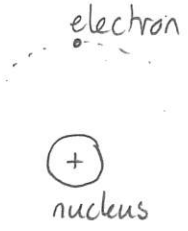
Lecture 41

Today: HW 5pm

Mon: Same section of Barnett.

Physics of atoms

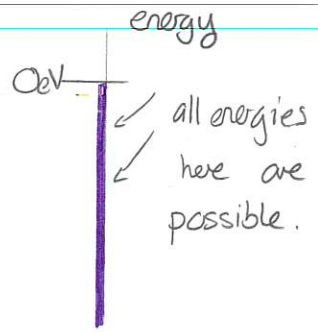


In classical physics an atom can be described in terms of an electron orbiting the nucleus. The electron has energy associated with its motion and also the attraction between the nucleus and the electron. The energy is a number which can be measured in various units:

Joules (J) ~ lift a 1 quart bottle of water through vertical height 1 yard ~ increase energy by about 10 J

electron-Volts (eV) ~ move a single electron from one side of a 1.5 V battery to another and the energy will change by 1.5eV

In classical physics, when the electron orbits in a circle it can have any conceivable energy (they have to be negative). It also turns out that this implies that the atom can emit or absorb electromagnetic light of any conceivable frequency. None of this agrees with actual observations



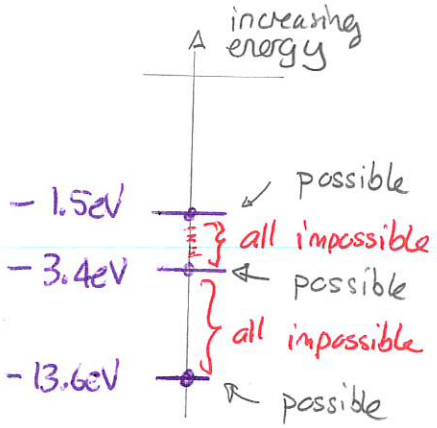
Demo: Show hydrogen spectra

Quantum theory of atoms

These observations were eventually successfully explained via quantum theory in the 1920s. In terms of the interaction between atoms and electromagnetic radiation the following are important:

1) in an atom of a given type (e.g. hydrogen) the possible values of energy are discrete. There are specific states corresponding to each energy value.

The particular arrangement of energy values and states depends on the atom. These are different for say Hydrogen and Cesium.



2) an atom can emit electromagnetic energy when it changes its energy state. Then the frequency of the emitted light is given by

$$\text{frequency} = 2.42 \times 10^{14} \left(\frac{\text{Hz}}{\text{eV}}\right) \times |\text{change in atom energy}|$$

3) an atom can only absorb electromagnetic radiation if the frequency of the radiation also matches the rule above. So there has to be a matching energy level change.

For example for the hydrogen atom possible energy changes are:

$-13.6\text{eV} \to -3.4\text{eV} \rightsquigarrow$ frequency 2.47×10^{15} Hz

$-13.6\text{eV} \to -1.5\text{eV} \rightsquigarrow$ " 2.93×10^{15} Hz.

$-3.4\text{eV} \to -1.5\text{eV} \rightsquigarrow$ " 4.60×10^{14} Hz

Demo: PhET Hydrogen atom models

- Show Bohr model. prediction
- show actual expt with spectrometer

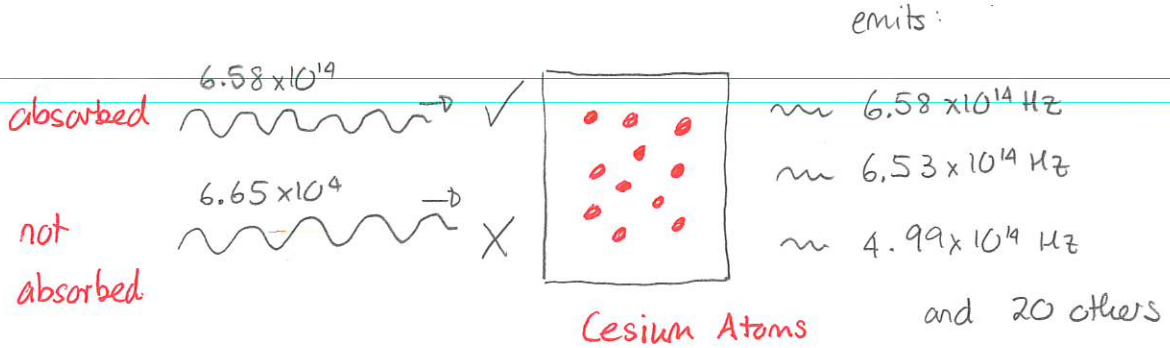
This explains why atomic spectra only consist of certain discrete frequencies. In general this applies to all atoms. Then:

1) the frequencies of light emitted or absorbed by any atom are particular to that type of atom. All atoms of the same type emit exactly the same set of frequencies.

2) standard optical techniques allow for very precise measurement of the frequencies of light emitted by any atom

Most importantly:

> A collection of atoms of one particular type will only be able to absorb certain very specific frequencies of electromagnetic radiation.



Demo: PhET simplified MRI

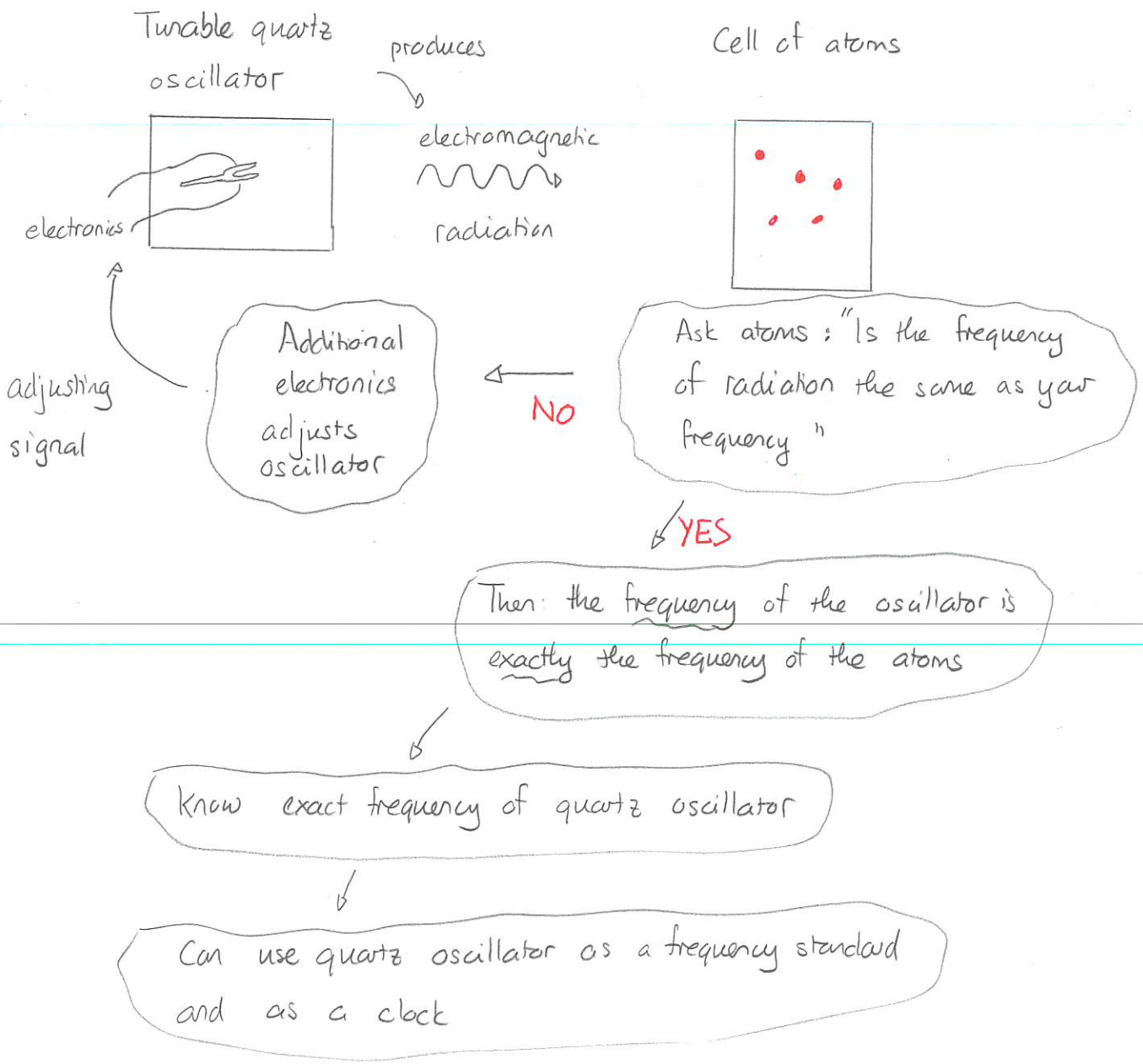
Show simplified NMR adjust freq to resonant

Model for an atomic clock

The basic scheme for an atomic clock involves

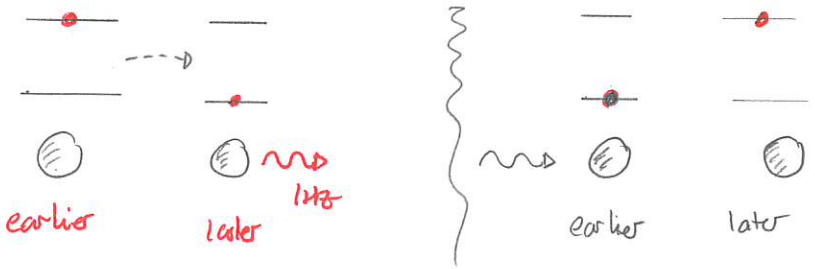
1) a cell of atoms of known type
2) a separate quartz oscillator
3) associated electronics

Schematically:



Demo: Engineerguy video.

We could imagine a slightly more realistic version of this atomic clock designed to produce a 1Hz signal. This would advance the second hand of a clock exactly once per second. The atoms would have two levels



only absorbs if signal is exactly 1Hz.