HK 60: Nuclear Astrophysics

Time: Wednesday 16:30–18:45 Location: H-ZO 60

Invited Group Report HK 60.1 We 16:30 H-ZO 60

The r-process nucleosynthesis: a long-standing mystery in astrophysics — •Stephane Goriely — IAA-ULB, Campus de la Plaine CP226, 1050 Brussels, Belgium

The rapid neutron-capture process, or r-process, is known to be of fundamental importance for explaining the origin of approximately half of the A>60 stable nuclei observed in nature. In recent years nuclear astrophysicists have developed more and more sophisticated r-process models, eagerly trying to add new astrophysical or nuclear physics ingredients to explain the solar system composition in a satisfactory way. The r-process remains the most complex nucleosynthetic process to model from the astrophysics as well as nuclear-physics points of view.

The identification of the astrophysical site and the specific conditions in which r-process nucleosynthesis takes place remain unsolved mysteries of astrophysics. The present contribution illustrates the complexity of the r-process nucleosynthesis by describing the nuclear mechanisms taking place during the neutrino-driven wind of supernova explosions and the decompression of neutron star matter, the two most-promising r-process sites. Future challenges faced by nuclear physics in this problem are discussed, particularly in the determination of the radiative neutron capture rates by exotic neutron-rich nuclei, as well as the need for more experimental information and improved global microscopic models for a reliable determination of all nuclear properties of relevance.

Group Report HK 60.2 We 17:00 H-ZO 60

Neutron-capture cross sections of Fe-peak seed nuclei — •I Dillmann[1], T Faestermann[1], G Korschinek[1], J Lachner[1], M Poutivtsev[1], G Rugel[1], F Käppeler[2], S Walter[2], C Domingo-Pardo[3], M Heil[3], R Reifarth[3], L Coquard[4], A Wallner[5], K Buczak[5], and C Lederer[5] for the CERN-nTOF-Collaboration — [1]Physik-Department and Excellence Cluster Universe, Technische Universität München — [2]Forschungszentrum Karlsruhe — [3]Gesellschaft für Schwerionenforschung — [4]Technische Universität Darmstadt — [5]VERA, Fakultät für Physik, Universität Wien

About 50% of the elements beyond iron are produced via the s process. In the vicinity of the Fe seed the resulting abundances are dominated by the weak s-process component. The neutron exposure here is not strong enough that the so-called local equilibrium is reached. Accordingly, the neutron capture rate of a nucleus, which experiences the entire mass flow, will affect also the abundances of all isotopes in the following reaction chain and hence the overall s-process efficiency as well.

Recently the neutron-capture cross sections of ^{54,58,60}Fe and ^{58,62,64}Ni were measured with the activation technique at kT= 25 keV. The number of produced ^{55}Fe, ^{59}Ni, and ^{63}Ni atoms were then determined with accelerator mass spectrometry.

For extrapolation to higher and lower temperatures an accurate knowledge of the energy dependence is required. A campaign to measure these cross sections with the time-of-flight technique is scheduled for 2009/10 at the CERN/n_TOF facility.

HK 60.3 We 17:30 H-ZO 60

R-process nucleosynthesis calculations with complete nuclear physics input — •Ilka Petermann[1,2], Almudena Arcones[1,2], Aleksandra Kelic[2], Karlheinz Langanke[2,1], Gabriel Martinez-Pinedo[2], Igor Panov[3], Thomas Rauscher[3], Karl-Heinz Schmidt[2], Friedrich-Karl Thielemann[3], and Nikolaj Zinner[4] — [1]IKP, TU Darmstadt, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [3]Department für Physik und Astronomie, Universität Basel, Switzerland — [4]Department of Physics, Harvard University, Cambridge, MA 02138

Elements heavier than iron are known to be made partly by the r-process, a sequence of rapid neutron-captures and subsequent beta-decays in explosive scenarios with high neutron densities. Its astrophysical site has not yet been identified, but observations indicate at least two possible sites contributing to the solar system abundance of r-process elements and confirm a robust mechanism of the production of elements heavier than Z=56. From the nuclear-physics point of view the r-process requires the knowledge of a large number of reaction rates involving exotic nuclei. We have developed a complete database of reaction rates that besides neutron-capture rates and beta-decay half-lives includes all possible reactions that can induce fission (neutron-capture, beta-decay and spontaneous fission) and the corresponding fission yields. In addition, these reaction rates were implemented in a fully implicit reaction network. We have performed r-process calculations for the neutrino-driven wind scenario to explore whether or not fission can contribute to provide a robust r-process pattern.

HK 60.4 We 17:45 H-ZO 60

Co-Production of Light p-, s- and r-Process Isotopes in the High-Entropy Wind of Type II Supernovae — •Khalil Farouqi[1], James W. Truran[1], Karl-L. Kratz[2], Ulrich Ott[2], Bernd Pfeiffer[2], Yoav Kashiv[3], and Friedrich-K. Thielemann[4] — [1]Chicago — [2]Mainz — [3]Jerusalem — [4]Basel

The nucleosynthesis origin of the light trans-Fe elements in the Solar System (SS), historically believed to be composed of different fractions of the p-, s- and r-processes, has been a fascinating subject for nuclear astrophysicists since more than 50 years. However, even the most recent astrophysical models have major short-comings the one or other way. We have performed large-scale dynamical network calculations within the high-entropy wind (HEW) scenario of SNe II in order to constrain the astrophysical conditions for the nucleosynthesis of the light trans-Fe elements. We find that for electron fractions in the range 0.450 $\leq Y_e \leq$0.495, only minor amounts of Zn to Rb but high abundances of the classical p-, s- and r-process nuclei of Sr to Ru are co-produced at low entropies (S) after an α-rich freezeout. No initial abundances of p-, s- or r-process seeds need to be invoked; hence, all components are primary, rather than secondary. Taking the isotopic composition of Mo as a particularly interesting example, we show that HEW trajectories with $Y_e \simeq$0.46 and S$\leq$50 are able to reproduce the SS ratio of ^{92}Mo/^{94}Mo. Furthermore, for slightly higher Y_e and S trajectories, our nucleosynthesis results can also explain the anomalous abundances of the Mo isotopes recently measured in SiC grains of type X, which are likely SN condensates.

HK 60.5 We 18:00 H-ZO 60

Stellar (n,γ) cross sections of neutron-rich nuclei. — •Justyna Marganiec[1,2], Iris Dillmann[1,3], Cesar Domingo Pardo[1,2], and Franz Käppeler[1] — [1]Forschungszentrum Karlsruhe, Institut für Kernphysik, 76344 Eggenstein-Leopoldshafen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, D-64291 Darmstadt, Germany — [3]Physik-Department E12, Technische Universität München, Garching, Germany

The neutron capture cross sections of neutron-rich nuclei are needed for nucleosynthesis studies of the heavy elements in the s and r processes. About half of the abundances between Fe and Bi are produced by the s process and the remaining part is due to the r process with a small contribution from the p process. The present results include the (n,γ) cross sections of ^{174,176}Yb, ^{184,186}W, ^{190,192}Os, ^{196,198}Pt, and ^{202,204}Hg. These data are important for the determination of the s-process abundances and for deriving the r-process contribution to the solar system abundances.

The measurements were carried at the Karlsruhe 3.7 MV Van de Graaff accelerator using the ^{7}Li$(p,n)^7$Be reaction for producing a quasi-stellar neutron spectrum. Activation in that spectrum allowed us to measure the Maxwellian averaged cross sections at a thermal energy of $kT = 25$ keV. The experimental results were extrapolated from $kT = 25$ keV to lower and higher temperatures.

HK 60.6 We 18:15 H-ZO 60

Photoactivation experiments at HIγS * — •A. Sauerwein[1], M. Fritzsche[1], N. Pietralla[1], C. Romig[1], G. Rusev[2], D. Savran[1], K. Sonnabend[1], A.P. Tonchev[2], W. Tornow[2], and H.R. Weller[2] — [1]Institut für Kernphysik, TU Darmstadt, Germany — [2]Triangle Universities Nuclear Laboratory, Duke University, Durham, NC, USA

The neutron capture cross section of the so-called s-process branching points determines the isotopic abundance ratio of several elements in the mass region above iron. Due to the instability of the branching point nuclei, a direct measurement of their neutron capture cross sections is experimentally challenging. Therefore, we perform the inverse $(\gamma$,n) reaction to verify theoretical predictions based on the Hauser-Feshbach formalism like TALYS [1] and NON-SMOKER [2]. The presented method was already used in various activation experiments at the High Intensity Photon Setup of the TU Darmstadt [3,4].

For the first time, photoactivation experiments on s-process branching point nuclei were performed at the High Intensity γ-Ray Source of the Duke FEL Laboratory. Naturally composed Cerium targets have been irradiated to investigate the branching point nucleus ^{141}Ce. The experimental method is presented and preliminary results are discussed.

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[1] A. J. Koning *et al.* AIP Conf. Proc. **769**, (2005) 1154
[2] T. Rauscher *et al.*, At. Data Nucl. Data Tab. **88**, (2004) 1
[3] J. Hasper *et al.*, Phys. Rev. C **77** (2008) 015803
[4] K. Sonnabend *et al.*, Astroph. J. **583** (2003) 506

HK 60.7 We 18:30 H-ZO 60

Properties of the first 1/2$^+$ state in ^{9}Be from electron scattering and astrophysical implications* — •Oleksiy Burda, Peter von Neumann-Cosel, and Achim Richter — Institut für Kernphysik, Technische Universität Darmstadt, Germany

The low-energy level structure of the ^{9}Be nucleus has long been a matter of interest, in particular with respect to the strength of three-body $\alpha + \alpha + n$ cluster configurations. This nucleus has the lowest neutron threshold ($S_n = 1.6654$ MeV) of all stable nuclei. Already the first excited J$^\pi = 1/2^+$ state lies at an excitation energy of several tens of keV above the ^{8}Be + n threshold. Parameters of this resonance are of great astrophysical importance since it is believed to provide an important route for the production of carbon and subsequently heavier nuclei triggering the r-process in core-collapse supernovae. Due to its closeness to the neutron threshold the resonance has a strongly asymmetric line shape but despite a large number of different experiments there still exist discrepancies between the various deduced resonance parameters [1]. We present high-resolution inelastic electron scattering experiments on ^{9}Be performed at the S-DALINAC. The resonance parameters of the first excited $1/2^+$ state in ^{9}Be are derived in a one-level R-matrix approximation from the present and older (e, e') data [2]. The astrophysically relevant $\alpha(\alpha n, \gamma)^9$Be reaction rate is extracted and discussed.

[1] F. C. Barker, Aust. J. Phys. 53 (2000) 247.
[2] G. Kuechler *et al.*, Z. Phys. A 326 (1987) 447.

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