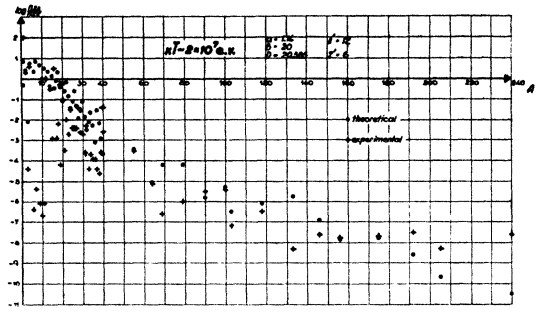

FIG. 1.

relative abundances of all nuclei, especially the approximate constance of abundance of heavy nuclei ($A>100$).[2] Working with a method proposed by one of us[3] we made an attempt to obtain the general law of distribution for the whole periodic system, looking for the average variation of abundances, without paying attention to the details of the distribution.[4]

The results for two temperatures are reproduced in the following Figs. 1 and 2, where experimental abundances are indicated following the data of Goldschmidt, and theoretical values were obtained by means of the formula:

$$\log\frac{n_{ZA}}{n_{Z'A'}}=a\times(Z-Z')+D\times(A-A')-B\times(M_{ZA}-M_{Z'A'})+\tfrac{3}{2}\log\frac{M_{ZA}}{M_{Z'A'}}$$

already used in previous papers.[5] Here n_{ZA} and $n_{Z'A'}$ indicate number of nuclei per cm^3; a, B, and D are parameters of the distribution. We neglected the factors representing the multiplicity of nuclear states and admitted that for $kT\gtrsim 10^7$ ev the contributions of excited states to the statistics of nuclei could be taken into account writing for the average energy E of nucleus: $E\cong Mc^2+kT$. We found by trial that for the temperatures of the order of 20 or 40 Mev ($B\sim 20$ or $B\sim 10$) the calculated abundances fit roughly the experimental curve, and we reproduce here two typical results between many possible ones corresponding to nearly the same parameters. The results obtained with $kT\sim 40\times 10^6$ ev ($B\sim 10$) are more satisfactory and give for U^{238} a theoretical abundance -6.95 compared with the observed -7.6 (whereas the other choice of parameter gives: -10.5). The total density of nuclei can be calculated using the general laws of equilibrium between nuclei, photons, and electrons,[3] (disregarding the eventual production of mesons) and assuming that initially the total charge is 0. In this way one obtains densities $\sim 10^{13}$ g/cm^3 for light nuclei, $\sim 10^6$ g/cm^3 for heavy nuclei. For protons one has: 1.7×10^{13} g/cm^3 or 3.6×10^{12} g/cm^3, at $kT\sim 40$ Mev or 20 Mev, respectively.

From the general satisfactory agreement between the calculated and observed points in Fig. 1, we deduce that nuclei were probably formed at conditions not very far away from those of thermal equilibrium. The high rate of nuclear reactions makes this assumption acceptable even if the phase of expansion at which nuclei were formed lasted only few seconds.[6]

A further inspection shows that there is no close correspondence between the relative abundances of isotopes in the two series of data (theoretical and observed ones). Obviously one should expect a change of relative abundances during the following cooling processes and, for radioactive nuclei or for nuclei formed in the known thermonuclear processes (H, Li, Be, B), continuous change with the time. We are inclined to admit that the observed ratios between the abundances of isotopic nuclei were established during the successive stages of cooling and expansion of matter, at lower temperatures: $kT\sim 10^6$ ev. Indeed previous calculations[1] show a close agreement between the theoretical and observed relative abundances of some isotopes at this temperature.

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[2] V. M. Goldschmidt, Geochem. Vert. d. El., (Oslo), **9** (1938).
[3] G. Wataghin, Comptes Rendus, **203**, 909 (1935); Phys. Rev. **66**, 149 (1944).
[4] G. Gamow, J. Washington Acad. Sci. **32**, 353 (1942).
[5] C. Lattes and G. Wataghin, Phys. Rev. **69**, 237 (1946); Phys. Rev. **70**, 430 (1946). Klein, Bescow, and Treffenberg used an equivalent formula (Eq. (1), loc. cit.) deduced with Gibbs thermodynamical method.
[6] G. Gamow, Phys. Rev. **70**, 572 (1946).

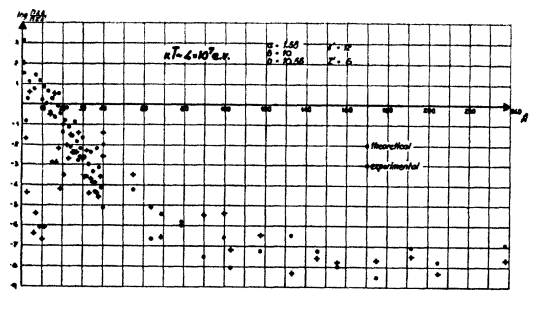

FIG. 2.

Absolute Cross Section for the Reaction $C^{12}(p, pn)C^{11}$ at High Energy

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November 21, 1947

RECENT measurements by Chupp and McMillan[1] have shown that the cross section for producing C^{11} from C^{12} by proton impact is independent of energy from 60 Mev up to at least 140 Mev; to find the absolute cross section for this process, it was only necessary to measure

the activity produced in carbon by a known proton current. The source of protons was the same as described in reference 1, using a $\frac{1}{2}$-in. thick Be target. In a position corresponding about to that marked B in Fig. 1 of this reference was placed a lead box having a 1-in. round hole in one side to admit protons. The protons coming through the hole passed through $\frac{1}{8}$ in. of copper to stop any slow particles, then through the sample to be activated (sheets of 5-mil polystyrene), then were collected in a thick insulated lead block. No defining slits other than the hole were used since other experiments showed that the action of the magnetic field gave ample collimation for this purpose; in fact, an excitation curve taken with a bare stack of carbon plates was reasonably accurate except for some loss of definition near the end of the range. Secondary emission from the collector block is known to be negligible from the fact that very little current is collected by the thin cyclotron targets when traversed by the deuteron beam. The energy of the protons going through the sample was equal to the mean proton energy ($\frac{1}{2}$ deuteron energy $-\frac{3}{4}$ energy loss in traversing Be target $=80$ Mev) less the 18-Mev loss in the $\frac{1}{8}$ in. of copper, or 62 Mev, which is on the flat part of the excitation curve.

The activity measurements were made by comparing the counting rates of the activated polystyrene sheets with a calibrated uranium standard; absorption corrections were small and back-scattering was minimized by mounting the sheets with no backing material. Three sheets were used in each run, and the individual counts agreed excellently. Another sheet behind the collector block served to evaluate the neutron background which gave a 1 percent correction. The proton-induced activity in sheets of 13.9 mg/cm^2 surface density (6.44×10^{20} carbon atoms/cm^2), expressed as the saturation activity at the end of a very long bombardment, was found to be 5950 disintegrations/sec. in the first run and 6010 disintegrations/sec. in the second run.

In order to measure the current, a lead was brought out from the collector to a vacuum-tube electrometer outside the cyclotron shield. This circuit used a Victoreen VX-32 tube as an inverted triode, i.e., the input was connected to the plate, while the grid current was observed. The potential of the cathode was varied manually so as to keep the grid current constant, thus maintaining constant potential differences between the electrodes, and the cathode potential was read. Under ideal circumstances this method would give directly the integrated current during the exposure; in practice, it was found that the cable insulation became very leaky when the cyclotron was running. To minimize this effect, vacuum-insulated cable was used from the center of the cyclotron to a point 12 feet outside the vacuum chamber, the remaining 60 feet of cable being RG-62. A lead shutter in front of the sample box could be closed to make leakage measurements without exposing the sample. With the cyclotron running, it was found that the leakage current varied with collector potential in an ohmic fashion, with an effective resistance of about 2×10^{11} ohms; also, the potential of zero leakage was determined. Then extra capacitance was added, the collector potential was set at 1.5 volts below the point of zero leakage, the shutter was opened, and the cyclotron was run steadily until the collector potential had risen 3 volts. Voltage readings were made at 1-minute intervals during the run. The collected current I is then given by:

$$I=(\Delta V/2R)\ \mathrm{ctnh}(\Delta t/2RC)$$
$$\sim(C\Delta V/\Delta t)[1+(1/12)(\Delta t/RC)^2],$$

where $\Delta V=$ total voltage rise, $\Delta t=$ time of exposure, $R=$ leakage resistance, and $C=$ capacitance. R can be evaluated from the shape of the voltage-time curve; if v represents the deviation of the curve from a straight line at the time mid-point, then:

$$IR=(\Delta V)^2/8v+\tfrac{1}{2}v.$$

In the first run, $\Delta V=3$ volts, $\Delta t=24$ min., $C=9120$ $\mu\mu$fd., and $v=0.25$ volt, from which $R=2.3\times10^{11}$ ohms, $RC=36$ min., and $I=1.97\times10^{-11}$ ampere. In the second run, $R=2.2\times10^{11}$ ohms, and $I=2.09\times10^{-11}$ ampere.

The above activity and current measurements can now be combined to get the activation cross section. Thus we get for the two runs $\sigma_a=0.075\times10^{-24}$ and 0.071×10^{-24} cm^2, respectively. Allowing for possible systematic errors, the result is given as 0.073 ± 0.010 barn.

An estimate of the total proton current is of some interest; from the area and position of the 1-in. hole and the theoretical energy and angle distributions this is estimated to be about 1/40 microampere, which agrees with the theoretical proton yield of 2 percent and the estimated deuteron current of about 1 microampere.

Also of interest is a determination of the relative yields of C^{11} from C, N(Be_3N_2), and O(BeO) samples bombarded simultaneously in a 60-Mev proton beam. The yields per atom were in the ratio C:N:O = 1:0.28:0.36.

The authors wish to thank Mr. Warren W. Chupp for his assistance in these measurements. This work was done under the auspices of the Atomic Energy Commission, under Contract No. W-7405-eng-48.

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The Mean Life of Negative Mesotrons in Sodium Fluoride*

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November 21, 1947

LAST year Conversi, Pancini, and Piccioni[1] showed that negative mesotrons, stopping in carbon, do disintegrate. This result seemed to indicate that the interaction of mesotrons with nucleons was much smaller than postulated in meson theories.[2,3] Since it seemed essential to prove that disintegration and nuclear capture are actually competitive