Aug. 8, 1961 R. D. CRAIG 2,995,658

MASS SPECTROMETERS

Filed Jan. 19, 1960 2 Sheets-Sheet 1

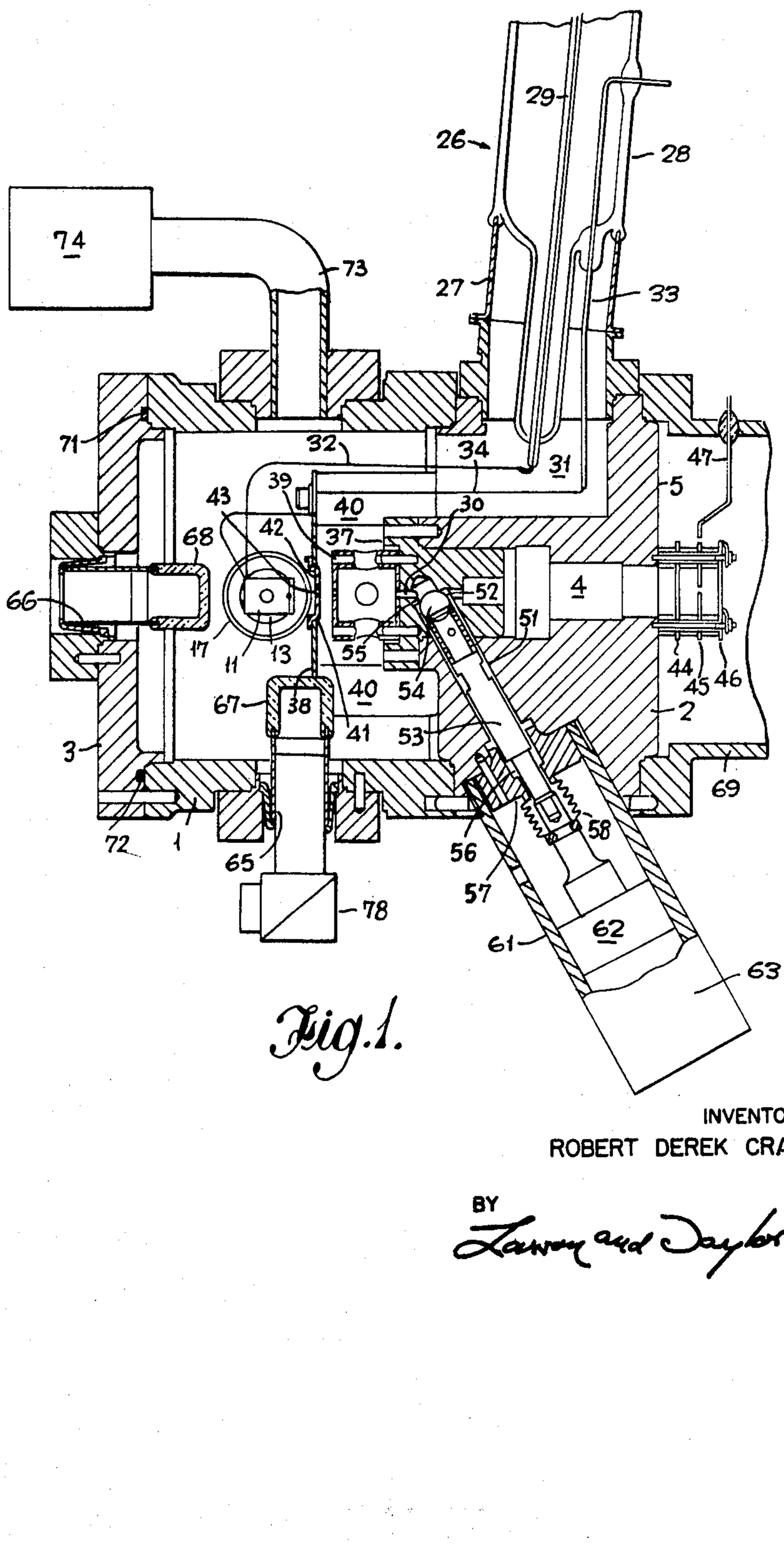

Fig. 1.

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Fig. 3.

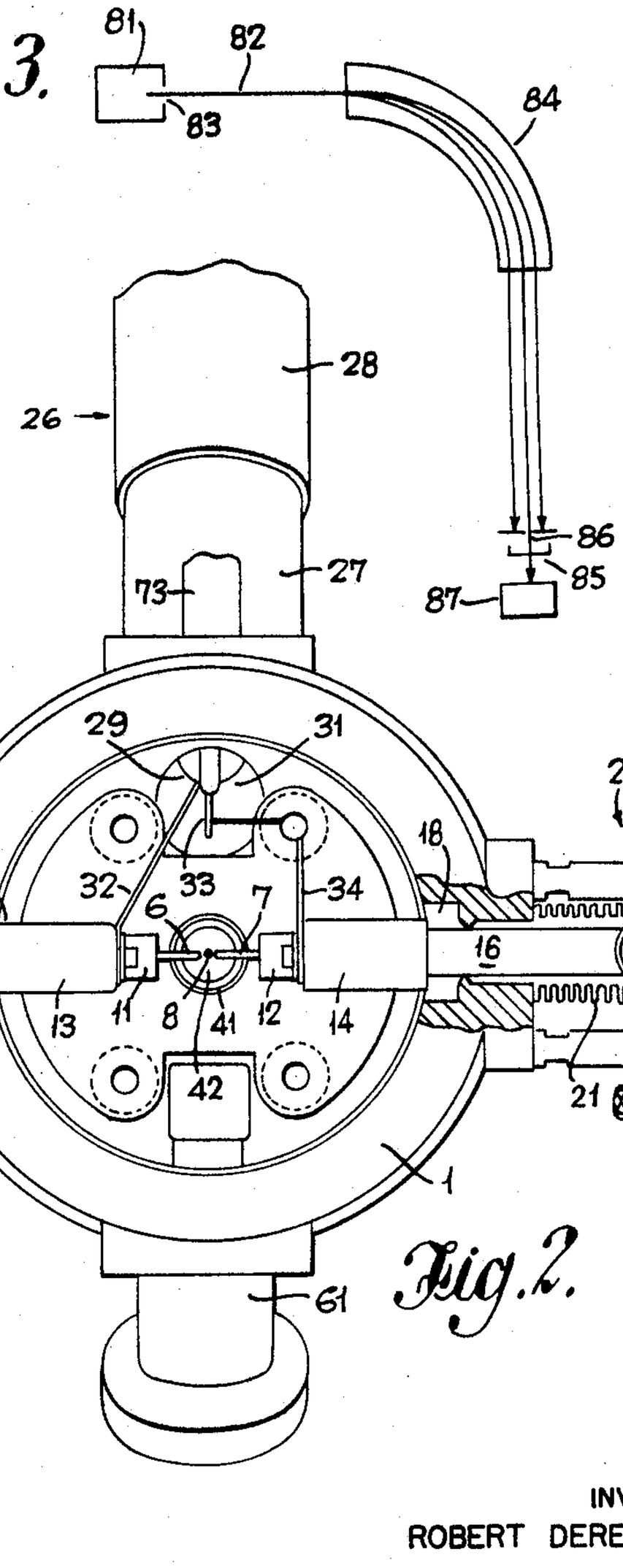

Fig. 2.

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2,995,658
Patented Aug. 8, 1961

2,995,658
MASS SPECTROMETERS

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Filed Jan. 19, 1960, Ser. No. 3,426
Claims priority, application Great Britain Jan. 19, 1959
2 Claims. (Cl. 250—41.9)

The present invention relates to mass spectrometers and more particularly to ion sources for mass spectrometers.

A mass spectrometer is an apparatus which can be adapted for analysing the constituent elements of a material. The material is ionized and this may, for example, be performed by causing an intermittent arc to form between two rod electrodes formed from the material and situated in vacuo. The resultant ions formed from the different constituent elements of the material will have different masses dependent on the position of the elements in the periodic table. Those ions with a positive charge are formed into a beam by accelerating and focusing electrodes and a narrow section of this beam is selected by an aperture known as the source slit. This narrow section of the beam is subsequently passed through an analysing field, or fields, where the ions are deflected laterally according to their mass and the field strength.

When an ion beam comprising ions of different mass passes through this analyser region it will therefore be dispersed and a mass spectrum will be formed. By collecting the dispersed beam on a suitable detector, which may be a photographic plate, an indication may be obtained of the constituent elements of the material and the quantity of each element present in the material.

It will be appreciated that the analyser region may simply comprise a uniform magnetic field alone or a non-uniform magnetic field alone or some combination of electric and magnetic fields as is well known in the art.

The material to be analysed is normally located in a chamber called an ion source. In this chamber, which is evacuated, the ions produced from the material are formed into a beam by the accelerating electrodes and are focussed so as to pass through the narrow source slit aperture. This aperture connects with the main body of the spectrometer which contains the analyser. If this small aperture is the only connection between the source and analyser regions and if separate pumping of these two regions is provided it is then possible to maintain a large pressure differential between the source and analyser regions under high vacuum conditions. This is desirable since for many problems the best possible analyser vacuum is required while the source vacuum may not be critical.

If it is required to change the material of the specimen, it may be necessary to open up the source, remove an existing specimen and replace it with a second specimen. If the ion source is connected to the main body of the spectrometer, this operation will destroy the vacuum in the main body and it will be necessary to restore the vacuum throughout the spectrometer every time the specimen is changed. This is undesirable since the restoration of the vacuum throughout the spectrometer takes a long time and it is therefore desirable to be able to isolate the main body of the mass spectrometer from atmospheric pressure in the ion source. If this is done only the vacuum in the ion source will be destroyed and since the volume of the ion source is small and because of the differential pumping described above the vacuum therein may be restored to a satisfactory level in a short time.

It is not however convenient to use normal types of valve for this purpose. A valve with an axially moving closing member is unsuitable because when such a valve is open it does not leave an uninterrupted path for the ion beam. A valve with a laterally moving closing member is also unsuitable since the use of a high vacuum necessitates very efficient sealing and this cannot easily be obtained with this type of valve.

The object of the present invention is to provide an ion source for a mass spectrometer having an improved type of valve adapted to seal the ion source from the main body of the mass spectrometer.

According to the present invention, an ion source for a mass spectrometer comprises a chamber, means for producing ions within said chamber, a duct extending from said chamber and adapted to be connected to the main body of the mass spectrometer, means for projecting a beam of ions from the chamber along said duct, a valve plunger movable in a direction inclined obliquely to the axis of said duct, a seating for one end of said valve plunger extending obliquely across said duct and perpendicularly to the direction of movement of said valve plunger and means for moving said plunger so that it may engage in a gas-tight manner with said seating and thereby form a gas-tight seal in said duct, and means for moving said plunger away from said seating so that it does not obstruct said duct.

The ion source also comprises a removable cover plate which will enable the specimens from which the ions are produced to be removed from the source and to be replaced with a different specimen when the valve plunger is in its closed position. This enables the specimen to be changed without destroying the vacuum in the main body of the mass spectrometer.

In order that the invention may be more readily understood, reference will now be made to the accompanying drawings in which:

FIG. 1 is a side view, sectioned on a plane through the axis of an ion source,

FIG. 2 is an end view of the ion source with the end cover plate removed and

FIG. 3 is a diagrammatic view of a mass spectrometer.

With reference to these three figures, the main body of the ion source is formed from a cylindrical metal drum 1 closed at one end by a fixed block 2 and closed at the other end by a removable end plate 3. This drum is conveniently formed from a stainless steel block. The block 2 is formed with a duct 4 which extends axially from within the ion source to the outer face 5 of the block 2. The material from which an ion beam is to be produced is formed into two thin rod electrodes 6, 7 which are positioned so that they extend radially across the inside of the ion source. Their ends are separated by a small gap which is aligned with the inner end of the duct 4. The two rod electrodes are respectively held in two clamps 11, 12 which in turn are respectively mounted on two insulators 13, 14. These two insulators are attached to the ends of rods 15, 16 which extend respectively through apertures 17, 18 in the cylindrical walls of the ion source and are sealed therein by flexible bellows 19, 21. Two devices, denoted by 22, 23, and each including three adjustable screws 75, 76, 77, which are capable of adjustment in three mutually perpendicular directions enable the rods 15, 16 to be moved relatively to one another so that the size and position of the gap 8 relative to the duct 4 can be varied. In normal operation, the two electrodes 6, 7 are aligned and extend radially across the ion source. A high voltage bushing 26 extends from the outside of the ion source and comprises a metal tube 27 and a glass insulating tube 28. One high voltage terminal 29 extends from the glass tube into an aperture 31 in the wall of the ion source, and a lead 32 connects the ends of this terminal to the rod electrode 6. A second high voltage terminal 33 also extends from the glass tube through the aperture 31 and is connected to rod elec-

trode 7 by a second lead 34. The two high voltage terminals are externally connected to suitable sources of electric potential. Conveniently, the terminal 33 is connected to a source of 20 kv., D.C., and the terminals 33 and 29 are connected across an intermittent source of 100 kv., A.C. The glass tube is sealed from the inside of the ion source and may be evacuated separately.

Between the gap 8 and the inner face 37 of the block 2 there is located a metal plate 38, which is connected to the lead 34, and an accelerating and focusing electrode 39. The plate 38 is formed with a central aperture 41 which is covered by a removable disc 42 with a central aperture 43. Both the plate 38 and the disc 42 are conveniently made of tantalum. The plate 38 is supported by insulators 40 from the face 37 of the block 2. The accelerating and focusing electrode has a central aperture. A slit 30 is formed at the end of the duct 4 in the surface 37. This slit is narrow and conveniently measures approximately .002 inch by .040 inch. On the end face 5 of the block 2 is mounted an electrically controlled shutter. This shutter is located over the end of the aperture 4 and is formed from three apertured conducting plates 44, 45, 46, mounted in parallel planes and insulated from one another. The two outer plates 44, 46 are earthed and the middle plate 45 is divided into two halves. One half is earthed and the other half may be connected either to earth or to a source of 2 kv. by a lead 47 through a suitable switch.

A duct 51 extends from the inner end 52 of the aperture 4 towards the outside of the block 2. This duct extends at an angle to the axis of the duct 4. A plunger 53 is adapted to move in this duct and at the inner end of the plunger is mounted a hardened steel ball 54 which is arranged to bear on a stainless steel seating 55. The seating extends across the duct 4. The outer end of the plunger 53 passes through an aperture 56 in a sealing block 57 and bellows 58 seal the plunger within the aperture. The plunger extends within a cylinder 61 and terminates in a piston 62. Fluid from a reservoir 63 may be passed into the cylinder 61 so as to move the plunger either inwardly or outwardly. This operation either presses the ball 54 on to its seating or else moves the ball clear of the end 52 of the duct 4.

Two tubes 65, 66 extend inwardly from the outside of the ion source towards electrodes 6, 7. The ends of the two tubes are closed with two glass bowls 67, 68 and these two bowls, which have surfaces which are easily cleaned, enable the inside of the ion source to be inspected, when the end plate 3 is in position, with the aid of a suitable light source viewing means 78.

The end face 5 is sealed on to the main body portion 69 of the mass spectrometer. The end plate 3 is bolted or otherwise attached to the body 1 of the ion source and is sealed thereto by means of a rubber ring 71 located in an annular groove 72 in the surface of the plate.

The ion source may be evacuated through a duct 73 which is connected to a suitable pump 74. The main body portion 69 of the mass spectrometer will also be evacuated by a suitably connected pump. The only connection between the ion source and the main body portion is through the duct 4. The ball valve formed by the ball 54 and the seat 55 will seal off this aperture and will allow the vacuum in the ion source to be destroyed without affecting that in the main body of the spectrometer. Hence when the valve is closed, the end plate 3 may be removed and the specimen electrodes 6, 7 may be replaced without destroying the vacuum in the main body of the mass spectrometer. When the electrodes 6, 7 are replaced it is possible also to replace the removable disc 42.

In operation, the electrodes are located in position within the ion source and when the end plate 3 is sealed in position the ion source is evacuated. The valve is opened and suitable potentials are applied to the electrodes 6, 7 and an intermittent arc is formed between

the adjacent ends of these electrodes. This arc produces ions of the constituent elements of the material of the electrodes. These ions are accelerated and focussed by the action of the plates 38 and 39 and are passed through the aperture 43. The beam then passes through the slit aperture 30 and the shape of this aperture controls the size of the beam. The beam passes into the duct 4 and if the ball 54 is retracted off the seat 55 the ion beam will pass through the block 2 into the electrically controlled shutter. If one half of the middle plate 45 of this shutter is connected to the 2 kv. supply and the other half of the plate is earthed, the ion beam will be deflected and will not pass through the aperture in the outer plate 46. If, however, both halves of the plate 45 are earthed the beam will pass through the aperture in the outer plate 46 into the main body of the mass spectrometer. The ion beam will then pass into an analyser of any of the well known types. The ion beam is controlled by the potentials on the electrodes and the electrodes must first be accurately lined up so that the ion beam will pass through the aperture 43. The plate 42 will be contaminated by stray ions and neutral particles and it may be necessary to replace this plate when the material of the electrodes is also changed.

The vacuum in the analyser region is lower than that in the ion source and the slit 30 effectively isolates the source from the duct 4 in so far as the vacuum is concerned. When it is required to change the specimen electrodes the ball valve is closed, the vacuum is released from the ion source, the end plate 3 is unsealed and removed, and the electrodes and the plate 42 are replaced. The end plate 3 is then sealed back on to the ion source and the vacuum is restored. It will be appreciated that a certain amount of gas at the source region pressure will be trapped between the slit 30 and the seating of the ball valve and when the ball valve is subsequently opened, this gas will pass into the analyser region. This space is therefore kept as small as possible, and therefore it is very convenient to have the ball valve acting at an angle to the axis of the aperture.

The plunger 53 has been described above as being moved by a hydraulic system. Alternatively the plunger could be removed by a mechanical system, or manually.

The invention is not confined to the type of ion production described, and any other well known method of production of ions may be used.

There is described above an ion source for a mass spectrometer which comprises a valve which enables the ions source to be sealed off from the main body of the mass spectrometer so that the specimen material may be changed without destroying the vacuum in the main body of the mass spectrometer.

FIG. 3 illustrates diagrammatically a mass spectrometer including an ion source 81 which may be of the type described above, and from which is projected a beam of ions 82. This beam of ions is passed through a slit 83 in the end wall of the source 81 and passes into the magnetic field 84 of a magnetic analyser. The beam is dispersed in this magnetic field into a spectrum and is received by a collector 85 through a slit 86. An amplifier 87 receives signals from the collector and gives an indication of the quantity of ions of each mass which are present in the material being analysed.

What I claim is:

1. An ion source for a mass spectrometer comprising a cylindrical metal drum forming a chamber, means for producing ions within said chamber, a block including surfaces defining a duct extending from said chamber and adapted to be connected to the main body of the mass spectrometer, means for projecting a beam of ions from said chamber along said duct, a valve plunger movable in a direction inclined obliquely to the axis of said duct, a hardened steel ball on the end of the valve plunger, surfaces to said block defining a stainless steel

seating for said steel ball extending obliquely across said duct and perpendicularly to the direction of movement of said valve plunger, means for moving said plunger so that it may engage in a gas tight manner with said seating and thereby form a gas tight seal across said duct, and means for moving said plunger away from said seating so that it does not obstruct said duct.

2. An ion source for a mass spectrometer comprising a cylindrical metal drum forming a chamber, a block including surfaces defining a duct extending from said chamber and adapted to be connected to the main body of the mass spectrometer, two rod electrodes extending within said chamber in two opposite directions substantially perpendicular to the axis of said duct, means for forming an intermittent arc between the adjacent ends of said electrodes so as to produce ions, means for projecting a beam of said ions from said chamber along said duct, a valve plunger movable in a direction inclined obliquely to the axis of said duct, surfaces to said block defining a seating for one end of said plunger extending obliquely across said duct and perpendicularly to the direction of movement of said valve plunger, means for moving said plunger so that it may engage in a gas tight manner with said seating and thereby form a gas tight seal across said duct, and means for moving said plunger away from said seating so that it does not obstruct said duct.

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