4.4: Time-of-Flight

Time-of-Flight. The time-of-flight (TOF) mass analyzer separates ions in time as they travel down a flight tube (Figure 4.4.1). This is a very simple mass spectrometer that uses fixed voltages and does not require a magnetic field. The greatest drawback is that TOF instruments have poor mass resolution, usually less than 500 . These instruments have high transmission efficiency, no upper *m/z* limit, very low detection limits, and fast scan rates. For some applications these advantages outweigh the low resolution. Recent developments in pulsed ionization techniques and new instrument designs with improved resolution have renewed interest in TOF-MS. (1)

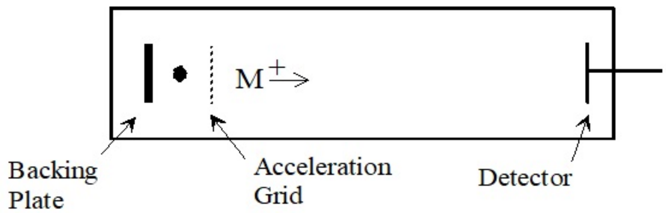

Figure 4.4.1: Time-of-Flight Mass Spectrometer.

In the source of a TOF analyzer, a packet of ions is formed by a very fast (ns) ionization pulse. These ions are accelerated into the flight tube by an electric field (typically 2-25 kV) applied between the backing plate and the acceleration grid. Since all the ions are accelerated across the same distance by the same force, they have the same kinetic energy. Because velocity (v) is dependent upon the kinetic energy, Equation 4.4.1 shows $(\mathrm{E}_{\text{kinetic}})$ and mass (m) lighter ions will travel faster.

$$\mathrm{E}_{\text{kinetic}} = \frac{1}{2} m v^2$$

$\mathrm{E}_{\text{kinetic}}$ is determined by the acceleration voltage of the instrument (V) and the charge of the ion $(\mathrm{e} \times z)$. Equation 4.4.2 rearranges to give the velocity of an ion (v) as a function of acceleration voltage and *m/z* value.

$$v = \sqrt{\frac{2\ \mathrm{V} \times \mathrm{e}}{m/z}}$$

After the ions accelerate, they enter a 1 to 2 meter flight tube. The ions drift through this field free region at the velocity reached during acceleration. At the end of the flight tube they strike a detector. The time delay (t) from the formation of the ions to the time they reach the detector dependents up on the length of the drift region (L), the mass to charge ratio of the ion, and the acceleration voltage in the source.

$$\mathrm{t} = \frac{\mathrm{L}}{\sqrt{\sqrt{2 \times \mathrm{C} \times}}} \sqrt{m/z}$$

Equation 4.4.3 shows that low *m/z* ions will reach the detector first. The mass spectrum is obtained by measuring the detector signal as a function of time for each pulse of ions produced in the source region. Because all the ions are detected, TOF instruments have very high transmission efficiency which increases the $\mathrm{S/N}$ level.

References

1. Cotter, R.J. Anal. Chem. **1992**, *64*, 1027A-1039A.

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