4.6: Ion Cyclotron Resonance

Ion Cyclotron Resonance. (1, 2, 3) The Ion Cy clotron Resonance (ICR) mass spectrometer uses a superconducting magnet to trap ions in a small sample cell. This type of mass analyzer has extremely high mass resolution (ca. 10^9) and is also useful for tandem mass spectrometry experiments. These instruments are very expensive and are typically used for specialized research applications. The ICR traps ions in a magnetic field that causes ions travel in a circular path (Figure $4.6.1$). This is similar to the path of an ion in a magnetic sector, but the ions are not traveling as fast and the magnetic field is stronger. As a result the ions are contained in the small volume of the trap.

The ion's cyclotron frequency (ω), is the angular frequency* of an ion's orbit. Equation $4.6.1$ shows this frequency is determined by the magnetic field strength (B) and the *m/z* value of the ion.

$$\omega = \frac{\mathrm{B} \times \mathrm{e}}{m/z}$$

After ions are trapped in this cell they are detected by measuring the signal at this cyclotron frequency. This signal is measured by placing electrodes on each side of the ions circular orbit. An RF voltage is applied to the transmitter electrodes at the cyclotron frequency of the ion of interest. This RF energy moves ions at the applied frequency to a larger orbit. As these ions travel around the ICR cell they are close enough to the receiver electrodes to induce a capacitive current. This capacitive current oscillates at the cyclotron frequency and is detected as the signal.

The ICR is also used as a Fourier Transform Mass Spectrometer (FT-MS). Instead of using a single excitation frequency, a fast RF pulse is applied to the transmitter electrodes. This simultaneously excites all the ions and produces a signal at the cyclotron frequency of each *m/z* ion present. This signal is similar to the Free Induction Decay (FID) produced in an FT-NMR experiment. A complete mass spectrum is obtained by using the Fourier transform to convert this signal from the time domain to the frequency domain.

*The angular frequency (ω) is in radians per second. The unit Hertz (Hz) is in cycles per second where there are 2π radians per cycle.

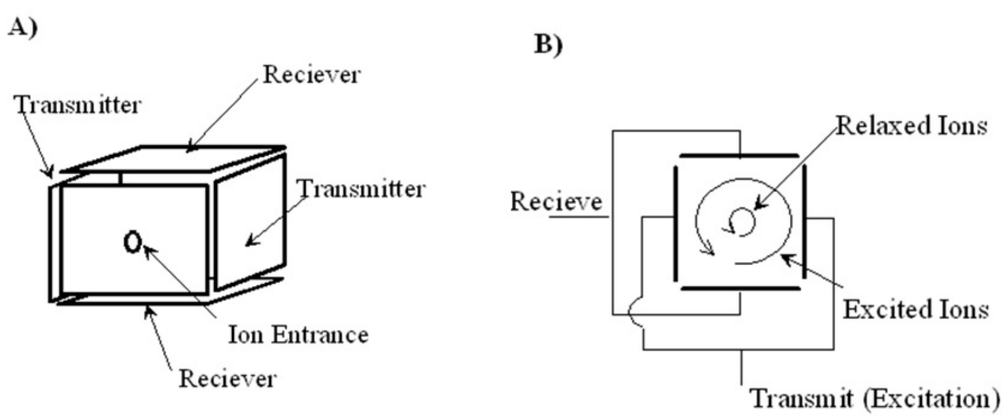

Figure $4.6.1$: Ion Cyclotron Mass Spectrometer. A)major components, B) ion motion within the trap.

References

1. Allison, J.; Stepnowski, R.M. Anal. Chem. **1987**, *59*, 1072A-1088A.
2. Wilkins, C.L.; Gross, M.L. Anal. Chem. **1981**, *53*, 1661A-1676A.
3. Buchanan, M.V.; Hettich, R.L. Anal. Chem. **1993**, *65*, 245A-259A.