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In this review, the authors discuss the main concepts of mass spectrometry, its historical development, and the future of the field. The introduction of this article starts with an explanation of the basic principles of MS that all methods have in common. Every method of MS seeks to analyze substances according to their mass to charge ratio, *m/z*, with the usage of electric and/or magentic fields. Most methods are done in vacuo, with samples entering into a vacuum system to be ionized. From their, they are passon onto low pressure regions that separate ions by their m/z ratio. After the separation, there is typically a detector that emits a signal to be processed in order to show a mass spectrum. While there are many ways to go about the separation process, these main features are the same throughout.

After introducing the concepts of MS, the historical development is detail. The impetus for MS were "canal rays," rays with positive charge of the same magnitude as the charge on Thompson's cathode rays. The difference between these canal rays and Thompson's cathode rays was that they did not have a uniform m/z like the cathode rays. This fact led Thompson to create the parabola spectrograph, the first scanning MS device. This machine consisted of a parabolic metal slit at the end of the tube containing the rays. Instead of using a photographic plate, a Faraday cup was used to collect the ions and get counts. The switch to the Faraday cup gave a more quantatative descpription of what was happening. Using magnetic fields, Thompson could select the m/z that he wanted to pass through the slit and the number of counts could be used to determine the intensity of that particular species. From this, Thompson was able to create a mass spectrum based on the intensity with which particles at different masses hit the detector.

After the pioneering work, a lot of MS involved improving upon this original design and applying it to understand phenomena. For instance, Aston using successive electric and magnetic field to collimate beams independent of their velocity and used this refined technique to find the existence of hundreds of isotopes. Dempster made a pump that took particles around a 180 degree angle at a given radius. Knowing that a particle with a constant velocity, v, in a constant magnetic field, B, with a specific m/z would move along a unique radius, r, such that:

(1) $$\frac{m}{z} = \frac{Ber}{v}$$

He was able to select what m/z would hit the detector by controlling the other parameters. This could be focused for other m/z to create a mass spectrum. Early methods of MS involved constant electric and magnetic fields and were not dynamic methods of detecting mass spectra. Time of Flight MS made use of the dynamics of the particles passing through to create a mass spectrum. This method was based on the idea that partilces with a give m/z in an electrostatic potential, U, with a constant kinetic energy would take different amounts of time to traverse the same length, l, following:

(2) $$t = \sqrt{m/z}\frac{1}{\sqrt{2Ue}}$$

Armed with this equation and data about the time it took ions to reach the detector, one could create a mass spectrum. Another dynamic method is Ion Cycltron Resonance, which relies on the a given m/z in a cycltron corresponding to a frequency, f:

(3) $$\frac{m}{z} = \frac{eB}{2\pi f}$$

Ions could be brought to resonante based on Equation (**??**) by scanning the magnetic field and a mass spectrum could be created. The method of Quadrupole MS makes use of an alternating and a static electric potential, V and U, to select for m/z. The set up involves for hyperbolic electrodes spaced equally apart and selects for m/z that follow a stable path through the aparatus. The motion of particles in this situation for V with an angular frequency ω are goverend by the Mathieu equations:

(4) $$\frac{d^2u}{d\xi^2} + (a_u - 2q_u cos(2\xi))u = 0$$

With u being the (x,y) displacement, $\xi = \omega t2$, and stability parameters a_u and q_u. The stability parameters depend on the amplitude of the alternating voltage, the size of the static potential, the mass of the partilce, and the spacing of the electrodes. Knowing the relations between these parameters allows for the selection of particles with a given m/z that is stable in a certain set up. Tandem MS involves combining multiple steps of MS for given scans. For instance, one could scan for an intial m/z in a subtance and then fragment that particle to find out about its own constituents. There are a number of ways to fragment a given particle, but the review gives details on Collision Induced Dissociation. In this case, the projectile is sent toward a target and fragments once it collides. The authers mention that photons and electron capture can also be used to dissociate projectiles.

In addition to developing new techniques for selecting m/z, other advances in MS involved new ways of ionizing substances. One such method was electron impact ionization, which inovlved electrons from a heated source interacting with a neutral gas in order to create ions. Another method to get ions is Electrospray Ionization. In this method, a substance being studied is in liquid form and passed through a needle with an applied voltage. This creates charged droplets that evoporate into an ionized gas that will go on through the MS process. Membrane Induced MS allowed for the introduction of specific elements to the vacuum with the usage of a semipermeable membrane. Plasma desorption ionization involved bombarding a substance with fission products to achieve ionization.

After the discussion of the techniques of MS, the authors go on to discuss where createing mass spectra have useful applications. One such application is the detection of isotopic abundances in different substances. In the realm of Physics, this has many applications. Using MS techniques, it is possible to separate a certain isotope from a substance or to detect the ratio of different isotopes in a given material. Having precision measurements of mass is also helpful for understanding nuclear structure and informing models that are based highly on theory. Mass measurements will help to inform our knowledge of the binding energy of different nuclei, which can be found from its mass and knowing the mass of the particles that make it up. With better mass measurements, we can get a better understanding of nuclear structure and the forces involved. In biomedicine, being able to separate isotopes is helpful for the detection of certain drugs. For instance, ratios of $^{14}C/^{13}C$ can be tested for in urine samples to detect the presence of performance enhancing drugs. MS is also useful for the study of proteins and identifying them by the constituents that make them up. An example of this was the use of MS in testing diseased and healthy cardiac tissue in a search for a biomarker that could detect chronic heart failure early and allowing for early intervention for those who had that specific protein. MS can also be used for imaging different structures using mass spectra, spatial, and time information. Not only does this method provide an image of the substance being studied, it also gives chemical information about what makes it up, which other methods are unable to do. Regarding the future, the authors talk about the possibility of small scale mass spectrometers that can be used outside of laboratory settings for analysis of substances, such as harmful chemicals and illict drugs. Its ability to analyze the contents of tissue makes it possible to see MS in cancer treatment in the future, as well.

Overall, this article has taught me a lot about the underlying ideas of MS. Using some method to create ions, manipulating their motion with the use of electric and magnetic fields, and making use of the equations of motion to select for given quantities along the way, and accurately predicting with those equations to determine what m/z has arrived at the target at the end, it is possible to come up with a mass spectrum for the target. Depending on what someone wants to study about a given material, there are many different methods to select from to come up with a solution that pertains to the problem. From here, I am curious about reading more on its applications in nuclear physics and the reference in this article have given me some ideas of where else to start looking for information.