

PROCESS AND APPARATUS FOR CHANGING
THE ENERGY OF CHARGED PARTICLES
CONTAINED IN A GASEOUS MEDIUM

TECHNICAL FIELD

This invention relates to a method of changing the energy of charged particles which are contained in a gaseous medium, and especially of ions generated in a high pressure ion source for a mass spectrometer in order to match the energy of the particles produced by the source with that required by the mass analyser.

BACKGROUND ART

There are many types of ion source in which, because of their principle of operation, it is impractical to vary the energy possessed by the ions formed over more than a very small range, for example, atmospheric pressure ionization sources for mass spectrometers. A problem frequently exists, therefore, in matching the energy of the ions produced with the value required by the mass analyser, especially in the case of magnetic sector mass spectrometers. The problem is also encountered in other fields apart from mass spectrometry, and although the present invention will be described with particular reference to mass spectrometry, it will be understood that it is equally capable of application in other fields where a similar problem is encountered.

In general, the potential energy possessed by an ion is determined by the electrical potential, relative to earth, at which it is formed, and in a conventional ion source for a magnetic sector mass spectrometer the ion is usually generated at a high potential and its potential energy is converted to kinetic energy by passing the ion through a slit at earth potential. The law of conservation of energy states that the sum of the potential and kinetic energies must be constant, and it is therefore possible to accelerate or retard the ion by means of passing it through slits at any electrical potential up to that at which it was formed, but it is not possible to increase the energy of the ion above the potential at which it was formed. Clearly, if an attempt was made to pass the ion through a slit at a higher potential, its kinetic energy would be reduced to zero before it reached the slit, and it would not pass through. However, the total energy possessed by the ion can be changed if the ion collides with, for example, an inert gas molecule. In this case, the sum of the kinetic energies of the ion and the molecule can be redistributed between the two particles dependent on their relative masses and direction of motion. Usually, because the average kinetic energy possessed by gas molecules at room temperature is very much less than that of an ion accelerated by a potential gradient of several kV, the effect of frequent collisions with gas molecules, assuming that the ion undergoes no chemical change, is that its kinetic energy is reduced.

A conventional magnetic sector mass spectrometer selects ions on the basis of their momentum/charge ratios, in contrast with a quadrupole spectrometer, which selects on the basis of mass/charge ratios. Consequently the ions for mass analysis must be injected into a magnetic sector instrument at a constant velocity, which implies a constant kinetic energy, and for various reasons this must generally be in the range 2-8keV in a high performance instrument. In a conventional ion source, this is easily achieved by forming the ion in a substantially field free region maintained at the necessary potential, and accelerating the ion by passing it

through an earthed slit at the entrance of the mass analyser. However, if the ion undergoes collisions with gas molecules after its formation, its kinetic energy will be changed, and this will degrade the resolution of the spectrometer.

There exist a number of types of ion sources with which it is very difficult to produce ions with a narrow range of kinetic energies at several keV, such as are required by a magnetic sector instrument. These include sources which operate at high gas pressures, such as atmospheric pressure ionization sources and electrospray ionization sources. Sources of this type are often capable of producing ions which are largely unfragmented from high molecular weight biochemicals which can be difficult to ionize by conventional methods, and are often appropriate for combination with a liquid chromatograph. The combination of sources of this type with magnetic sector spectrometers is therefore of considerable importance, because it is often important to obtain information which only a high resolution magnetic sector spectrometer can yield from compounds which can often only be ionized without fragmentation by a source of the type described, especially when the sample cannot easily be separated into pure components for mass spectral analysis by a technique like field desorption or neutral atom bombardment. The process of electrospray ionization, which is capable of producing unfragmented ions of high molecular weight from thermally unstable or involatile biochemicals, will now be described in greater detail so that as an example, the use of the invention with an electrospray source can be described. It is based on the work of M. Dole et al (described, for example in *Journal of Chemical Physics*, 1968, volume 49, p2240). A solution containing the sample to be ionized is sprayed from a capillary tube into a region containing an inert gas at approximately atmospheric pressure, towards a small orifice in a plate which leads into the vacuum system of the mass spectrometer. A high electrical potential is applied between the spraying capillary and the walls of the chamber containing the inert gas (including the plate with the small orifice). A separation device, usually a nozzle skimmer system like that described by Kantowitz and Gray in the *Review of Scientific Instruments*, 1951, Vol. 22 p328, is placed between the region of atmospheric pressure and the vacuum system in order to reduce the quantity of gas which flows into the vacuum system and to produce a better collimated molecular beam.

The principle of operation of the electrospray source is as follows. The solution containing the sample is slowly displaced through the capillary so that a jet of liquid is produced. The electric field in the chamber results in the jet becoming charged, and as the solvent evaporates it breaks up into a series of charged droplets. The applicants believe that sample ions, clustered with a certain number of solvent molecules, are then ejected from the evaporating droplets, and these solvated ions pass through the small orifice into the mass spectrometer. An additional pressure reduction stage, comprising a separately pumped chamber and a second nozzle skimmer system, can be incorporated between the high pressure region of the source and the mass spectrometer. Electrospray ion sources for mass spectrometers incorporating these features are known, and are described, for example, in U.S. Pat. No. 4,209,696.