U.S. Department of Energy –Final Scientific / Technical Report
Project Title: Nuclear Astrophysics Data from Radioactive Beam Facilities

Principal Investigator: Alan A. Chen

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Final Report:

The scientific aims of this project have been the evaluation and dissemination of key nuclear reactions in nuclear astrophysics, with a focus on ones to be studied at new radioactive beam facilities worldwide. These aims were maintained during the entire funding period from 2003 – 2006. In the following, a summary of the reactions evaluated during this period is provided.

Year 1 (2003-04): ^{21}Na(p,γ)^{22}Mg and ^{18}Ne(α,p)^{21}Na

The importance of the ^{21}Na(p,γ)^{22}Mg and the ^{18}Ne(α,p)^{21}Na reactions in models of exploding stars has been well documented: the first is connected to the production of the radioisotope ^{22}Na in nova nucleosynthesis, while the second is a key bridge between the Hot-CNO cycles and the rp-process in X-ray bursts. By the end of Summer 2004, our group had updated these reaction rates to include all published data up to September 2004, and cast the reaction rates into standard analytical and tabular formats with the assistance of Oak Ridge National Laboratory's computational infrastructure for reaction rates.

Since September 2004, ongoing experiments on these two reactions have been completed, with our group's participation in both: ^{21}Na(p,γ)^{22}Mg at the TRIUMF-ISAC laboratory (DRAGON collaboration), and ^{18}Ne(α,p)^{21}Na at Argonne National Laboratory (collaboration with Ernst Rehm, Argonne). The data from the former was subsequently published and included in our evaluation. Publication from the latter still awaits independent confirmation of the experimental results.

Year 2 (2004-05): The ^{25}Al(p,γ)^{26}Si and ^{13}N(p,γ)^{14}O reactions

For Year 2, we worked on evaluations of the ^{25}Al(p,γ)^{26}Si and ^{13}N(p,γ)^{14}O reactions, in accordance with our proposed deliverables and following similar standard procedures to those used in Year 1. The ^{25}Al(p,γ)^{26}Si reaction is a key uncertainty in the understanding the origin of galactic ^{26}Al, a target radioisotope for gamma ray astronomy; the ^{13}N(p,γ)^{14}O reaction in turn is the trigger reaction for the transition into the Hot-CNO cycles in novae and X-ray bursts.

A graduate student of mine, who has been supported part-time by this grant, completed the evaluation of the ^{25}Al(p,γ)^{26}Si reaction as part of his plans to measure this reaction at TRIUMF for his Ph.D. thesis project. I also hired a part-time undergraduate student for the 2004-05 academic year to assist with the evaluations, including that of the ^{13}N(p,γ)^{14}O reaction.

Year 3 (2005-06): The $^{40}Ca(\alpha,\gamma)^{44}Ti$ and $^{26}Al(p,\gamma)^{27}Si$ reactions

This year's progress was closely coupled to new results coming from our collaboration on the DRAGON spectrometer team at TRIUMF. The $^{40}Ca(\alpha,\gamma)^{44}Ti$ and $^{26}Al(p,\gamma)^{27}Si$ reactions were both measured, and significant modifications to their respective reaction rates were required. Both are required input toward predicting the respective amounts of Titanium-44 and Aluminum-26 produced in our galaxy, in supernovae, massive stars, and nova explosions. The $^{26}Al(p,\gamma)^{27}Si$ reaction rate was successfully completed.

The $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction in particular served as the Ph.D. thesis for Christian Ouellet, and therefore the evaluation of this rate fell naturally within his thesis project. Christian successfully defended his thesis in 2007 and is now working for me on the McMaster DOE-funded Nuclear Data Project. In light of the recent data from his thesis, Christian is now putting the final touches on this evaluation, and will disseminate it through the Oak Ridge National Laboratory reaction rate database.

List of Personnel:

The following personnel were involved with our project:

Postdoctoral Fellow: Dr. Jonathan Pearson (0.5 FTE DOE support)
Graduate Student: Christian Van Ouellet (McMaster University, Ph.D. student)
Undergraduate Students: Anthony Olivieri (McMaster University, undergraduate)
Benjamin Wales (McMaster University, undergraduate)
Kiana Setoodehnia (McMaster University, undergraduate)

Relevant Publications:

1. *Measurement of the $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction relevant for supernova nucleosynthesis*, C. Vockenhuber, C.V. Ouellet, L. Buchmann, J. Caggiano, A.A. Chen, H. Crawford, John D'Auria, B. Davids, L. Fogarty, D. Frekers, A. Hussein, D.A. Hutcheon, W. Kutschera, A.M. Laird, R. Lewis, E. O'Connor, D. Ottewell, M. Paul, M.M. Pavan, J. Pearson, C. Ruiz, G. Ruprecht, M. Trinczek, B. Wales and A. Wallner, Physical Review C **76** 035801 (2007).

2. *Measurement of the E_{CM} = 184 keV resonance strength in the $^{26g}Al(p,\gamma)^{27}Si$ reaction*, C. Ruiz, A. Parikh, J. José, L. Buchmann, J.A. Caggiano, A.A. Chen, J.A. Clark, H. Crawford, B. Davids, J.M. D'Auria, C. Davis, C. Deibel, L. Erikson, L. Fogarty, D. Frekers, U. Greife, D. Hutcheon, M. Huyse, C. Jewett, A.M. Laird, R. Lewis, P. Mumby-Croft, A. Olin, D.F. Ottewell, C.V. Ouellet, P.D. Parker, J. Pearson, G. Ruprecht, M. Trinczek, C. Vockenhuber, and C. Wrede, Physical Review Letters **96** 252501(2006).

3. *Multichannel R-matrix analysis of elastic and inelastic resonances in the ^{21}Na+p compound system,* C. Ruiz, T. Davinson, F. Sarazin, I. Roberts, A. Robinson, P.J. Woods, L. Buchmann, A.C. Shotter, P. Walden, N.M. Clarke, A.A. Chen**,** B.R. Fulton, D. Groombridge, and J. Pearson and A.S. Murphy, Physical Review C **71**, 025802 (2005).

4. *The ^{21}Na(p,γ)^{22}Mg Reaction from E_{cm} = 200 to 1103 keV in Novae and X-ray Bursts*, J.M. D'Auria, R.E. Azuma, S. Bishop, L. Buchmann, M.L. Chatterjee, A.A. Chen, S. Engel, D. Gigliotti, U. Greife, D. Hunter, A. Hussein, D. Hutcheon, C. Jewett, J. José, J. King, A.M. Laird, M. Lamey, R. Lewis, W. Liu, A. Olin, D. Ottewell, P.D. Parker, J. Rogers, C. Ruiz, M. Trinczek, and C. Wrede, Physical Review C **69** 065803 (2004).