

April 28, 1959

C. EGGLE ET AL

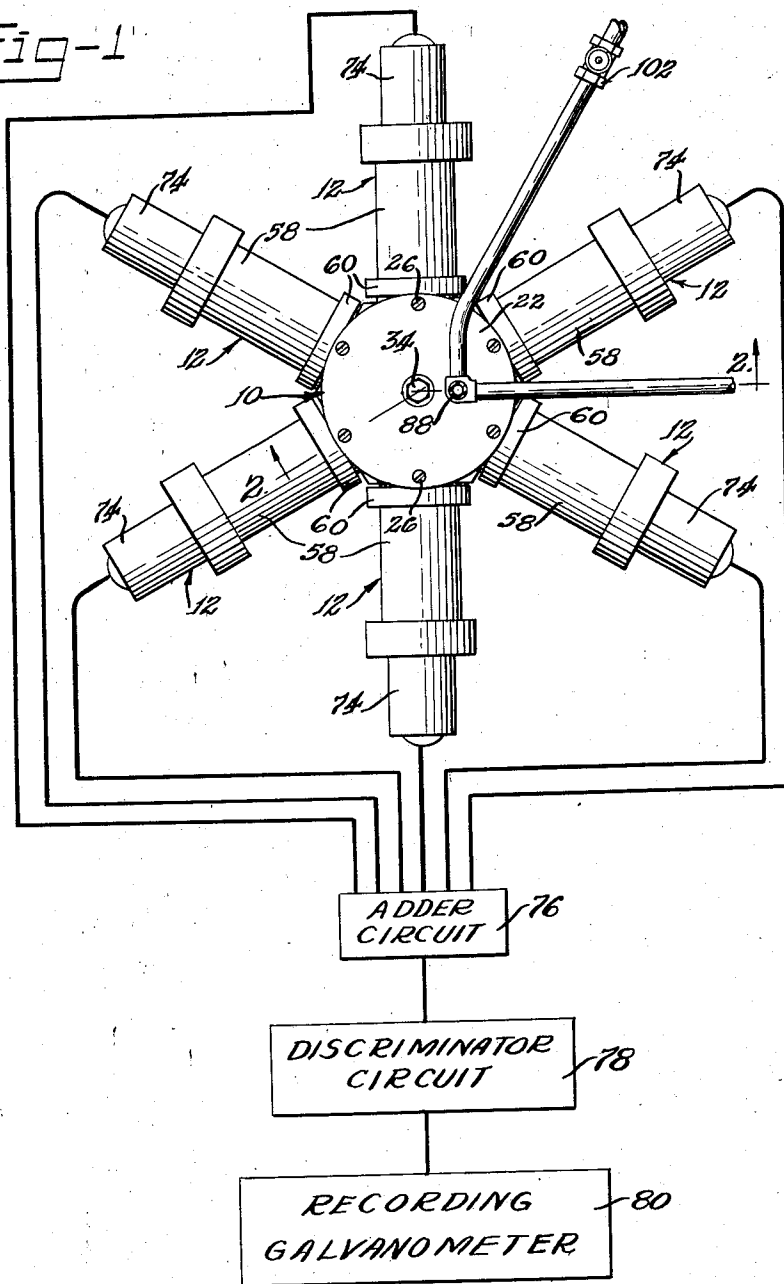
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GASEOUS SCINTILLATION COUNTER

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3 Sheets-Sheet 1

Fig-1



INVENTORS

Charles Eggle

Charles M. Huddleston

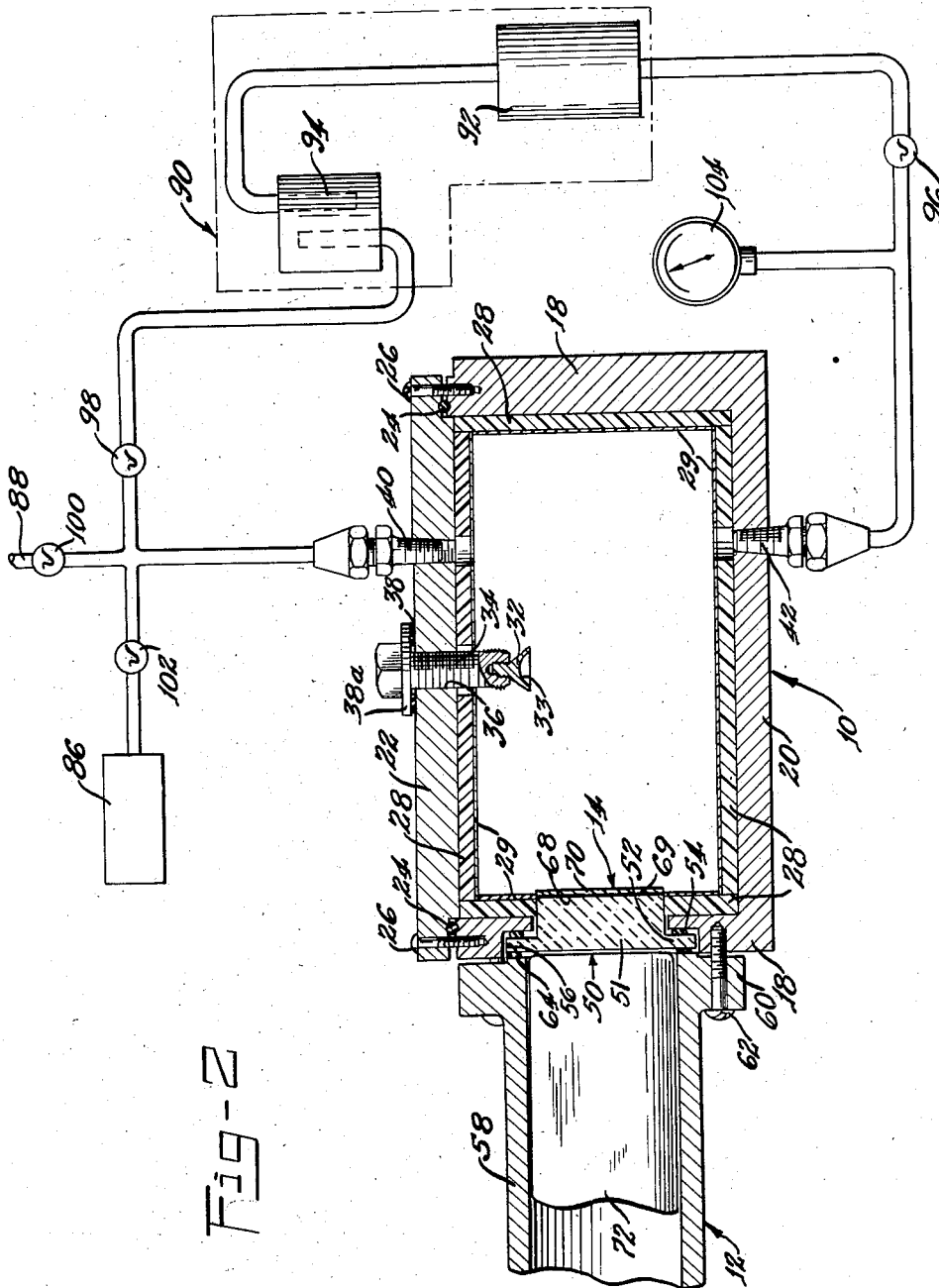
By:

Roland G. Anderson
Attorney

C. EGGLER ET AL
GASEOUS SCINTILLATION COUNTER

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INVENTORS
Charles Egger
Charles M. Huddleston
By:
Roland A. Anderson
Attorney

April 28, 1959

C. EGGLEER ET AL

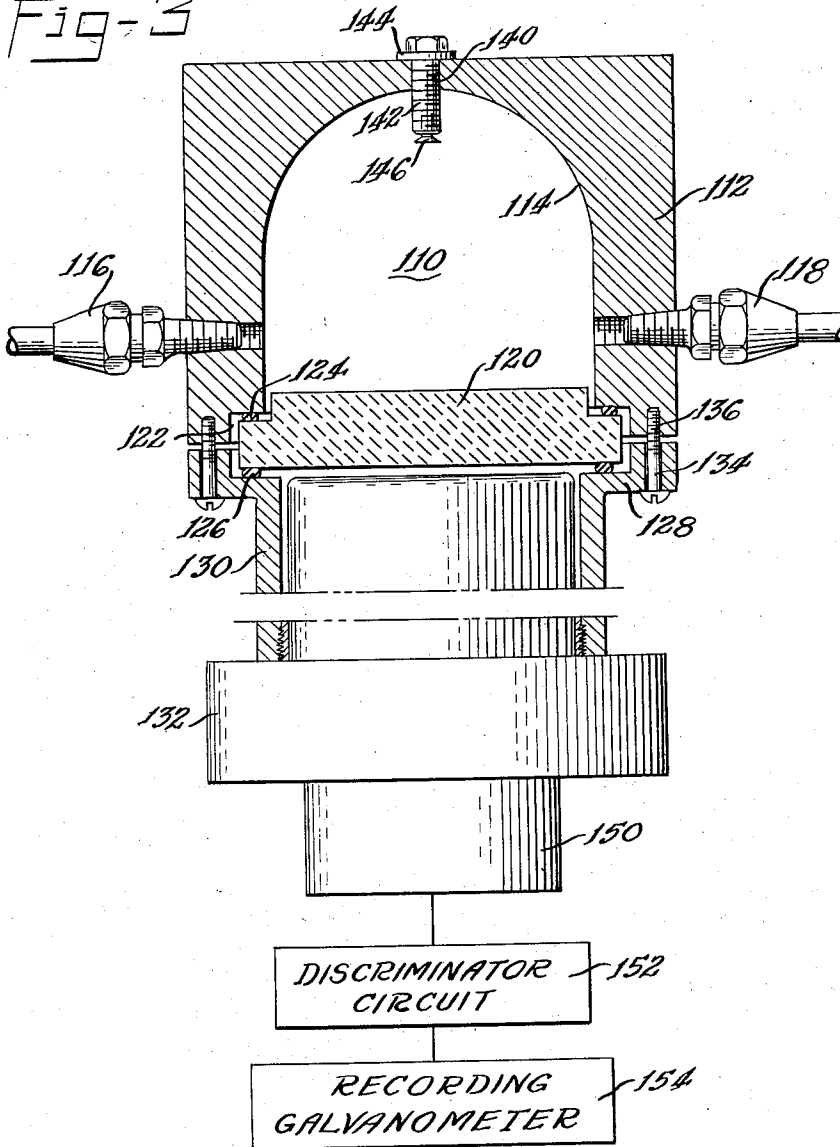
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Fig-3



INVENTORS
Charles Eggleer
Charles M. Huddleston

By: Roland A. Anderson
Attorney

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GASEOUS SCINTILLATION COUNTER

Charles Eggler, Downers Grove, and Charles M. Huddleston, Naperville, Ill., assignors to the United States of America as represented by the United States Atomic Energy Commission

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10 Claims. (Cl. 250—71)

This invention relates to apparatus for detecting the presence and measuring the energy of subatomic particles, more particularly, it relates to gaseous excitation counters.

The most widely used generic type of counter for subatomic particles is an apparatus having, in combination, an electrical field induced by two oppositely charged electrodes in a gas-filled tube, wherein the passage of a charged particle through the gas will result in ionization of gas molecules along the particle path. The resulting positive ions will move to the negative electrode and the corresponding negative ions to the positive electrode. The migration of these ion pairs culminates in an electrical impulse within a circuit connected to the electrodes. Depending upon the electrical potential between the electrodes within the tubes and the manner in which these tubes are operated they are termed ionization chamber counters, proportional counters, or Geiger counters. Ionization chamber counters record an impulse in response to the passage of an ionizing particle when the primary ions formed by the incident particle within the chamber collect on an electrode. Proportional and Geiger counters record an electrical impulse in response to a shower of secondary ions released within the electrical field of the counter tube by the passage of an ionizing particle. Proportional counters are further distinguished by the characteristics that the gas density and the strength of the electrical field within the counter tube is adjusted so that all the kinetic energy of the ionizing particles is absorbed by the gas within the tube and secondary ions are formed within the tube only in strict proportion to the total number of primary ions formed by the incident particles. By use of the proportional counter the energy of individual ionizing particles may be measured. One limiting feature of all gas-filled tube counters is that the time lapse between response to the passage of an ionizing particle, and the extinction of the resulting charge and restoration of the tube to a condition of sensitivity to subsequent particles, is relatively long.

A second generic type of subatomic particle counter makes use of luminescent phosphors. When rapidly moving subatomic particles or ionizing electromagnetic radiation impinges upon any of certain complex crystalline materials known as luminescent phosphors such materials are energized and in response thereto emit, by means of multistep internal physical processes, quanta of visible light. Counting devices utilizing luminescent phosphors as sensing elements or targets are termed scintillation counters. In addition to the phosphor target, scintillation counters contain a photosensitive means for detecting light quanta emissions from the phosphor target, and suitable means for indicating the emissions. Frequently, a fluorescent substance is combined with the phosphor target to heighten light emission in frequency bands most readily detected by the photosensitive means. Phosphors are prepared for use in scintillating counters in solid or liquid form, and in such forms are only responsive to

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primary incident particles generally having an energy greater than two electron volts.

Scintillation counters may be adapted to measure the energy of subatomic particles and when so used serve as proportional counters. In order to assure adequate resolution, the scintillator target in a proportional counter must have a density commensurate with the energy of the incident particles in such a relationship that the incident subatomic particles traverse a relatively long path within the target before their energy is dissipated and the particles are absorbed. The density of liquid and solid phosphors is necessarily considerable, and therefore low energy particles are absorbed at the surfaces of solid and liquid phosphor scintillator targets in conventional scintillation counters, and thus, measurement of low energy particles is rendered inefficient or impractical. A further limitation on the counting of low energy particles by scintillation counters is the fact that particles having less than two e.v. kinetic energy fail to activate the phosphor target of the counter. In general, the resolution of a conventional scintillation counter when used as a proportional instrument is reliable only within a tolerance of plus or minus 10%. Although scintillation counters are on the whole faster than gas tube counters, many phosphors have a delayed light quanta emission in response to incidence of subatomic particles; and accordingly, these counters may be characterized by delay in their response.

The present invention relates to a heretofore unknown third generic type of subatomic particle counter which utilizes the excitation emission of a gas and is called herein a gaseous excitation counter. It has long been known that molecules of gas, when excited to higher states of energy by the incidence of subatomic particles or electromagnetic radiation, emit photons at wave lengths generally shorter than the wave lengths of visible light. The processes of gaseous excitation and emission are instantaneous and may be induced by the passage of particles only slightly above thermal energies. Despite the apparent attractiveness of gaseous excitation counters from the standpoint of rapid response and sensitivity to low energy particles, no successful gaseous excitation counters were constructed prior to this invention due to the difficulties encountered with detecting the short wave length quanta emission of the excited gas and due to difficulties encountered with self-absorption of the photon emission within the excited gaseous target. The present invention relates to a method and apparatus to overcome the heretofore unresolved impediments inherent in gaseous excitation counters.

One object of the present invention is, therefore, to provide a method and apparatuses for utilizing gas excitation emission as a sensing means to count incident subatomic particles.

Another object of the invention is to provide a rapid counter having a target element response time shorter than is presently known in any counter.

Another object of the present invention is to provide a gaseous proportional counter having a variable density target element which is readily adjusted to accommodate high or low energy incident particles.

Still another object of the present invention is to provide a proportional counter having the rate of response comparable to that attained by scintillation counters and having the resolution power of a gas filled electronic tube counter.

Other aims and objects of the invention will appear from the following specifications, drawings and claims.

The present invention comprises, briefly, methods and apparatuses for utilizing gaseous excitation emission in a counter wherein a suitable gas readily excited by incident

particles is confined within a chamber in association with a fluorescent material and a photosensitive counting means optically coupled to the fluorescent material. When the excited gas molecules emit ultra-violet radiation, the fluorescent material is irradiated and reemits visible band light readily detected by conventional photosensitive means.

Various embodiments and practical arrangements of the component parts of the invention are illustrated in the accompanying drawings in which:

Fig. 1 is a view of one embodiment of the present invention adapted for use as a coincidence counter; electrical components are shown in schematic form;

Fig. 2 is a sectional view of the embodiment of Fig. 1 taken along line 2—2 and includes a schematic diagram of gas pressure control means and gas purification means adapted to use with the embodiment of Fig. 1;

Fig. 3 is a sectional view of a second embodiment of the invention wherein the interior of the chamber is shaped to focus radiation onto the photosensitive means, and wherein the apparatus is adapted to utilize a gaseous fluorescent material.

Referring to the drawings, Fig. 1 shows a gas-tight chamber 10 surrounded by a plurality of photosensitive means 12. The chamber 10, more clearly shown in Fig. 2, contains gas-tight windows 14, sides 18, a bottom 20, and a removable top 22. The top 22 is secured to the sides 18 of chamber 10 with a gas-tight seal 24 and a plurality of screws 26. The interior of the chamber 10 is provided with liners 28 which have a metallic silver coating 29 on the interior surfaces for the purpose of obtaining highly reflective surfaces. A preferred liner material, and the one illustrated in the embodiment disclosed herein is methyl methacrylate plastic with a metallic silver coating. Plastics, metals, and Pyrex glass have been used successfully as liner materials. The chamber 10 is provided with a stage 32 positioned in the interior of the chamber at the end of a threaded member 34 which may be inserted into the chamber through a threaded port 36 in the top 22. The threaded member 34 is provided with a gas-tight gasket 38 and washer 38a to assure a tight seal. The stage 32 contains a cavity 33 adapted to hold the sample of radioactive source material being examined.

The chamber 10 is provided with two gas ports 40 and 42 located, respectively, in the top 22 and the bottom 20. The pressure of the gas within the chamber may be controlled by regulating the flow of gas through these two ports, the details of the method by which this is accomplished will be made clear below.

It has been found that elemental gases readily excitable to ultra-violet emission by the incidence of subatomic particles and not having ultra-violet quenching characteristics are suitable for use as a gaseous excitation target in our apparatus. Noble nonradioactive gases and particularly argon and helium are preferred gases for use as the gaseous excitation target in the present device. The following conditions of purity of the target gas, however, must be met. Many contaminants readily absorb quanta in the far ultra-violet frequency range; hence, the requisite purity of the gas contained within the chamber is determined by the ultra-violet absorption characteristics of the contaminating materials. Even a minute trace of a substance having strong absorption characteristics in the frequency range of the quanta emission of the excited gas molecules will seriously distort the quantitative responsiveness of the apparatus. In order to assure preservation of the quantitative response of the instrument, it has been found that use of a pure elemental gas, such as argon or helium, continuously repurified yields the most reliable results. Gaseous targets of argon having less than one in a thousand parts contaminant, and helium having less than one in a hundred parts contaminant, yield satisfactory results.

Referring again to the embodiment of the invention illustrated in Figs. 1 and 2, a plurality of transparent win-

dows 14 are positioned in walls 18 of the chamber 10. The windows 14 are comprised of planar optically clear structures 50 having a transverse contour readily adapted to form a gas-tight seal. The window illustrated in Fig. 2 is a quartz crystal; however, any of a number of materials possessing structural rigidity and transparency in the visible and ultra-violet frequency bands are satisfactory window materials; examples of such materials, in addition to quartz crystal, are Pyrex glass and clear synthetic plastic resins.

Fig. 2 illustrates the window contour which comprises a plain cylindrical portion 51, and a flange 52 which seats against a gasket 54. The flange 52 and gasket 54 are positioned in a recess 56 within the chamber wall 18. The window 14 is held securely in place by a flanged case 58, forming the housing of the photosensitive means 12. A flange 60 on the case 58 is provided with fasteners 62 which hold the case 58 securely fixed with respect to the wall 18 of the chamber 10. A second gasket 64 makes a seal against the exterior surface of the window 14 when the fasteners 62 are made tight.

Next to the interior surface 68 of the window 14 is a layer of fluorescent material 69. Most fluorescent materials and their solvents are characterized by some residual volatility which remains within the coating 69 long after the coating has been applied and dried. Such a tendency to volatilize contaminates the gas within the chamber and disturbs the quantitative response of the excitation emission of the gas. In order to overcome this undesirable outgassing, the fluorescent layer 69 is deposited on the inside surface of a clear polystyrene disk 70 abutting the interior surface 68 of the window 14, thus limiting contamination of the gas in the chamber.

Fluorescent materials are a subclass of luminescent phosphor compounds. The fluorescent subclass compounds are distinguished from phosphor compounds generally by the fact that when irradiated by electromagnetic radiation of suitable wave length the fluorescent compounds are activated and reemit photons in the visible frequency bands with a persistence of emission of optical photons shorter than 10^{-8} seconds after irradiation. Optical photons refer generally to visible light, 4000 to 7000 Angstroms wave length. Fluorescent compounds reemit light substantially instantaneously after activation, whereas phosphor compounds generally have a reemission period of appreciable duration.

A number of different fluorescent compounds are readily activated by "far ultra-violet" radiation. Far ultra-violet designates herein generally a region of the electromagnetic spectrum having wave lengths between 500 and 4000 Angstrom units. Examples of such fluorescent materials are fluorescein mixed with a suitable solvent, or a mixture of four grams per liter of 2,5-diphenyl oxazole with sixteen grams per liter diphenylhexatriene in phenylcyclohexane. These two fluorescent materials which are in a liquid state when prepared for use must to held before the window 14 in a thin layer by means of a transparent couvent or cell. Such an arrangement is not illustrated in the drawings.

The preferred fluorescent material for use in the present invention and the one illustrated in Fig. 2 is $\frac{1}{2}$ to 4% tetraphenylbutadiene in a suitable solvent such as toluene or amylacetate, applied to one surface of a thin polystyrene disk 70, shown in a cross-sectional view in Fig. 2. The polystyrene disk 70 holds a film only two or three thousandths of an inch thick comprised of the dried fluorescent tetraphenylbutadiene residue between the surface of the disk 70 and the window surface 68. This arrangement possesses the advantage of limiting volatilization of the fluorescent materials and subsequent contamination of the target gas. Tetraphenylbutadiene absorbs nearly one hundred percent of all incident ultra-violet light of wave lengths less than 4000 Angstroms and

reemits visible light in the region of 4000 Angstrom units wave length.

The photosensitive means 12 comprises a photomultiplier tube 72 mounted within the casing 58 and positioned so that the photosensitive cathode of the tube 72 is adjacent the window 14 and optically aligned therewith. RCA tube 5819 and DuMont tube 6292 are conventional photomultiplier tubes suitable for use in the invention disclosed herein. The region of maximum response of the DuMont tube is between 4300 and 5300 Angstrom wave lengths; the RCA tube has a similar range. The photomultiplier tube 72 is electrically connected to an amplifier 74 which is also housed in the case 58 with the photomultiplier tube 72. The photosensitive means, in addition to the photomultiplier tube 72 and amplifier 74 comprises an adder circuit 76, a discriminator circuit 78, and a recording electrical meter apparatus 80. The electronic circuit illustrated schematically in Fig. 1 is old in the scintillation counter art and will be described here only briefly. The output of the amplifiers 74 from all the photosensitive means 12 is fed into the adder circuit 76 which responds only to simultaneous impulses from more than one photomultiplier tube 72. This arrangement eliminates most false counts due to extraneous disturbances in the electronic system. The output signal from the adder circuit 76 is fed into the pulse height discriminator circuit 78, which may be readily adjusted to count only pulses of a specified narrow band of heights. The discriminator circuit output is fed into the recording meter means 80 which is conveniently comprised of a sensitive recording galvanometer.

The gas pressure and gas composition within the interior of the chamber 10 is readily regulated by means of adjustments in valves which connect the interior of the chamber 10 to a vacuum source 86, a gas supply 88, and a conventional convective gas purification train 90, comprising a heated cylinder of calcium or charcoal 92, a condenser 94, and two valves 96 and 98 for regulating the flow of the gas out of the chamber through the port 42 and into the chamber from the purification train 90 through port 40. A valve 100 controls the flow of gas from the high pressure gas supply 88 flowing into the chamber 10, and a valve 102 controls the connection between the vacuum source 86 and the interior of the chamber 10. By the arrangement illustrated in the drawings, it is possible to obtain gas pressures of from a few millimeters of mercury pressure to in excess of four atmospheres pressure. Other arrangements of valves, pipes and components will serve satisfactorily to regulate the pressure of the gas within the chamber 10 and the flow rate of the gas through the purification train; however, the preferred arrangement disclosed here has a maximum flexibility with a minimum number of connections. A gas pressure gauge 104 is connected to the interior of the chamber 10 through port 42.

The instrument is prepared for operation by placing a small portion of the radioactive material to be examined in the cavity 33 in the platform 32. Access may be had to this platform 32 by removing the threaded member 34 or by removing the entire top 22 of the chamber 10. Chamber 10 is reassembled with the active material in the interior and all connections and junctions made gas-tight. The valve 102 is opened and the valves 100, 98, and 96 are closed while the interior of the chamber is evacuated; thereafter, the valve 102 is closed and the valve 100 opened to introduce a quantity of a pure inert gas into the chamber 10. By means of regulation of the valves 102 and 100, the desired gas pressure may be obtained within the chamber 10, and thereafter the valves 102 and 100 are closed. The valves 96 and 98 are thereupon opened. Application of heat to the filter 92 will create a convective gas flow wherein the gas will circulate from the chamber 10 through the purification train 90 and back into the gas chamber 10.

Ionizing particles emanating from the sample posi-

tioned on the platform 32 will pass into the gas, excite the gas molecules along the particle trajectories and eventually disappear when the particles are extinguished and absorbed within the interior of the chamber 10. The gas pressure is adjusted so that the density of the gas is sufficient to absorb the kinetic energy of the particles before they reach the interior walls of the chamber 10. Accordingly, when examining a very low energy stream of particles the gas pressure will be adjusted to a low value, and when examining a stream of high energy particles the gas pressure will be adjusted to a high value. For example, 5 m.e.v. alpha particles have a mean range of 7 to 9 centimeters in helium at two atmospheres pressure; in argon the range of the alpha particles at one atmosphere is approximately three centimeters. By reason of the fact that the gas pressure and thereby the target density may be adjusted through a wide range of values, particles of a wide energy range may be studied without loss of sensitivity or efficiency of the instrument. The gas density is readily adjusted so that regardless of the energy in the exciting particles, their trajectories will be within the optical field of the photosensitive means 12 and their total kinetic energy will be transferred to the gas molecules before they cross the chamber 10 and strike one of the chamber walls. Hence the total kinetic energy of both high and low energy particles may be measured in the apparatus of the present invention.

The passage of subatomic particles through the gaseous target transfers kinetic energy from the incident stream of particles to the gas molecules which, in the resulting excitation states, emit photons in the ultraviolet and particularly far ultra-violet frequency bands. The excitation emissions fall upon and excite the fluorescent material 69 on the disk 70 where in turn the fluorescent material reemits visible light which falls upon the photo-multiplier tubes 72 and immediately initiates electrical impulses which pass through the adder circuit 76, discriminator circuit 78 and into the recording means 80.

By counting the pulse heights in discrete narrow bands, which is readily accomplished by successive adjustments in the discriminator circuit 78, a record of the relative frequency of particles in each discrete energy range may be obtained. The energy spectrum of the ionizing particles may then be obtained directly from the data recorded. If the discriminator is adjusted to pass impulses in a wide band of pulse heights, the total activity of a wide energy band of exciting particles may be recorded. Hence, the present invention is useful as a sensitive apparatus for measuring the energy of a stream of ionizing or exciting particles, and it is also useful as a counter for determining the total number of particles. Counts as high as 10^9 events per second have been observed with the above apparatus. Excellent sensitivity has been obtained in models of the above apparatus wherein particles of 4.8 m.e.v. energy are distinguishable from particles of 5.47 m.e.v. energy. The instrument is theoretically one hundred percent efficient and readily distinguishes between alpha and gamma emissions of nearly identical energy. A variety of subatomic particles and electromagnetic radiations may be examined with the various embodiments of our invention.

It is possible to construct an instrument of slightly greater sensitivity by applying fluorescent materials to the interior surfaces of the chamber 10 but not over the windows 14. Such an arrangement is not illustrated explicitly in the drawings, but it may be readily visualized by reference to Fig. 2. Due care must be exercised in all instances to prevent contamination of the target gas by volatilization of the fluorescent material. This is readily accomplished by the use of transparent plastic or quartz structures to separate the fluorescent material from the target gas.

Another embodiment of our invention is described below and illustrated in Fig. 3. It has been found that gaseous nitrogen molecules when activated by ultra-violet rays reemit, as a fluorescent substance, light rays in the region of 3250 Angstrom units wave length. Accordingly, a gaseous fluorescent material, namely nitrogen gas, may be mixed with an excitation gaseous target and therewith absorb with very high efficiency the entire excitation emission of the primary target gas. Examples of such mixtures of gas suitable for adaptation in our excitation counter are argon and nitrogen mixed in a ratio of between two and ten parts per hundred nitrogen to argon. The impurity of the argon and nitrogen for use in our invention must be held to within less than one part per thousand ultra-violet quenching contaminants. A second suitable mixture comprises helium and nitrogen wherein the nitrogen is present between one and four parts per million parts of helium. The impurity of these constituent gases for efficient use in our invention must be held to less than one in ten thousand parts ultra-violet quenching contaminants.

Fig. 3 illustrates a modification of our inventive apparatus adapted to utilize the aforesaid fluorescent properties of nitrogen. In the illustrated embodiment of Fig. 3, a mixture of argon and nitrogen in the ratio of five percent nitrogen in ninety-five percent argon is confined within a chamber 110 recessed within an aluminum block 112. The chamber 110 is parabolic and has highly effective polished surfaces 114 which focus all emitted light on a photosensitive means which is described below. The chamber 110 is provided with two gas-tight ports 116 and 118. These two ports are analogous and perform identical functions to the ports 40 and 42 illustrated in the embodiment of Figs. 1 and 2. These ports 116 and 118 are connected to a vacuum, a gas supply, gauge valves, and a gas purification train all of which are similarly arranged and in all respects are identical to the vacuum, gas supply, valves, gauge, and gas purification train illustrated in Figs. 1 and 2. Gas pressures within the chamber 110 between one hundredth and four atmospheres may be readily obtained with the gas means illustrated in Fig. 2 when it is connected to chamber 110 through the ports 116 and 118.

A clear quartz window 120, which is adapted to form an air-tight seal across the open end of the parabolic chamber 110, is held in a small recess 122 within the aluminum block 112 by two gaskets 124 and 126 and a flange 128 of a case 130. The case 130 houses a photomultiplier tube 132 coupled optically to the interior of the chamber 110 through the quartz window 120. The case 130 and the window 120 are held securely in place by a plurality of retainer bolts 134 which pass through the flange 128 into threaded holes 136 in the aluminum block 112.

A threaded opening 140 in the aluminum block 112 provides a port for inserting a bolt 142 provided with a gas-tight washer 144. The end of the bolt 142 is provided with a stage 146 for holding a small sample of radioactive material which is to be examined.

The photomultiplier tube 132 is contained within a quartz envelope and is sensitive to radiation between 2500 and 5300 Angstrom wavelengths. It is 50% efficient when irradiated with 3000 Angstrom wave length rays. Tubes having the above characteristics are available commercially. The one illustrated in the drawings and described herein is type A6255 manufactured by the Electrical Musical Instrument Company of England.

The embodiment of our invention illustrated in Fig. 3 is a single photomultiplier tube instrument in contrast to the multiple tube instrument illustrated in Figs. 1 and 2. Referring to Fig. 3, an amplifier 150 is positioned within the case 130 immediately adjacent the photomultiplier tube 132. The tube 132 is connected to the input of the amplifier 150. The amplifier is connected electrically through its output to a discriminator pulse height circuit

152 which may be readily adjusted to count only impulses within a specified narrow range of pulse heights. The pulse heights are, as a practical matter, directly proportional to the total excitation emission and hence directly proportional to the energy of the exciting particles. The output signal of the discriminator pulse height circuit 152 is conducted electrically to a recording galvanometer 154 wherewith a visual indication of the pulse heights and total number of pulses in discrete energy or pulse height bands may be observed and automatically recorded.

The apparatus of Fig. 3 is prepared for use by the same sequence of steps as the apparatus of Figs. 1 and 2. The sample is positioned on the stage 146, the chamber 110 is made gas-tight, the mixture of argon and nitrogen described above is introduced into the chamber, and the pulse height discriminator 152 is adjusted to the desired band width and energy level. The instrument may be utilized to count the total number of incident particles or it may be used to count those particles in discrete narrow bands of energy levels and therefore measure the relative energy of the incident particle stream.

The present invention is intended not to be limited to the specific embodiments disclosed above but includes all equivalents and obvious modifications and is limited in scope only by the following claims.

What is claimed is:

1. An apparatus for counting subatomic particles and electromagnetic radiation comprising a gas-tight chamber, an elemental gas within the chamber responsive to subatomic particles and electromagnetic radiation to produce ultra-violet excitation quanta and having less than one in a thousand parts ultra-violet absorbing contamination, a fluorescent material optically associated with the gas, said fluorescent material responsive to the ultra-violet excitation quanta to produce visible excitation quanta, and photosensitive counting means optically coupled to the fluorescent material.

2. An apparatus for counting subatomic particles and electromagnetic radiation comprising, in combination, a gas-tight chamber, an inert elemental gas contained within the chamber, the gas being adapted to emit far ultra-violet radiation in response to excitation by passage of subatomic particles and electromagnetic radiation, the gas having less than one in a thousand parts ultra-violet radiation quenching impurities, a transparent window in the wall of said chamber, a fluorescent means disposed on the window for emitting visible light when irradiated by ultra-violet rays, and electronic light sensitive means disposed exterior to the chamber and adjacent to the window, a discriminator circuit connected electrically to the light sensitive means and a meter means responsive to the discriminator circuit whereby subatomic particles entering the chamber excite the gas causing the emission of ultra-violet radiation whereupon a light impulse proportional to the energy of the ultra-violet radiation is produced by the fluorescent means, the light impulse is converted to an electrical impulse by the light sensitive means, and the electrical impulse is selected by the discriminator circuit for delivery to the meter means.

3. A proportional counting apparatus adapted to measure the relative energy of incident subatomic particles and electromagnetic radiation comprising, in combination, a gas-tight chamber having a transparent window, fluorescent material responsive to ultra-violet irradiation disposed on the window, an inert elemental gas within the chamber and adapted to emit ultra-violet radiation in response to excitation by subatomic particles and electromagnetic radiation, the gas having less than one in a thousand parts ultra-violet radiation quenching impurities, means for regulating the gas pressure within the chamber, photosensitive counting means responsive to the emission of visible light by the fluorescent material optically

coupled thereto and means for continuously purifying the gas during operation of the apparatus.

4. The apparatus of claim 3 wherein the excitable gas is argon, the chamber window is transparent polystyrene and the fluorescent material is comprised of the dried residue of a coating of between one-half and four percent tetraphenylbutadiene in a volatile solvent applied to the interior of the window.

5. The apparatus of claim 3 wherein the excitable gas is helium, the chamber window is quartz crystal, and the fluorescent material is a coating on the window of tetraphenylbutadiene.

6. A coincidence proportional counter comprised of a gas-tight chamber having a plurality of transparent quartz windows and having highly reflective interior surfaces, a quantity of argon gas having less than one part in a thousand impurities confined within the chamber, a coating of tetraphenylbutadiene on one surface of each window, means for controlling the gas pressure within the chamber, a gas purification train, means for continuously circulating a portion of the gas from out of the chamber through the gas purification train and back into the chamber, a plurality of electronic photosensitive means mounted exterior of the chamber, one adjacent each window and each optically coupled to the tetraphenylbutadiene coating on the respective windows, an adder circuit, the electronic photosensitive means being electrically connected to the adder circuit, a discriminator circuit, the output of the adder circuit being electrically connected to the discriminator circuit, an electrical indicating means, the output of the discriminating circuit being connected electrically to the indicating means.

7. An apparatus for counting subatomic particles and electromagnetic radiation comprising, in combination, a gas-tight chamber having a transparent window, a quantity of a noble gas within the chamber adapted to emit ultra-violet radiation in response to excitation by subatomic particles and electromagnetic radiation and having less than one in a hundred thousand parts ultra-violet radiation quenching impurities confined within the cham-

ber, a trace quantity of a second substantially pure elemental gas mixed with the first gas and adapted to emit visible light in response to ultra-violet irradiation, and a photosensitive counting means mounted adjacent the window and optically coupled to the gas confined within the chamber.

8. The apparatus of claim 7 wherein the noble gas is argon and the second elemental gas is nitrogen having less than one in a thousand parts impurity, the ratio of nitrogen to argon being between 2 and 10 parts per hundred.

9. The apparatus of claim 7 wherein the noble gas is helium and the second elemental gas is nitrogen, the constituent gases having less than one in ten thousand parts impurity, the ratio of nitrogen to helium being one to four parts per million.

10. An apparatus for indicating the presence of subatomic particles and electromagnetic radiations comprising a gas-tight chamber, a noble gas contained within the chamber to produce ultra-violet quanta excitations in response to irradiation by subatomic particles and electromagnetic radiation, said gas having less than one in 1000 parts ultra-violet radiation quenching impurities, a photosensitive means optically coupled to the chamber, and a fluorescent medium coupling the gas excitations to the photosensitive means by producing visible indications in response to the excitations.

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