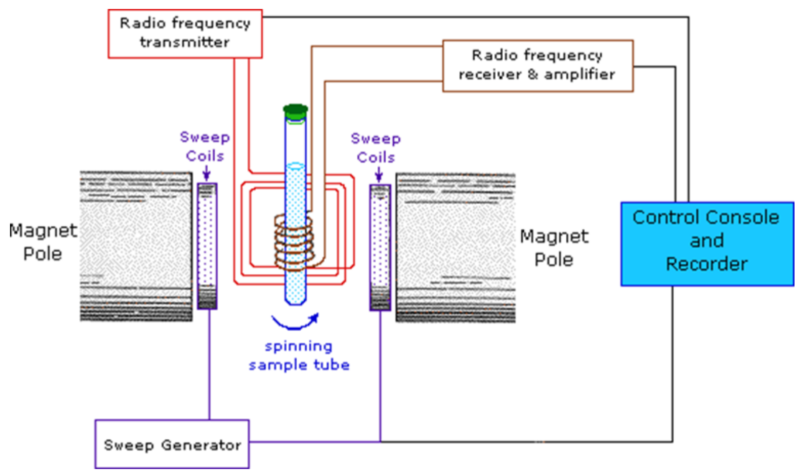
5.3: Spin 1/2 Spectra

But for ^1H, ^{13}C, ^{15}N and other nuclei, we only have to deal with **two** orientations. The energy difference between the two spin states at a given magnetic field strength will be proportional to their magnetic moments. For the four common nuclei noted above, the magnetic moments are: ^1H μ = 2.7927, ^{19}F μ = 2.6273, ^{31}P μ = 1.1305 & ^{13}C μ = 0.7022. These moments are in **nuclear magnetons**, which are 5.05078•10^{-27} JT^{-1}. The following diagram gives the approximate frequencies that correspond to the spin state energy separations for each of these nuclei in an external magnetic field of 2.35 T. The formula in the colored box shows the direct correlation of frequency (energy difference) with magnetic moment (h = Planck's constant = 6.626069•10^{-34} Js) for a specific applied magnetic field.

A typical CW-spectrometer is shown in the following diagram. A solution of the sample in a uniform 5 mm glass tube is oriented between the poles of a powerful magnet, and is spun to average any magnetic field variations, as well as tube imperfections. Radio frequency radiation of appropriate energy is broadcast into the sample from an antenna coil (colored red). A receiver coil surrounds the sample tube, and emission of absorbed radiofrequency (RF) energy is monitored by dedicated electronic devices and a computer. An NMR spectrum is acquired by varying or sweeping the magnetic field over a small range while observing the RF signal from the sample. An equally effective technique is to vary the frequency of the radiofrequency radiation while holding the external field constant.



The energy of the two spin states can be represented by an energy level diagram. We have seen that $\nu = \gamma B$ and $E = h\nu$, therefore the energy of the photon needed to cause a transition between the two spin states is

$$E = h\gamma B_o$$

When the energy of the photon matches the energy difference between the two spin states an absorption of energy occurs.

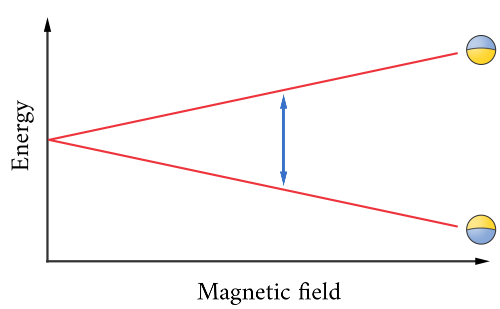


Figure 5.3.1: Absorption of a RF photon between two spin states split by the applied magnetic field.

In the NMR experiment, the frequency of the photon is in the radio frequency (RF) range. In NMR spectroscopy, ν is between 60 and 800 MHz for ^1H nuclei. In clinical MRI, ν is typically between 15 and 80 MHz for hydrogen imaging.

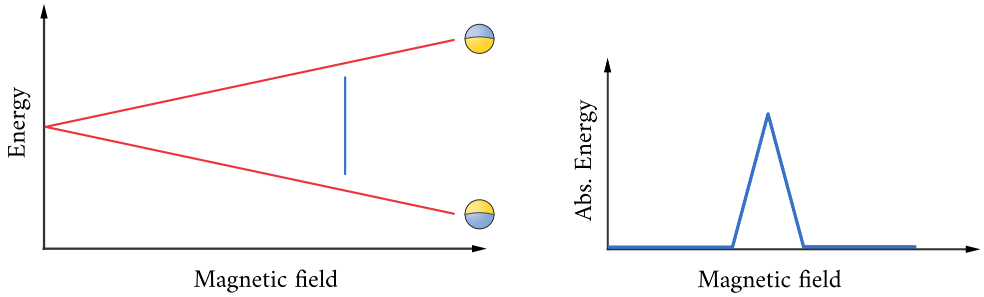


Figure 5.3.2: Continuous wave NMR by varying magnetic field with a fixed RF frequency.

The simplest NMR experiment is the continuous wave (CW) experiment. There are two ways of performing this experiment. In the first, a constant frequency, which is continuously on, probes the energy levels while the magnetic field is varied. The energy of this frequency is represented by the blue line in the energy level diagram. The CW experiment can also be performed with a **constant** magnetic field and a frequency which is **varied**. The magnitude of the constant magnetic field is represented by the position of the vertical blue line in the energy level diagram.

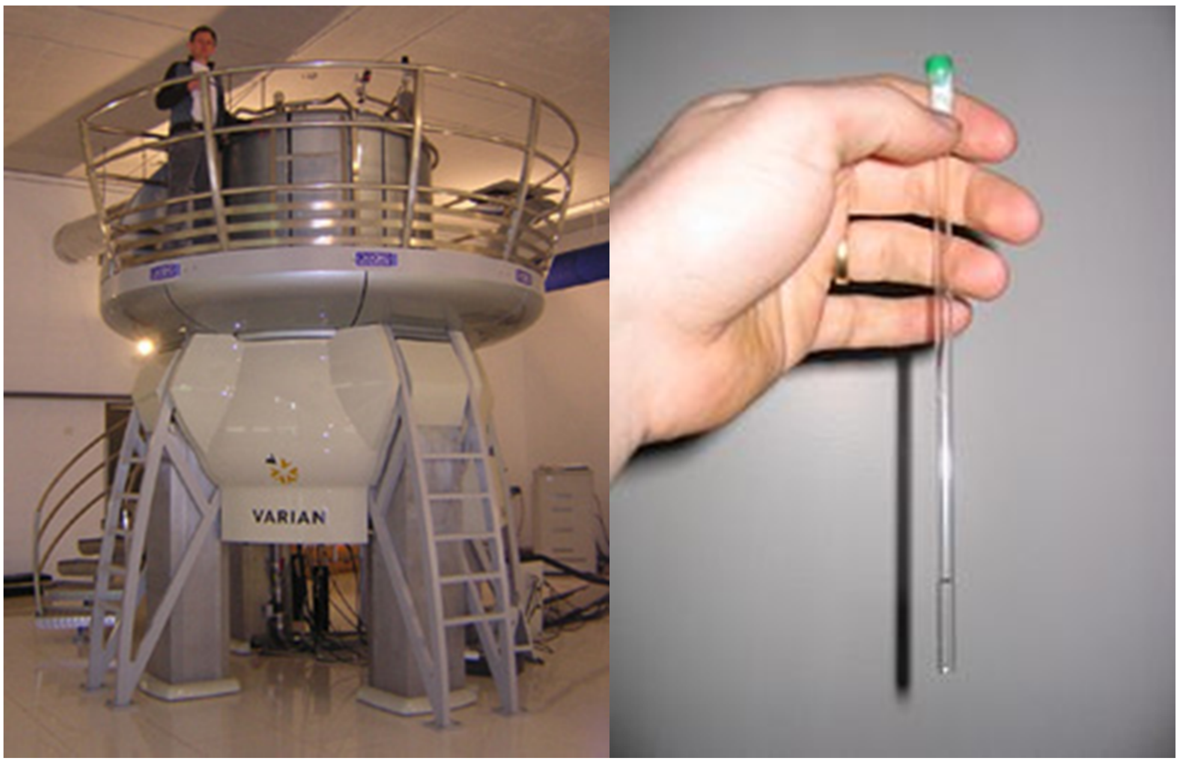


Figure 5.3.2: A 900MHz NMR instrument with a 21.2 T magnet at HWB-NMR, Birmingham, UK (left). The NMR sample is prepared in a thin-walled glass tube (right)

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