Intro to Quantum Physics F3241

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Week 7

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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:	$\lambda_n = 364.6 \frac{n^2}{n^2-4}$ nm
Rydberg-Ritz formula:	$\frac{1}{\lambda_{mn}} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$ for $n > m$

Rydberg's formula for Hydrogen

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

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

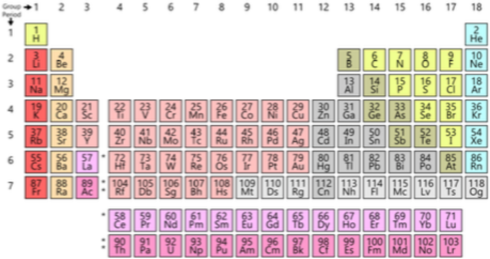
For Hydrogen, $R_H = 1.0968 \times 10^7 \mathrm{m}^{-1}$

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



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.

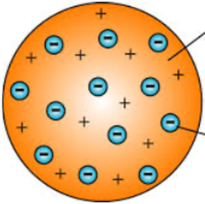
Coulomb's constant $k = \frac{1}{4\pi\epsilon_0} = 1.44e^{-2}$ MeV fm

A whirlwind intro to electrodynamics

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

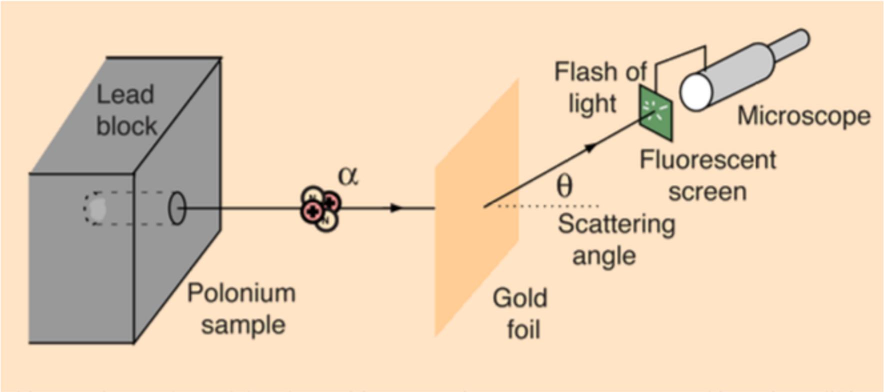
What is the potential energy associated with this force?

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:

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Conservation of total Energy

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

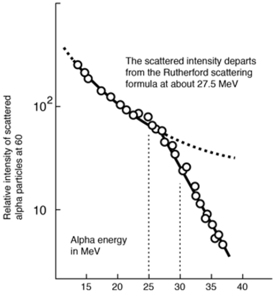
Initially:

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*
$\theta =$ *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