Die Wirkungsquerschnittsformel wurde mit Erfolg auf Spallationsprodukte, erzeugt bei Energien von 0,17 sowie 2 und 6 GeV, angewandt. Die Genauigkeit, mit der die Parameter bestimmt werden konnten, verlangt, daß die experimentellen Werte innerhalb eines Faktors 2 mit den berechneten übereinstimmen. Nur bei den Neonisotopen ist diese Forderung nicht erfüllt. Dies zeigt, daß bereits von der Masse 20 an (zu kleineren Werten hin) der sogenannte Fragmentationsprozeß eine Rolle spielt, d. h. daß bei diesen Energien Kernbruchstücke der Masse 20 vom Targetkern abgesprengt werden können.

Zusammenfassung

Für die Edelgasisotope, die unterhalb der Targetmassenzahl liegen, und für Tritium konnten Wirkungsquerschnitte mit einer Genauigkeit von etwa 20% bestimmt werden. Die Ergebnisse zeigen gegenüber Bestrahlungen bei niederer Energie keine wesentlichen Besonderheiten. Die Wirkungsquerschnitte für die leichten Verdampfungsteilchen zeigen abnehmende Tendenz. Innerhalb der erwarteten Genauigkeit stimmen die Ergebnisse für die Argonisotope mit den berechneten Werten nach RUDSTAMS Formel gut überein. Es ist auffallend, daß die bei niedriger Energie gemessene höhere Produktion von He^3 in Eisen immer noch vorhanden ist. Im Gegensatz dazu ist das He^3/Tritium-Verhältnis wesentlich kleiner als 1 für Kupfer. Es wäre von Interesse, das He^3/Tritium-Verhältnis auch bei Nachbarelementen des Eisens zu bestimmen.

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Ne in some Stone Meteorites*

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Ne^{20}, Ne^{21} and Ne^{22} has been measured in several stone meteorites. Good agreement with other cosmic ray produced rare gas isotopes was obtained. No indication of primeval neon was found in the chondrites, but one urelite showed excess Ne^{20}.

Ne in meteorites is produced by cosmic ray induced spallation, or is trapped gas of the atmosphere in which the meteorite was originally formed. It can therefore give information on the cosmic radiation and cosmic ray age of the meteorite and of the primeval atmosphere of the parant body of the meteorite.

Extensive work has already been done on iron meteorites [1, 2], less on stones. GERLING and LEVSKII [3] measured He, Ne and A in 9 stone meteorites, however, some of their results show relatively large errors. REYNOLDS and LIPSON [4] published data on the rare gas content of Nuevo Laredo and recently GOEBELS et al. [5] of Ramsdorf.

Samples used

Table 1 contains a short description of the measured meteorites.

Experimental technique

The crushed meteorite sample was reacted in a nickel crucible with borax as flux for 2 h at 1250 °C. To prevent gas discharges, induced by the induction heater, about 10 mm Hg of triple distilled CO_2 were added. After the crucible had cooled down below 300 °C the evolved rare gases were cleaned with titanium (about 8 g Ti-foil, .00025″ thick). Using charcoal, A was separated from the Ne and He, and the latter were then toeplered into a sample tube. Mercury cut-offs were

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Meteorite	Classification	Total recovered mass	Date of fall	Origin of sample
Holbrook	Cryst. Sph. hyp. chond.	220 kg	July 19, 1912	Aliquot of crushed sample used by GEISS and HESS[7] and EBERHARDT and HESS[8]
Richardton	Veined Sph. br. chond.	90 kg	June 30, 1918	
St. Michel	Wh. hyp. chond.	17 kg	July 12, 1910	
Bjurböle	Sph. hyp. chond.	330 kg	March 12, 1899	
Furnas County	Aubrite	1000 kg	Feb. 18, 1948	
Olivine Brenham	Pallasite	> 1000 kg	found 1882	
Goalpara	Urelite	3 kg	found 1868	US Nat. Mus. Washington
Novo Urei	Urelite	2 kg	Sept. 4, 1886	

Table 1. Description of meteorites. Data from PRIOR and HEY [6].

used in the extraction line and the extraction vessel was opened with a flange and metal gasket. The mercury cut-offs and Toeplerpump were backed with CO_2. The meteorite sample and extraction jacket were freed of adsorbed gases by passing steam through the double wall extraction jacket.

Extensive tests showed completeness of the extraction. All samples were reheated a second time. No Ne^{21} could be detected in the reruns ($<\frac{1}{2}\%$ of total Ne^{21}). Some extractions were made by melting the meteorite in a graphite crucible at ~ 1550 °C. The isotopic composition and total amounts agreed with the borax-extractions.

Besides the reheating of the sample, frequent blank runs were made. Small amounts of atmospheric Ne were found, due to inleakage through the cold Pyrex tubing. Therefore all isotopic composition runs were repeated, varying the sample size (.3 to 2 g), and therefore the blank correction by at least a factor two. Good agreement between the individual runs was always obtained.

The amounts of neon were measured by isotopic dilution. Air neon was used as spike and prepared by the usual methods [9]. Intercalibration with Dr. P. SIGNER from the University of Minnesota showed absolute agreement within 5%. The isotopic composition was measured on a small trochoidal masspectrometer [10]. The machine was operated static, and calibrated by running air-neon.

Table 2 contains the result. The blank correction has been applied. The Ne^{21} concentrations are accurate to 5% absolute and 3% relative, the Ne^{20}/Ne^{22} ratios to 2% and the Ne^{21}/Ne^{22} to 1%. The results of Goalpara and Novo Urei are from a single run and the Ne^{21} concentration is estimated from the ion beam intensity. Therefore the errors are larger.

Meteorite	$\frac{Ne^{21}}{Ne^{22}} \cdot 10^{-2}$	$\frac{Ne^{20}}{Ne^{22}} \cdot 10^{-2}$	$Ne^{21} \cdot 10^{-8}$ cc STP/g
Chondrites			
Holbrook	95.5 ± 1	92.0 ± 2	$6.70 + .35$
Richardton	95.5 ± 1	91.5 ± 2	$9.50 \pm .50$
St. Michel	95.0 ± 1	92.0 ± 2	$8.20 \pm .40$
Bjurböle	93.5 ± 1	92.5 ± 2	$4.45 \pm .25$
Achondrites			
Furnas County	93.5 ± 1	90.0 ± 2	58.5 ± 2.5
Goalpara	87.5 ± 2	98 ± 5	$8.8 \pm .9$
Novo Urei	90.0 ± 2	129 ± 5	$2.7 \pm .3$
Pallasite			
Olivine Brenham	106.0 ± 1	94.0 ± 2	36.5 ± 2.0
Atmospheric neon	2.9	1030	—

Table 2. Results. All errors are absolute. The Ne^{21} concentrations are accurate relative to 3% (except Goalpara and Novo Urei).

Discussion of results

Ne^{21} has very low cosmic and terrestrial abundance relative to Ne^{20} ($Ne^{21}/Ne^{20} = 2.8 \cdot 10^{-3}$ in air). Therefore, all Ne^{21} in the measured meteorites is made by spallation. The same is true of He^3, but not necessarily [7] of A^{38}. Table 3 shows the He^3/Ne^{21}, He^3/A^{38} and Ne^{21}/A^{38} ratios. These ratios depend on the chemical composition of the meteorite. He^3 is made from all the elements, Ne^{21} mainly from Na, Mg, Al and Si, A^{38} mainly from Ca, K, Fe and Ni. Not much experimental data on the corresponding cross-sections is available at the present time.

Chondrites are generally very constant in chem-

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Meteorite	He^3/Ne^{21}	He^3/A^{38}	Ne^{21}/A^{38}
Holbrook	4.1	26	6.3
Richardton	3.5	29	8.2
St. Michel	3.8	30	7.7
Bjurböle	3.7	14	3.6
Furnas County	3.8	115	30
Olivine Brenham	2.9	130	45

Table 3. Ratio of spallation produced rare gases. Data from: A^{38} GEISS and HESS [7]; He^3 EBERHARDT and HESS [8]; Ne^{21} this paper.

ical composition. A comparison of the compositions of Holbrook, Richardton, St. Michel and Bjurböle shows, that the macroscopic cross sections for the production of He^3, Ne^{21} and A^{38} should not vary by more than 10%. This is in excellent agreement with the measured He^3/Ne^{21} ratios which agree within 8% (average 3.8). "Cosmic ray ages" deduced from Ne^{21} therefore agree with the He^3 ages. Any diffusion loss of He^3 seems very unlikely as one would certainly expect variations from one meteorite to another. The average Ne^{21} production rate in chondrites is $2.5 \cdot 10^{-15}$ cc STP g^{-1} $year^{-1}$ using the He^3-ages of EBERHARDT and HESS [8].

Furnas County and the olivine of Brenham have higher Mg contents than the chondrites but are lower in Na and Al. The He^3/Ne^{21} ratio $= 3.8$ in Furnas County shows, that the macroscopic Ne^{21} production cross-section is about the same as in a chondrite, and the influence of the different chemical composition cancells out. Brenham has a lower He^3/Ne^{21} ratio. This may be due to the high Mg content. The Ne^{21}/Ne^{22} ratio is much higher than in the other meteorites, indicating that the reaction Mg^{24} (p, α) played an important role. Novo Urei and Goalpara have a chemical composition similar to Furnas County. To calculate their Ne^{21} "cosmic ray age" the production rate for chondrites can be used without introducing an error of more than 30%. We calculate 35 my for Goalpara and 10 my for Novo Urei.

GERLING and LEVSKII [3] found in the achondrite Pesyanoe large amounts of He^4; Ne^{20}, Ne^{22}; A^{36}, A^{38} with about atmospheric isotopic composition. They concluded, that these were remnants of the primeval atmosphere in which the meteorite was formed. Some of the chondrites investigated by GEISS and HESS [7] have high A^{36}/A^{38} ratios. They gave two possible explanations: either formation of A^{36} by thermal neutrons from Cl^{35} or trapped primeval gas. They had excluded atmospheric contamination by careful experimental techniques. The low He^3/A^{38} ratio of Bjurböle favours the second explanation [8]. Furthermore, the required thermal neutron fluxes are high and could hardly by provided by cosmic ray interactions.

No indication of excess Ne^{20} was found in Bjurböle or in any other chondrite. Holbrook has the lowest A^{36}/A^{38} ratio of all 4 chondrites. Taking its Ne^{20}/Ne^{21} ratio as that of spallation produced neon, we can calculate limits for the excess non spallation Ne^{20} of the other 3 chondrites (see Table 4). EBERHARDT and GEISS [11] have shown, that these limits do not exclude the possibility that part of the A^{36} is primeval.

Meteorite	Non spallation Ne^{20} $\cdot 10^{-9}$ cc STP/g
Richardton	$\leqq 5$
St. Michel	$\leqq 5$
Bjurböle	$\leqq 4$

Table 4. Limits of non spallation Ne^{20}.

Novo Urei shows a high Ne^{20}/Ne^{21} ratio. This could certainly be interpreted as primeval gas. On the other hand, both urelites are very porous stones and give off larger amounts of gas during the initial pumping and extraction than the other meteorites. We cannot exclude the possibility of adsorbed atmospheric neon in this particular meteorite.

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