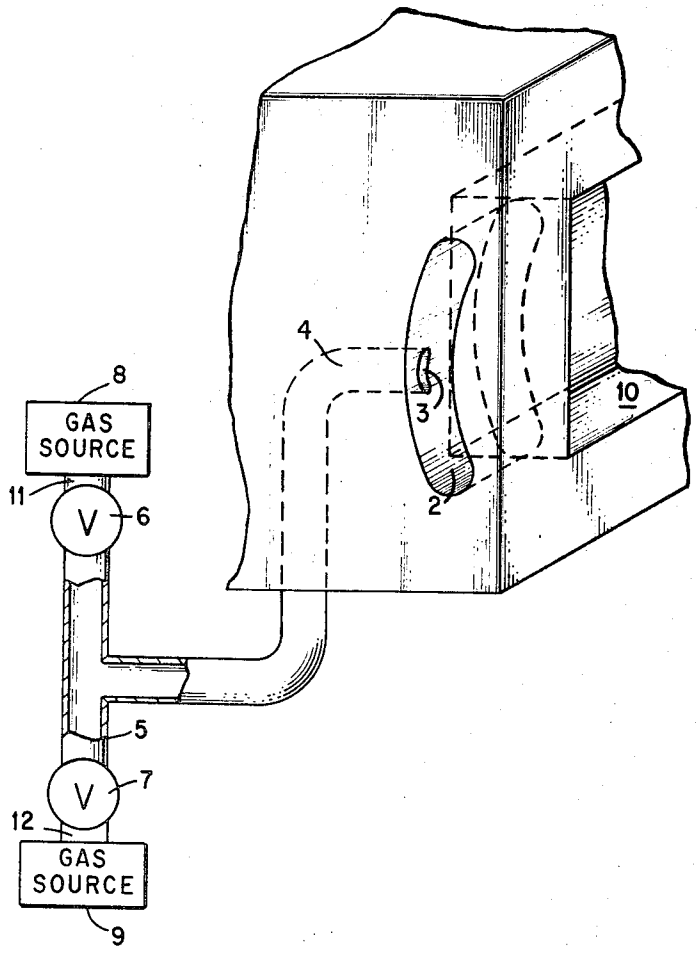
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MEANS FOR CONTROLLING CALUTRON FILAMENT ACTIVATION

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MEANS FOR CONTROLLING CALUTRON FILAMENT ACTIVATION

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ABSTRACT OF THE DISCLOSURE

A calculation for the separation of isotopes of the alkaline earth, the rare earth and certain other elements is modified to provide a source of gas and means for feeding gas from the source at a controlled rate into the region near the calutron ion source filament to substantially prevent activation normally caused by the calutron charge vapor, such that the calutron arc discharge is better stabilized and the purity of the collected isotopes in the calutron receiver is substantially improved. The feed gas is selected from the group including CS_2, S_2Cl_2, H_2S, and CCl_4. In addition, argon or nitrogen gas may be mixed with the above selected gas before being fed to the region near the filament.

Background of the invention

The field of art to which the invention pertains is ion-producing mechanisms for use in the electromagnetically operated equipment known as calutrons for the separation of isotopes or elements.

U.S. Patent No. 3,115,575, issued Dec. 24, 1963, to William A. Bell, Jr., et al., for "Improved Ion-Producing Mechanism for Calutrons" relates to the use of a unitized construction to house both the arc chamber and the oven chamber of a calutron ion source to facilitate assembly and maintenance and to improve operation thereof.

U.S. Patent No. 3,260,844, issued July 12, 1966, to Elwood D. Shipley et al., for "Calutron with Means for Reducing Low Frequency Radio Frequency Signals in an Ion Beam," relates to the use of two series of parallel, overlapping plates with each plate being connected to a grounded coil, and with both series of plates being closely positioned on respective sides of the calutron ion beam from source to receiver. With such an arrangement, the undesirable, low frequency RF, ion beam oscillations are substantially negated, thus reducing ion beam blowup, and improving beam focus and quality.

In U.S. Patent application Ser. No. 548,805, filed May 9, 1966, now U.S. Patent No. 3,312,849, there is disclosed an isotope receiver for a calutron having an oil reservoir in its collection pocket so as to maintain a film of oil on the ion collecting surfaces, thus achieving higher purity collection of low abundance isotopes.

In U.S. Patent application Ser. No. 461,568, filed June 4, 1965, now U.S. Patent No. 3,376,414, there is disclosed means for improving the vacuum pumping in a calutron as well as the ion beam resolution and output. This is accomplished by providing a calcium boiler within the calutron tank unit and being positioned such that the calcium vapor from the boiler is directed toward the calutron ion beam so that the vapor "sees" the greatest portion of the ion beam.

Each of the above prior devices contributes in one way or another to the more efficient operation of a calutron. However, there still exists a need for some means to provide stable operating conditions in the ion source of a calutron for certain separations (to be described below) which is highly desirable since instabilities introduce contaminants into the enriched isotopic materials. One of the areas where instabilities can exist is in the process of forming ions within the source. The charge material in an arc chamber, in vapor form, is subjected to bombardment by energetic electrons supplied by a heated filament. The pressure or quantity of feed material vapor is normally regulated by control of "oven" temperatures involved in feed material vaporization (if initially in a non-vapor form). Whenever adequate control of feed vapor rate by temperature control is not adequate, a support gas (argon or nitrogen) is normally utilized in the arc chamber to aid in arc stability.

Since arc stability in prior devices also involves the bombarding electrons, the electrical circuits associated with the arc and the filament of such prior devices are equipped wtih feedback circuitry to adjust the applied current or voltage to compensate for changes within the arc. For example, when a gradual increase in arc chamber pressure tends to increase arc current, the feedback system senses this change and causes the filament current to be reduced and thereby reduces the temperature of the filament. The cooler filament emits fewer electrons and thereby the arc current is reduced to achieve stability thereof. The same control method is also intended to be effective in the control of fluctuations in arc current caused by changes in the work function of the filament material due to the presence of certain charge materials.

For about two-thirds (about 35 to 50) of the separations performed in the calutron, the above control of arc stability is relatively satisfactory. For the remaining separations, involving primarily the alkaline earth and rare earth elements, the above control is inadequate for the quality of isotopic separation that is desired. In the separation of the isotopes of these later elements, the rate of electron emission from the filament is altered rapidly and extensively by the amount of feed vapor reaching the filament. Changes of filament conditions (heating and cooling) permit additional feed condensation or alloying on the filament surface. These changed conditions further increase the ability of the filament to emit electrons (filament activation) and the process continues until conditions are so unstable as to operate "protective" interlocks in the supply circuitry. Even before this extreme condition is reached, substandard isotopic separation results from the unstable condition. Thus, there exists a need for some means of preventing the depositing or alloying of feed materials on the filament or overcoming the effect thereof, especially when the calutron is utilized in separations involving the alkaline earth, the rare earth and certain other elements. The present invention was conceived to meet the above need and to solve the above undesirable problem of filament activation.

Summary of the invention

In view of the above problem, it is the object of the present invention to provide some means to substantially reduce filament activation during the operation of a calutron in the separation of the isotopes of the above-men-

tioned elements to thus provide for more stable and efficient operation thereof.

The above object has been accomplished in the present invention, since the problem of filament activation in the operation of a calutron for the separations of alkaline earth, the rare earth, and certain other elements has been substantially solved, by the use of a selected feed gas which is effective in decreasing filament activation when fed into the region near the filament, e.g., the electron collimating slot. The gases which have been found effective for decreasing filament activation include carbon disulfide (CS_2), hydrogen sulfide (H_2S), sulfur monochloride (S_2Cl_2), and carbon tetrachloride (CCl_4).

The mechanism by which the above gases reduce filament activation is not known; however, it may be a process of surface poisoning which reduces both the electron emission rate and the sensitivity of electron emission as a function of temperature. In any event, their use has solved the problem of filament activation as will be evident from the test data to be described hereinafter. Not only does the ion source operate in a more stable manner, but the purity of the collected isotopes has been substantially improved when one or another of the above filament deactivation gases is utilized in the operation of a calutron for separations involving the above-mentioned elements. It should be noted that for some separations, a conventional support gas, such as argon or nitrogen, is mixed with the filament deactivating gas before being fed into the electron collimating slot of the calutron ion source for the reasons to be described hereinafter.

Brief description of the drawing

The single figure in the drawing is a schematic, partial showing of the ion source unit of a calutron and the manner of feeding gas from one or two gas sources into the electron collimating slot of the arc chamber section of the source unit.

Description of the preferred embodiment

The preferred embodiment of the present invention is shown in the single figure of the drawing. The complete details of the ion source unit, except for the present inventive concept, may be the same as those described in the above-mentioned U.S. Patent No. 3,115,575, or in an improvement over that patent as described in U.S. Patent No. 3,272,983, to A. M. Veach, et al., issued Sept. 13, 1966, for example. The complete details of the ion source unit are not necessary for an understanding of the present invention and only those parts necessary for such an understanding are shown in the present drawing.

In the drawing, a conventional source unit **1** is provided with an arc chamber **10**, an electron collimating slot **2**, and a gas feed tube **4** having an opening **3** into slot **2**. Feed gas is fed into the tube **4** and slot **2** from a gas source **8** and/or a gas source **9**, depending upon the isotope separation to be accomplished. Gas may be fed from source **8** into tube **4** by means of a tube **11**, an adjustable leak valve **6**, and a T **5**. Also, gas may be fed from source **9** into tube **4** by means of a tube **12**, an adjustable leak valve **7**, and the T **5**. The leak valves **6** and **7** may be of the type described in U.S. Patent No. 3,222,026, issued Dec. 7, 1965, to Joe T. Green, for example. Gas from source **8** is either argon or nitrogen, which is sometimes used in conventional calutron ion sources as a support gas for arc stability. Gas from source **9** is utilized in the present invention as the means for substantially reducing the calutron source filament activation during separations involving the alkaline earth, the rare earth and certain other elements. The feed gas from source **9** is selected from the group including CS_2, H_2S, S_2Cl_2, and CCl_4.

A calutron utilizing the source unit of the present invention can be operated in three different modes; that is: (1) feeding a filament deactivation gas from source **9** into the collimating slot **2** and valving off the gas source **8**; (2) feeding a filament deactivation gas from source **9** and feeding an arc support gas from source **8**, simultaneously, into the slot **2**; and (3) feeding an arc support gas from source **8** into the slot **2** and valving off the gas source **9**. Mode 1 or 2 is utilized in separations involving the above filament activating elements and can also be utilized in any other separations, if desired, while mode 3 is utilized only for separations involving elements other than the above filament activating elements. No novelty is claimed for the conventional mode 3 type of operation, but it has been mentioned only in that the above device could be used in conventional separations, if such were desired.

One of the rare earth elements which causes extreme filament activation is cerium. In conventional, prior calutron operation, the charge material is normally $CeCl_3$, and argon is normally used as a support gas. Problems arising from filament activation and high voltage sparking are normally so excessive that the purity of separated isotopes is below the desired standard due to the contamination caused by the above instabilities of the ion source; and, also, operation under these conditions is extremely difficult. A change of the charge material to CeO_2+CCl_4 (internal chlorination), although slightly reducing the ion output, improved the stability of the arc. Some improvement in beam resolution as determined by collector peak-to-valley current ratios, was also achieved. However, filament activation was still a problem and the purity of the separated isotopes still left much to be desired.

In contrast, complete control of filament activation was achieved throught he use of the present invention by feeding closely regulated amounts of a filament deactivation gas, CS_2, for example, into the electron collimating slot of the source unit of the present invention. In typical operations of a calutron unit, the valley currents at the calutron receiver, when using CS_2, were always less than one-half the value normally monitored when the filament was activated during conventional, prior operation. The assays of collected isotopes, utilizing the present invention, demonstrate that superior purity is achieved in separation runs during which filament activation is avoided. The following tables, I and II, illustrate the results obtained using CS_2 for filament deactivation and those obtained when CS_2 is not used during cerium separation runs.

TABLE I

Filament Condition	Feed System	Peak-to-Valley Current Ratio, $142Ce/140-142Ce$	Av. Q/t ma.	CCR, g./hr.	PE, percent
Activated	CeO_2+CCl_4+Ar	10/1	9.1	1.3	3.8
	$CeCl_3+Ar$	1.4/1	12.2	2.5	2.6
	$CeCl_3+CCl_4$	40/1	----	----	----
Deactivated	$CeCl_3+CS_2$	3.8/1	----	----	----
	$CeCl_3+CS_2+CCl_4$	90/1	9.9	1.6	3.3

TABLE II

Isotope	Natural Abundance, percent	Expl. CX [1] Sample Purity, percent	Series MX [2] Sample Purity, percent		
			(a)	(b)	(fp)
136	0.193	75.9	35.38	22.24	13.89
138	0.250	66.45	14.32	----	7.87
140	88.48	99.95	99.70	----	98.80
142	11.07	98.1	92.77	----	81.01

[1] Filament deactivated.
[2] Filament activated.

The advantages of filament deactivation during the separation of the isotopes of gadolinium have also been demon-

strated. Typical results obtained during the Gd separation runs are shown in the following tables, III and IV.

TABLE III

Run No.	CS_2 Feed Rate, atm.-cc./min.	Filament Current, amp.	$^{154}Gd+_{ma}$	Peak-to-Valley Current Ratio, $^{154}Gd+/^{154-155}Gd+$
NF 18	0.00	[1] 380	0.10	1.0/1
	0.05	390		
	0.20	430		
	0.25	440		
	0.35	460		
	0.40	[2] 470	0.18	4.5/1
NF 20	0.00	[1] 370	0.12	1.2/1
	0.08	380		
	0.16	390		
	0.20	400		
	0.26	420		
	0.34	[2] 440	0.12	3.0/1
NF 24	0.00	[1] 390	0.33	1.5/1
	0.30	430		
	0.50	[2] 460	0.37	3.1/1

[1] Filament activated.
[2] Filament deactivated.

TABLE IV

Filament Condition	Feed System	Isotopic Purity percent ^{152}Gd
Deactivated	$Gd_2Cl_3+CS_2+CCl_4$	35.8
Activated	$Gd_2O_3+CCl_4$	32.1
		24.1
		33.8
		24.5
		20.8
		25.6
		22.4
		25.2
		24.3
		23.8
		Av.. 25.7

It can be seen from Tables III and IV, respectively, that the "peak-to-valley" current ratios have been substantially improved (an indication of more stable operation), and the isotopic purity has been substantially improved when the filament deactivation gas CS_2 is utilized in gadolinium separations in the calutron of the present invention. It should be noted that comparable results have been obtained for gadolinium separation runs when another filament deactivation gas, H_2S, is utilized in the operation of the present device. The other filament deactivation gases, S_2Cl_2 and CCl_4, are not as effective deactivation agents as CS_2 and H_2S, but they can and do provide for more stable operation and better isotope purity in the operation of a calutron than heretofore possible. Thus, the use of CS_2 or H_2S is preferred in carrying out the present invention.

The data set forth in the above tables, relating to those separation runs where filament deactivation is provided were obtained by utilizing only CS_2 feed gas to the collimating slot **2** of the source unit **1** shown in the drawing, and the gas source **8** is valved "off," which corresponds to the mode **1** type of operation mentioned hereinabove. It should be noted that comparable results have been achieved when both an arc support gas from source **8** and a filament deactivation gas from source **9** are combined in the T **5** and fed to the slot **2** of the source unit. In such an operation (mode **2**), the quantity of support gas fed from source **8** is about **5** times the quantity of filament deactivation gas fed from source **9** for best operation results. Using such a ratio of gas feed rates, an isotope purity of 89.5% was achieved for ^{235}U utilizing argon gas from source **8**, H_2S from source **9**, and a charge material comprising UCl_3. On the other hand, the best isotope purity for ^{235}U that was achievable in the operation of prior calutrons was 86%. It should be noted that it is necessary to feed gas from both sources **8** and **9** in the separation of the isotopes of uranium since the arc in the source unit could not be started without the use of argon as a support gas.

Comparable results have also been achieved in separation runs for the isotopes of plutonium, utilizing

$$PuO+CCl_4$$

as the charge material, and a combined gas feed of H_2S and argon.

It should be understood that the present invention is not limited for use with the particular elements mentioned hereinbefore, but is equally useful for isotope separations for all of the other rare earth and alkaline earth elements, and other elements which give rise to filament activation.

The source unit of the present invention can be used in combination with any one or more of the above-mentioned related patents or applications, and preferably with the benefits of all of their teachings in the interest of providing a calutron system wherein more stable operation is achieved and the maximum of isotopic purity is obtained, which are obviously desirable in any calutron operation.

This invention has been described by way of illustration rather than by way of limitation and it should be apparent that it is equally applicable in fields other than those described.

I claim:

1. In a calutron for the separation of isotopes of filament activating elements, including an ion source, an ion receiver spaced from said source for receiving ions from said source, an evacuated tank enclosing said ion source and receiver, and means for providing a magnetic field encompassing the space between said source and receiver for effecting the separation of said isotopes prior to their arrival at said receiver, said ion source provided with a charge bottle for containing a charge material comprising a selected one of said elements, heater means associated with said charge bottle for vaporizing said one element, an arc chamber provided with an ion exit slit in magnetic focus alignment with said ion receiver, said arc chamber further provided with an electron collimating slot at one end and another slot at the other end, an electrically heated filament mounted adjacent to said collimating slot, an anode mounted adjacent to said another slot and in axial alignment with said filament, power supply means connected between said filament and the wall of said arc chamber for establishing an arc discharge therebetween and through said slots and arc chamber, means for feeding said one vaporized element into said arc chamber in the path of said arc discharge where ionization thereof is effected, and means for withdrawing ions from said arc chamber through said exit slit, the improvement comprising a source of gas selected from the group consisting of CS_2, S_2Cl_2, H_2S, and CCl_4, means

for feeding gas from said source at a controlled rate into a region near said filament to substantially prevent filament activation normally caused by said selected charge vapor, whereby said arc discharge is more stabilized and the purity of the isotopes collected by said received is substantially improved.

2. The calutron set forth in claim 1, wherein said selected one of said elements is from a group consisting of the alkaline earth, the rare earth and the actinide elements.

3. The calutron set forth in claim 1, wherein said selected one of said elements is from a group consisting of cerium, gadolinium, uranium, and plutonium, and wherein said region for feeding the gas is said electron collimating slot.

4. The calutron set forth in claim 3, and further including a second source of gas selected from the group consisting of argon and nitrogen, and means for feeding gas from said second source at a controlled rate and

simultaneously with said selected gas from said first source into said collimating slot.

5. The calutron set forth in claim 4, wherein the feed rate of gas from said second source is about 5 times the feed rate of gas from said first source, said selected first gas is H_2S, said selected second gas is argon, and said selected charge material is UCl_3.

6. The calutron set forth in claim 3, wherein said selected one of said charge material elements in compound form is $CeCl_3$, and said selected filament activation prevention gas is CS_2.

7. The calutron set forth in claim 6, wherein CCl_4 is included with the vapor of said charge material.

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