

[lex71] Mass spectrometer

The mass spectrometer is an indispensable tool in chemistry and chemical engineering research. It allows for a quick determination of the molecular mass of reaction products. The idea behind the mass spectrometer is to launch ionized molecules with given kinetic energy into a magnetic field directed perpendicular to its path.

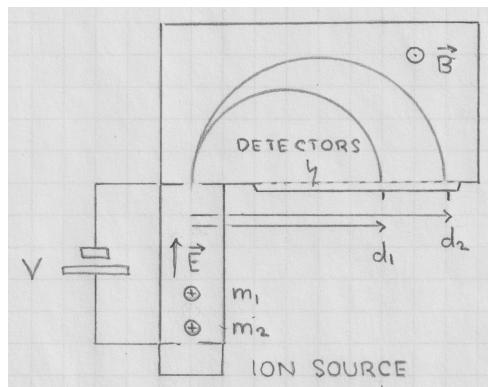
Ionizing radiation (e.g. from a radioactive sample) knocks off an electron (a tiny mass reduction) from molecules placed into the apparatus. The positively charged ion is accelerated by the electric field across a potential difference and thus picks up a known amount of kinetic energy. The ionized molecule then enters a region of magnetic field, where its path is curved into a semicircle as shown. An array of detectors determines the diameter.

(a) Determine the speed v of an ion with charge $+e$ and (unknown) mass m as it enters the magnetic field after having moved through a potential drop V .

(b) Determine the diameter d of the semicircular path through the region of uniform magnetic field as a function of m, e, v, B .

(c) Use this result to express the mass m of the molecule as a function of d, e, B, V , which are directly known for each measurement.

(d) Infer a relation between the relative mass uncertainty, $\Delta m/m$ and the relative uncertainty, $\Delta d/d$, in the diameter recorded by the detectors.



Solution: