CROSS SECTIONS FOR PRODUCING SOME LIGHT-NOBLE-GAS NUCLIDES. Robert C. Reedy[1], [1]Institute of Meteoritics, MSC03-2050, Univ. New Mexico, Albuquerque, NM 87131 USA <rreedy@unm.edu>.

Introduction: Good models for making cosmogenic nuclides, usually theoretical calculations, are needed for the best interpretations of measurements in solar-system samples. Important inputs to the theoretical calculations are the cross sections for making a nuclide from its major target elements. Protons make almost all nuclides produced by solar energetic particles and a fraction of the nuclides made by galactic-cosmic-ray (GCR) particles [1]. Most GCR-produced nuclides are made by neutrons, and proton cross sections are often used for neutrons or as a basis for estimating neutron cross sections.

Proton cross sections were recently compiled and evaluated for the long-lived radionuclides ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{53}Mn [2]. These cross sections are much better than those used previously, especially over a decade ago, when there were very few cross-section measurements. These proton-induced cross sections will also be used with some new measurements of neutron-induced cross sections [J. Sisterson et al., this meeting] to get better excitation functions for GCR production of cosmogenic nuclides.

Isotopes of the noble gases, such as ^{3}He and ^{21}Ne, are often used in cosmogenic-nuclide studies, such as for determining exposure ages and for estimating how much a sample was shielded from the cosmic rays. Cross sections for making ^{3}He, ^{20}Ne, ^{21}Ne, and ^{22}Ne were compiled, and cross sections as a function of energy from threshold to many GeV were evaluated for all major target elements. For ^{3}He and ^{22}Ne, these evaluated cross sections include the decay of 12.32 year ^{3}H and 2.60 year ^{22}Na, respectively.

Measured Cross Sections: Most target and product pairs only have cross sections measured for protons. Measurements from earlier compilations, private communications, and theses were used. The international cross-section compilation called Cross Section Information Storage and Retrieval System (CSISRS) at the National Nuclear Data Center of the Brookhaven National Laboratory was queried. Papers that cited cross-section measurements were examined for other measurements. Minor sources are not given here, but some can be found in older papers.

^{3T}He. The symbol ^{3T}He refers the sum of the independent cross sections for making only the nuclide ^{3}He plus those for making only ^{3}H. Almost all measured cross sections for ^{3}He do not include the decay of ^{3}H, so cross sections for making both ^{3}He and ^{3}H were compiled. For reactions with oxygen, the measured cross sections of [3] for making ^{3T}He to those for ^{3}H were 2.12, and that ratio was used with seven ^{3}H cross sections from CSISRS for ^{3T}He cross sections. There are no measurements below 225 MeV. The cross sections for O(p,x)^{3T}He are not well determined.

Only for Al and Fe are there many measurements for making both ^{3}He and ^{3}H. From those measurements and from a few cases for Mg and Si, it was determined that, at a given proton energy, the cross section for making ^{3}He is about 1.2 times that for making ^{3}H. Thus, the data used to get evaluated cross sections for making ^{3T}He from Mg, Al, Si, Fe, and Ni are 2.2 times the cross sections for only ^{3}H and 1.83 times the independent cross sections for making ^{3}He. As can be seen from the data for proton reactions with Al shown in Fig. 1, both sets are consistent.

For Mg, Al, and Si, most measurements were from [4-7]. The CSISRS database was used for Fe and Ni. There are very few measurements for Na and Ca.

$^{20-22T}$Ne. Most measurements reported cross sections for all 3 neon isotopes and included ^{22}Na decay in their ^{22T}Ne cross sections. The main sources for proton-induced reactions were [4-9]. There are fewer data and more scatter for Si. The measurements and evaluation for the Mg(p,x)^{21}Ne are shown in Fig. 1.

CSISRS has 3 sets of measurements for making Ne isotopes from Mg with neutrons of energies from 5 to 19 MeV that are in good agreement. The curve for the Mg(n,x)^{21}Ne reaction in Fig. 1 used those data connected to the proton results above 60 MeV.

Results: The compiled cross sections for these 4 nuclides were plotted as a function of energy for each major target element. Usually most measurements were in good agreement. A smoothed curve that was roughly a smooth average of the better measurements was usually adopted. The evaluated cross sections (called R8P) for these 4 nuclides are plotted in Fig. 1.

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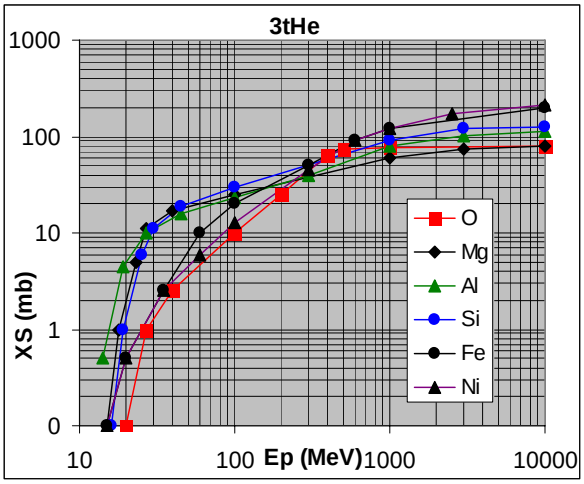
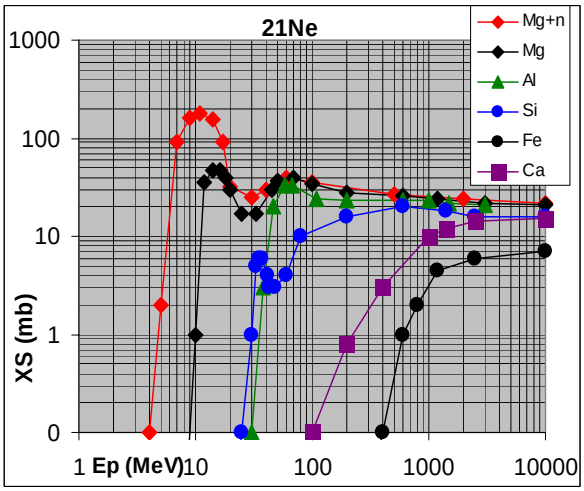
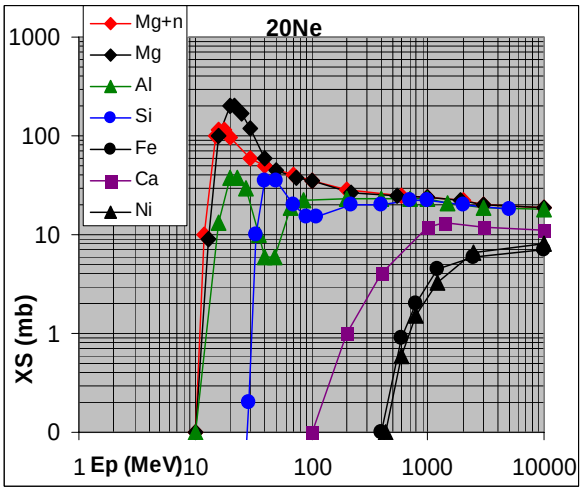
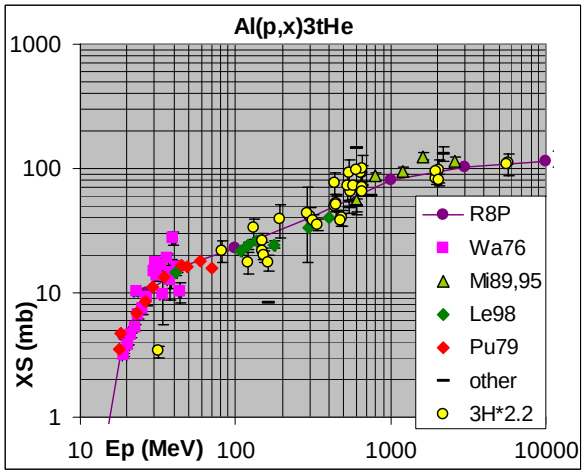
References: [1] Reedy R. C. and Arnold J. R. (1972) *JGR, 77*, 537-555. [2] Reedy R. C. (2007) *LPS XXXVIII*, Abstract #1192. [3] Kruger S. T. and Heymann D. (1973) *Phys. Rev. C, 7*, 2179-2187. [4] Walton J. R. et al. (1976) *JGR, 81*, 5689-5699. [5] Michel R. et al. (1995) *Nucl. Instrum. Meth. B, 103*, 183-222. [6] Leya I. et al. (1998) *Nucl. Instrum. Meth. B, 145*, 449-458. [7] Sisterson J. M. et al. (1999) *LPS XXX*, Abstract #1283. [8] Baros F. and

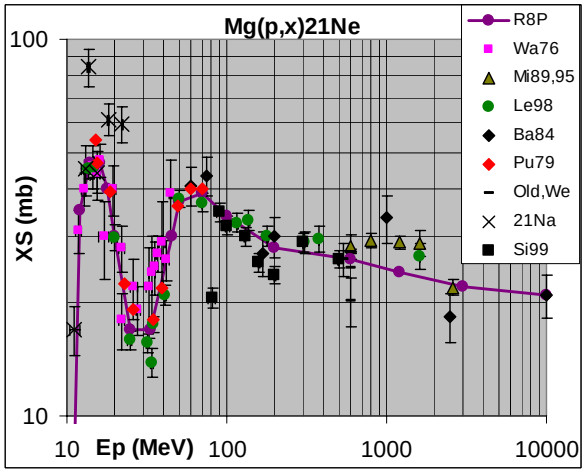
Regnier S. (1984) *J. Physique*, *45*, 855-861. [9] Pulfer P. (1979) Thesis, Univ. Bern, Switzerland.











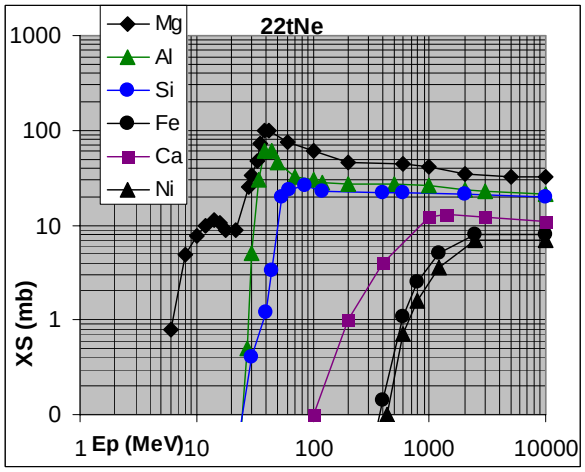


Fig. 1. Evaluated cross sections for making ^{3}He and Ne isotopes from major target elements by incident protons and for Mg(n,x)^{20,21}Ne are plotted as a function of energy. Also shown are the data and evaluations for the Al(p,x)^{3T}He and Mg(p,x)^{21}Ne reactions.