experiment obtained by Huntington and Seitz[2] who calculated the activation energy for self-diffusion in copper on basis of a vacancy mechanism. The following experimental measurements provide preliminary data on the disorder produced at elevated temperature, presumably vacancies, in pure gold.

Gold wires, 99.999 percent pure, of 16-mil diameter were quenched in a blast of gaseous helium to room temperature. The wires were then immediately immersed in liquid nitrogen. The time required for the quench from the high temperature was 7 ± 3 milliseconds. About a third of a second was required to get the wire from room temperature to liquid nitrogen temperature.

After quenching, an increase in the residual electrical resistivity at liquid nitrogen temperature was detected. Measurements were made on the annealing of the quenched-in resistance. About one-third of the resistance increase can be annealed at temperatures in the vicinity of room temperature. The resistance at liquid nitrogen temperature was measured as a function of the annealing time at -21.7°C and also at -2.7°C. From these data the energy required to move a vacancy is 0.4 ev$\pm$0.14 ev.

The remaining two-thirds of the resistance anneals out at some temperature between 100°C and 500°C.

Quenches were made from five different high temperatures, from 920°C to 690°C and the increment in resistance quenched in from these temperatures varied, respectively, from 0.82 percent to 0.065 percent. The large change in the amount of resistance quenched-in with the temperature from which the quench was made indicates that stresses arising from thermal gradients are not the source of the resistance increase. Further, these data may be used to determine the energy required for the production of a vacancy. However, errors in measuring the temperature from which the quenches are made give rise to large errors for the energy to form a vacancy, and with this difficulty we can at present only estimate this energy as lying between 1 ev and 2 ev. More accurate measurements are in progress.

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Some Experiments on Ge^{75} and Ge^{75m}†

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Ge^{75} has not been investigated by spectroscopic means. The half-life is known[1-3] to be 80 min and the beta-ray end point has been measured by aluminum absorption and found to be[1,2] 1.3 Mev.

In the present investigation germanium enriched in Ge^{74} was bombarded by neutrons, and measurements were made with the help of a magnetic lens spectrometer, scintillation spectrometer, and coincidence counting techniques. In all of the work the activity was quite weak.

The beta-ray spectrum was measured in the lens spectrometer and two beta-ray groups were found having end-point energies, relative abundances, and logft values of 1.137 Mev, 85 percent, log$ft=5.2$; 0.614, 15 percent, log$ft=4.5$. In addition, two internal conversion lines were seen. There was a well-resolved line at 0.408 Mev and an unresolved group at about 0.520 Mev.

The gamma-rays were measured from observations of photoelectrons from a uranium radiator. A line at 0.265 Mev was found and also a Compton distribution for a line around 0.600 Mev. The line at 0.265 Mev was confirmed with the help of a scintillation spectrometer. In addition, weak lines at 0.418 and 0.572 Mev were seen on the scintillation spectrometer.

Beta-gamma coincidence experiments were performed using ordinary counters. No coincidences were found between the high energy group of beta-rays and gamma-rays showing that the high energy group leads to the ground state.

Some of the gamma-rays seen in Ge^{75} are also seen in the transition[4-7] Se$^{75}\rightarrow$As^{75}. Those which appear in both are the ones at 0.265 and 0.408 Mev. Although a careful search for internal conversion lines of low energy was made, none was seen.

Since the ground state of As^{75} has a configuration $p_{3/2}$, and the transition from the ground state of Ge^{75} to the ground state of As^{75} is allowed, the configuration of the ground state of Ge^{75} is probably $p_{1/2}$. The fact that the higher states of As^{75} are excited by the K-capture transitions from Se^{75} infers that the ground state of Se^{75} has the configuration $g_{9/2}$. It is interesting to note that both beta-ray groups of Ge^{75} have logft values corresponding to allowed transitions.

We have produced a metastable state of Ge^{75}. This state was produced both by a Ge^{74} (separated) (n,γ) reaction and As$^{75}(n,p)$ reaction. The energy of the gamma-ray was measured photographically on a scintillation spectrometer and was found to be 0.175 Mev. The half-life of the state was found by setting on the line with a scintillation spectrometer connected to a differential pulse-height selector. The half-life is 48 ± 2 sec. While this experiment was in progress a similar experiment was reported by Flammersfeld.[8]

Assuming the radiation to be $E3$, using the empirical lifetime formula of Goldhaber and Sunyar,[9] and the expected conversion coefficient and K/L ratio, the half-life comes out 88 sec compared with the measured half-life of 48. If, on the other hand, this radiation has been assumed to be $M4$, the half-life would have been of the order of 10^6 sec.

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† Supported by the joint program of the ONR and AEC.

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K^{40} Radioactive Decay: Its Branching Ratio and Its Use in Geological Age Determinations*

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The ratio of K-capture to beta-emission for the naturally occurring radioactive isotope K^{40} has been determined. For this purpose argon was extracted from four different samples of microcline and purified. The volume of the extracted argon was measured by means of a McLeod gauge built into the apparatus, and the amount of radiogenic A^{40} was ascertained by mass spectrometric analysis of the isotopic abundances in the extracted argon. The potassium contents of the samples of microcline were determined by chemical analysis and the amount of K^{40} has been estimated using the recent value[1] of Nier, 0.0119 ± 0.0001 percent, as the isotopic abundance of K^{40} in potassium.

Previous determinations of the branching ratio by direct measurements have used counting techniques,[2-9] whereas those based on indirect measurements have used age data couplied with either Ca^{40} or A^{40} extraction data to get the branching ratio,[10-12] except Ingham *et al.*,[13] who measured both A^{40} and Ca^{40} to get the branching ratio.

The argon was extracted by heating a sample of known weight of powdered microcline (75 g in each case) with metallic sodium in vacuum to about 600°C, and it was purified by treating the gas in a calcium furnace to constant volume. The results of the isotopic analysis of argon thus obtained are shown in Table I. All

TABLE I. Isotopic analysis of argon from samples of microcline.[a]

Sample No.	Locality	Run	A^{40}/A^{36}	Radiogenic argon, %	Average
1	Hybla, Ont.	1	39800 ± 4000	99.3 ± 0.1	99.4 ± 0.1
		2	59400 ± 5000	99.5 ± 0.1	
2	Frontenac Co., Ont.	1	3790 ± 320	92.0 ± 0.7	92.7 ± 0.5
		2	4460 ± 220	93.4 ± 0.3	
3	Monteagle Twp., Ont.		>90000	100.0 ± 0.1	100.0 ± 0.1
4	Leeds Co., Ont.		6310 ± 520	95.3 ± 0.4	95.3 ± 0.4

[a] In column 4 the errors given are mean deviations of observations.

of them contain a very high percentage of radiogenic argon and two of them contain nearly pure radiogenic argon.

The extraction of argon from the first two samples (Table I) was repeated and the volumes measured agreed within less than 3 percent. Mass spectrometric analyses were carried out for each separate run and the amounts of radiogenic argon calculated from these analyses showed agreement within 1.5 percent for each pair of runs for each sample. For one sample, purity of argon was tested spectroscopically. Occurrence of faint band spectra indicated the presence of some impurities whose identifications were not definite. The same sample was then analyzed in the mass spectrometer, scanning the entire mass range from 14 to about 100. Traces of impurities at masses 18 and 28 were detected whose total effect was not more than one percent.

All the samples of microcline used in this investigation are from the Grenville area where ages range from about 850 to 1050×10⁶ yr, but since they were not collected from pegmatite veins which have been precisely dated no exact values can be assigned for the ages of the minerals. However, for one sample (Hybla), a fairly definite value for its age (t) may perhaps be given because the locality of Hybla is close to Wilberforce and a pegmatite at Wilberforce has been accurately determined to be 1030×10^6 yr old by both chemical and isotopic lead determinations.[14–16] The age of the Hybla sample has, therefore, been taken to be 1030×10^6 yr. As no more definite value for t can be assigned to the rest of the samples, they have been assumed to be of the same age as the Hybla sample and the branching ratio calculated with the results given in Table II. However, it is quite possible that the real ages of these samples are younger and lie in the range 850 to 1050×10^6 yr, in which case it is interesting to note that the variations in the values of the branching ratio are similar to this possible spread in the age value of the samples.

The volume measurements of the extracted argon are believed to have been made within an accuracy of one percent. The values of the branching ratio have been calculated using the total half-life for K^{40} of 12.7×10^8 years obtained by Sawyer and Wiedenbeck.[8] The results are in good agreement with the low range of values of the branching ratio obtained by some workers using direct measurements[4, 9] and also with those obtained by Aldrich and Nier.[12] The results are consistent within the range expected from the spread in the age data, and the author is hopeful that further work may establish the branching ratio with the precision required for its application to geological age determinations. For this purpose, samples of potassium bearing minerals are needed from localities which are well dated by other reliable radioactive methods. Further work using such samples is in progress.

TABLE II. Volume of argon from microcline samples and calculated branching ratio of potassium 40. The last column (B.R.) gives the branching ratio for total half-life 12.7×10^8 yr. Each sample had a total weight of 75 g and was assumed to have an age of 1030×10^6 yr.

Sample No.	Potassium[a] grams	Argon[b] std. cc	Radiogenic A^{40} std. cc	$\frac{\text{g radio-}A^{40}}{\text{g }K^{40}}$	B.R.
1	7.88	0.0246	0.0244	4.65×10^{-2}	0.066
2	7.84	0.0230	0.0214	4.10×10^{-2}	0.059
3	7.85	0.0204	0.0204	3.90×10^{-2}	0.055
4	7.62	0.0204	0.0193	3.80×10^{-2}	0.053

[a] Estimated from chemical analysis.
[b] Measured with McLeod gauge.

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The Very Long Lifetime of C^{14} β-Decay*

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THE very long lifetime of C^{14} is one of the difficulties of β-decay theory which still remains. The spins of C^{14} and N^{14} have been measured to be 0 and 1, respectively. The interpretation of the forward angular distributions associated with the reactions $C^{13}(d, p)C^{14}$ and $C^{13}(d, n)N^{14}$, along the line of Butler's theory,[1] leads to the conclusion that C^{14} and N^{14} both have even parity. One expects therefore an allowed β-decay according to the G. T. selection rules. The spectrum actually has the allowed shape; however, the ft value is very large: $\log ft=9$ to compare, among other cases, with the β-decay of He^6 where $\log ft=2.95$ (super-allowed).[2]

An explanation of the C^{14} anomaly in terms of "L-forbiddenness" has been proposed.[3] It is assumed that in the light nuclei, the orbital angular momentum L is a very good quantum number; then $C^{14}\rightarrow N^{14}$ is supposed to be a ${}^1S_0\rightarrow{}^3D_1$ transition, whereas $He^6\rightarrow Li^6$, for example, is ${}^1S_0\rightarrow{}^3S_1$. The allowed shape of the C^{14} spectrum is then explained either by assuming a small admixture (very small indeed) of ${}^3S_1$ in the N^{14} ground state or by showing that the transition ${}^1S_0\rightarrow{}^3D_1$ is governed by a matrix element which simulates the allowed shape.

L is certainly a rather good quantum number in the very lightest nuclei (deuteron, H^3, He^3), whereas strong noncentral effects show up in heavy nuclei, as evidenced by the success of Mayer's model. It is quite reasonable, therefore, to assume that L is a good quantum number in the medium light nuclei considered above. The question arises, then, whether the L assignments which have been proposed to explain the β-decay are consistent with other experimental data and whether they can be tested by further experiments.

In fact, the electric properties of N^{14} and Li^6 are consistent with ${}^3D_1$ and ${}^3S_1$ assignments, respectively. In those nuclei which have isotopic spin $T=0$, the magnetic moment is given by the simple expression (in units $e\hbar/2Mc$):

$$\mathbf{M}=\tfrac{1}{2}\mathbf{L}+(\mu_P+\mu_N)\mathbf{S},$$

which gives 0.33 for ${}^3D_1$ whereas $\mu_{N^{14}}=0.40$ and 0.85 for ${}^3S_1$ whereas $\mu_{Li^6}=0.82$. Whether the small differences can be explained in terms of relativistic effects, exchange moment effects, or in terms of noncentral forces remains to be seen. The quadrupole