contraction during the transitions from one of such regions into another.

It is known, however, that the distribution of red giants in *R-L*-diagram is limited from above by a line on which the pulsating-variables are located, and that between this line and the upper part of the main sequence only very few stars are known.

It seems possible to understand the existence of this limit, and the pulsational instability of the stars located near it, on the basis of the following simple considerations. As was shown by the author,[2] the condition that the nuclear energy production is more important than the energy liberation due to the gravitational contraction can be written in the form: (notations of reference 2)

$$\frac{R}{M} > \frac{\gamma G m}{(n+1.75)\epsilon}\cdot x^{-1}, \qquad (1)$$

where x is the concentration of the element responsible for the energy production. Accepting the concentration of the light elements to be about 10^{-4} (what is necessary to understand the observed lifetimes of the red giants) we obtain:

$$\frac{R}{M} > 3\times 10^{-23}\,\frac{\text{cm}}{\text{g}}; \qquad \frac{[R/R(\odot)]}{[M/M(\odot)]} > 1. \qquad (2)$$

The limiting line, representing this condition in the *R-L*-diagram, has the same general direction as the line of pulsating stars and can be brought into the coincidence with it by a small adjustment of the value of x. Above this limiting line the evolution is always purely gravitational (until the stars gets into the main sequence) and no "lateral" structure, corresponding to different light elements, can be expected. The number of stars observed in this region must be statistically very small because of the short time scale of the gravitational contraction.

These considerations also bring us to the conclusion that the pulsative instability of the stars near the limiting line must be due to the conditions existing during the transition from the state of thermonuclear evolution into the state of purely gravitational contraction.

G. Gamow

The George Washington University,
Washington, D. C.,
March 24, 1939.

[1] G. Gamow and E. Teller, Phys. Rev. **55**, 654 (1939).
[2] G. Gamow, Phys. Rev. **55**, 718 (1939), formula (6).

The Ionization of Mercury

In view of the importance of the results published recently by Bell and by Nottingham,[1] it seems of interest to mention briefly similar results which have been obtained by a different method. Experiments have been done by the writer[2] with a modified space-charge tube sealed off from the pumps with most of the precautions taken by Nottingham, except that getter was not used. The primary beam was apparently exceptionally homogeneous. It was found that a sharp increase in the ionization always occurred at nearly 10.4 volts. This has been assumed to represent the low energy edge of the main ionization continuum of Hg I, and with this calibration the following ionization processes have been noted.

(1) The current from the space-charge filament decreased continuously as the primary voltage was increased up to five volts, after which ionization set in and varied with the voltage in the manner found by previous workers.[3] It has been found unnecessary to postulate the formation of Hg^- ions to explain the initial drop, because this is due to the effect of the primary electron beam on the space-charge filament.

(2) A rapid rise in the ionization occurred above 10.38 volts with a maximum at 10.81 volts in agreement with the maximum found by Nottingham.

In later runs the ionization between 8.5 volts and 12 volts has been studied by a sensitive method, used previously by R. H. Sloane[4] in analysis of gas discharges, in which there is performed an automatic double differentiation of the current from the space-charge filament relative to the primary voltage. It was found that the second differential curve had first a large positive maximum corresponding to the 10.38-volt inflection and then became almost discontinuously negative to about the same extent, passing through a sharp minimum at 10.50 volts. It is difficult to see how this could be instrumental in origin.

Between 10.5 and 12.0 volts the second differential curve was on the average negative, but rose to positive values at three broad maxima, with intermediate negative minima. The fluctuations correspond to waves in the probability of ionization curve in positions consistent with those found by Nottingham. The points of inflection are those points where the second differential is zero. The maxima in the differential curve had amplitudes about five percent of that representing the 10.38-volt inflection and were about five times as broad. Their character makes it doubtful if they are connected with the onset of new ionization processes, and suggest rather that they correspond to changes in the probability of processes which had commenced at lower voltages.

The second differential curve has also some 20 small sharp peaks between 10.4 and 12.0 volts. Their positions can be correlated with most of the critical potentials previously reported in this region, but the reality of all has not yet been definitely established and the probability of chance coincidences is large.

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Queen's University,
Belfast, Northern Ireland,
March 10, 1939.

[1] M. E. Bell, Phys. Rev. **55**, 201 (1939); W. B. Nottingham, Phys. Rev. **55**, 203 (1939).
[2] Initially in conjunction with G. E. Swindell.
[3] B. L. Snaveley, Phys. Rev. **52**, 174 (1937); F. L. Arnot and M. B. McEwen, Proc. Roy. Soc. **A165**, 133 (1938).
[4] R. H. Sloane, Phil. Mag. **18**, 193 (1934).

Production of Neutrons in Uranium Bombarded by Neutrons*

It is conceivable that the splitting of the uranium nucleus may have associated with it the emission of neutrons. These could either evaporate from highly excited fragments (this process is made more probable by the large neutron excess of the fragments, which lowers the binding energy of the neutrons) or be emitted at the instant of fission. This letter is a preliminary report on experiments undertaken to ascertain whether, and in what number, neutrons are emitted by uranium subject to neutron bombardment, and also whether the number produced exceeds the total number absorbed by all processes whatever.

A source of neutrons was placed in the center of a spherical bulb, 13 cm in diameter, which was immersed in the center of a large tank of water, 90 cm in diameter and 90 cm high. The activity induced in a rhodium foil placed in the water at various distances from the source was measured with and without uranium oxide inside the bulb. If we denote by $a(r)$ the activity induced at the distance r, the integral $\int a(r)r^2dr$ is proportional to the total number of slow neutrons present in the water. A comparison of the integrals with and without uranium gives, in principle, the possibility of deciding whether or not, with uranium present, there is a net increase in the number of neutrons. This result will be independent of the initial energy of the neutrons since in the water they all become slow neutrons.

With radon+beryllium as a source of neutrons a 6 percent increase in the integral with uranium was found. If this increase were caused only by neutrons emitted by the processes discussed above, it would correspond to a yield of about two neutrons per each neutron captured. Since, however, a radon+beryllium source emits also neutrons with energies of several million electron volts one can also interpret the increase observed, or at least part of it, as due to $(n, 2n)$ processes in which a high energy neutron knocks out a nuclear neutron without being captured.

The experiment was therefore repeated with photoneutrons emitted from a block of beryllium irradiated with the gamma-rays from one gram of radium. Since these neutrons have energies considerably lower than 10^6 ev an $(n, 2n)$ process is highly improbable. Because of the large dimensions and the shape of the beryllium block and the radium source, it was not feasible, however, to secure, in this experiment, the requisite spherical symmetry. The resulting loss of precision makes a comparison of the two integrals inconclusive. Since, however, at large distances from the source the activity with uranium is about 30 percent larger than without uranium, it follows that neutrons of energy larger than that of the photoneutrons are produced in the process. This result is in agreement with the direct observations of Szilard and Zinn; we thank them for informing us of their results prior to publication. Close to the bulb the activity with uranium is, instead, about 60 percent of the activity without uranium. This decrease is due to the absorption of neutrons by uranium; the total absorption cross section of uranium, due to fission and other processes, can be deduced from this result to be of the order of 5×10^{-24} cm^2.

If the volume integral of the differences in the activities with and without uranium be calculated, the contribution from parts in the neighborhood of the bulb is negative and gives the order of magnitude of the number of neutrons absorbed. The contribution of the distant parts of the volume is positive and gives the order of magnitude of the number of neutrons produced. These two contributions are of the same order of magnitude and the present accuracy is inadequate to decide which one is larger. Improved experiments are in progress in order to increase the accuracy.

Roberts, Meyer, and Wang[1] have reported the emission of delayed neutrons subsequent to the bombardment of uranium by neutrons. Such delayed neutrons cannot contribute appreciably to the effects that have been described here. This was ascertained by observing that no activity was induced in the rhodium detector after the removal of the source.

We are indebted to the Association for Scientific Collaboration for the loan of the photoneutron source used in these experiments.

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March 16, 1939.

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* Publication assisted by the Ernest Kempton Adams Fund for Physical Research of Columbia University.

[1] Roberts, Meyer, and Wang, Phys. Rev. **55**, 510 (1939).

Structure of the Be I Line λ4573A

The beryllium spectrum has been investigated many times with instruments of high resolving power in the hope of finding hyperfine structure. All attempts have hitherto been unsuccessful. All lines, as it has been proved, are single, with two exceptions: Kruger and Wagner[1] found a weak component near the Be II line 4673A and Parker[2] claimed to detect an asymmetrical structure of the Be I line 4573A. In connection with another experiment I reinvestigated the chief Be I lines (4573, 3321 triplet, and 2349A) and Be II lines (3131A doublet) excited in a liquid-air-cooled hollow cathode discharge tube of the type described by Ritschl[3] by means of aluminum-coated Fabry-Perot etalons and Lummer-Gehrcke plates (13 and 20 cm long). All lines were found to be single and no asymmetry could be detected in the line 4573A, although this line was investigated very thoroughly. Fig. 1 is a microphotometric record of an enlargement of a photograph of this line taken with a Fabry-Perot etalon of 27.2 mm separation of plates. The rise of the intensity towards the middle of the interference pattern results from the uneven illumination of the slit of the spectrograph; the anomalous height of the second maximum to the right of the middle results from a small scratch on the photographic plate. The high symmetry of the fringes is evident. If an asymmetry were present it should have been detected, firstly because the resolving power of my instrument is more than three times the resolving power of the Lummer-Gehrcke plate used by Parker in his investigations ($\leqslant$700,000), and secondly because I used lower currents (0.35 amp.) than Parker (0.5 amp.) and as I have remarked, the lowering of current is as important for obtaining small breadths of the line as an intensive cooling. That the lines were very sharp is shown by a comparison of the breadth of the resonance line 2349A in my experiments (0.012A, 0.2 amp.) with that in the experiments of Kruger and