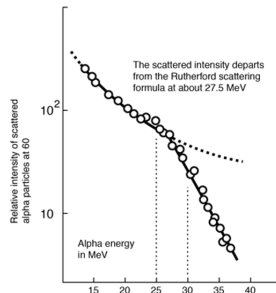
e = electron charge

k = Coulomb's constant

r = target-to-detector distance

KE = kinetic energy of alpha

θ = scattering angle



Higher Energy reveals Deeper Structure

10 MeV: An atom contains a nucleus!

1 GeV: A nucleus contains nucleons!

10 GeV: A nucleon contains partons!

10 TeV: Now!

A Conundrum