Nuclear Data Project McMaster University

Status Report: Oct. 1, 2007-Sept. 30, 2008

USNDP: November 5-7, 2008

Part 1: Nuclear Structure and Decay Data Evaluation

Prepared and presented by: B. Singh

Tributes

- Professor Martin W. Johns (1913-2008)

  Back in 60's, Martin collaborated with Katherine Way and others on nuclear structure evaluations. We are indebted to him for his incentive, interest and leadership in the data project!

1. Midstream evaluation of A=88: C.D. Goodman, T.A. Hughes, M.W. Johns, K. Way: NDT-A 8, 345-371 (1970).

2. Midstream evaluation of A=89: M.W. Johns, J.Y. Park, S.M. Shafroth, D.M. Van Patter, K. Way: NDT-A 8, 373-406 (1970)

3. Midstream evaluation of A=90: J.B. Ball, M.W. Johns, K. Way: NDT-A 8, 407-436 (1970)

Murray Martin and Agda Artna: Ph.D.'s from McMaster during 60's when Martin chaired the department.

After retirement in 1979, Martin was the one of the main persons to formally establish Nuclear Data Project at McMaster in 1980, which has since been operating. During 1980-1987, he also volunteered to share data evaluation of two very voluminous A chains: 149 and 151

1985Sz01: Nuclear Data Sheets for A=149: J.A. Szucs, M.W. Johns, B. Singh, NDS 46, 1- (1985)

1988Si15: Nuclear Data Sheets for A=151: B. Singh, J.A. Szucs, M.W. Johns, NDS 55, 185- (1988)

- Dr. Thomas W. Burrows (1943-2008)

  Since the start of the data project at McMaster in 1980, Tom helped all of us at McMaster for 28 years, courteously, promptly and efficiently, with the use of the suite of ENSDF and NDS codes. We remain greatly indebted to him!

ENSDF Work

- **Permanent Responsibility**:

A=1 (2005), **31** (2008,s),
32 (1998,w), **33-35** (1998)
36-37 (1998,w), **38** (2007)
39 (2006), **40** (2004),
41 (2001), **42** (2000),
43 (2001), **44** (1999),
64 (2006), **89** (1998,s),
98 (2003), **100** (2007),
149 (2004), **151** (2008),
164 (2001), **188** (2002),
190 (2003), **194** (2006)

- Note: The number in parentheses gives the year of last revision in ENSDF database
- w: work in progress
- s: revision submitted

- During FY-2008, work was done on other A-chains and nuclides also, which are outside McMaster's A-chain responsibility

Mass-chain Evaluations Published or Submitted Since October 1, 2007

- **A=78**: A.R. Farhan and B. Singh (submitted Feb 2008; post-review)(*) (previous: 1990)
- **A=31**: C. Ouellet and B. Singh (submitted August 2008; pre-review) (previous: Endt 1998)
- **A=85**: B. Singh (submitted Sept 2008; pre-review) (previous: 1990)
- **A=89**: B. Singh (submitted Sept 2008; pre-review) (previous: 1998)
- **A=38**: J.A. Cameron and B. Singh, NDS **109**, 1-170 (2008) (previous: Endt: 1998)
- **A=100**: B. Singh, NDS **109**, 297-516 (2008) (previous: 1997)
- **A=135**: B. Singh, Yu. Khazov and A. Rodionov, NDS **109**, 517-698 (2008)(*) (previous 1998)
- **A=240**, B. Singh and E. Browne, NDS **109**, 2439-2499 (2008)(*) (previous: 2004) (**)
- **A=151**: B. Singh (2008, in ENSDF, waiting publication in NDS) (previous: 1997)
- (*) shared with other center, at least 50% work at McMaster.
- (**) updated in response to user requirements.

Nuclide updates

Following 49 nuclides were updated for ENSDF: (by Singh)

Most are (far-off the stability line) New Nuclides and nuclides for which excited state and/or gamma-ray data became available for the first time;

^{32}Al, ^{32,33}Ne, ^{34,35}Mg, $^{32-36}$Na, ^{39,40}Mg, ^{42,43}Al, ^{62}Ni, ^{76}Ni, ^{76}Y, ^{82}Nb, ^{86}Tc, ^{88}Se, ^{101,103}Sn, ^{107}Te, ^{110}Mo, ^{110}I, ^{110}Xe, ^{111}Tc, ^{114}Cs, ^{115}Tc, ^{115}Rh, ^{116}Cs, ^{119}Ba, ^{129}Nd, ^{129}Pm, ^{129}Sm, ^{130}Ag, ^{130}Cd, ^{130}In, ^{130}Eu, ^{144}Ho, ^{144}Tm, ^{163}Eu, ^{164}Ta, ^{164}Eu, ^{165}Eu, ^{209}Hg, ^{219,220}Po, ^{235}Ac.

- Review work: A=25 (by Cameron), 187 (by Singh) for ENSDF; ^{217}Rn and ^{213}Po radioisotopes for DDEP (by Singh)

PHYSICAL REVIEW C **77**, 064301 (2008)

Determination of the $2_1^+ \rightarrow 0_1^+$ transition strengths in ^{58}Ni and ^{60}Ni

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(Received 24 March 2008; published 2 June 2008)

Gamma-ray angular distribution measurements following the ^{nat}Ni$(n, n'\gamma)$ reaction were carried out at 1.6 and 1.8 MeV neutron energies. Through the Doppler-shift attenuation method, the lifetime of the 2_1^+ state in ^{58}Ni is determined as $\tau = 1.00^{+0.15}_{-0.10}$ ps, which yields a $B(E2; 2_1^+ \rightarrow 0_1^+)$ value of $9.4^{+1.0}_{-1.2}$ W.u. From previous measurements and this work, average values of $\tau = 0.94(3)$ ps and $B(E2; 2_1^+ \rightarrow 0_1^+) = 10.0(4)$ W.u. are recommended as standards for normalization. In addition, a longer lifetime of $\tau = 1.30^{+0.30}_{-0.20}$ ps has been determined for the 2_1^+ state in ^{60}Ni, which yields an $E2$ strength of $10.7^{+1.7}_{-2.5}$ W.u. Our results support an enhancement of proton-core excitations and related quadrupole and pairing strengths in the light Ni isotopes, in agreement with mean-field and shell-model calculations.

DOI: 10.1103/PhysRevC.77.064301 PACS number(s): 21.10.Tg, 21.10.Re, 25.40.Fq, 27.40.+z

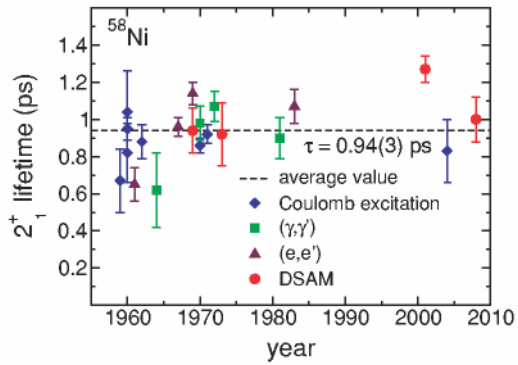


FIG. 5. (Color online) Average value obtained for the lifetime of the 2^+_1 state in ^{58}Ni. The average comprises twenty measurements, including this work, and gives a final standard value of $\tau = 0.94(3)$ ps.

XUNDL work

Compilation of Data from Current Literature

- Between October 1, 2007 and September 30, 2008, 430 compiled (checked for internal level-scheme and data consistency) datasets prepared by McMaster group have been included in XUNDL. Another 20 datasets compiled at other centers were checked and edited.
- **60** datasets in XUNDL were updated to incorporate newer related papers from the same groups.
- Represent about 220 primary publications in experimental nuclear structure.
- Frequent scanning of web pages of primary nuclear physics journals:
  (PR-C, PRL, NP-A, PL-B, EPJ-A, JP-G, IJMP-E, Chinese Phys Lett, ArXiv-preprints, others)
- As of Nov. 2 we are up-to-date on the coverage of structure data from current papers in above journals;
  except 3 papers published in PR-C, Oct. 30 - Nov 2, which are being compiled.
- Major participation in this effort by undergraduate student: Scott Geraedts since March 2007.
- Datasets checked and edited by B. Singh, before submission to NNDC for inclusion in XUNDL
- Communication with authors actively continue to resolve data-related inconsistencies and/or to request additional data details; about 50 communications this year.

NSR compilation work (keywording)
(Oct 1, 2007 – Sept 30, 2008)

Undergraduate student participation (subcontracts with NNDC)

Scott Geraedts: PR-C: 11 issues: October 2007 to August 2008;
~800 articles. Work is continuing with keywording of Sept issue
of PRC just completed.
Max Mitchell: miscellaneous articles (about 250)

B. Singh provided local training for keywording process and checked most of the keyworded for technical content and formatting.

M. Bhattacharya provided consultations on email on specific questions.

I personally feel that undergraduate student participation has potential.

Work in Progress
(as of October 1, 2008)

A=32. Complete all ENSDF style datasets for all reactions and adopted properties. Work on this A chain started in September 2008. Expected completion in March 2009.

A=36, 37. Complete all ENSDF style datasets for all reactions and adopted properties. Expected submission of A=37 in March 2009; A=36 in September 2009.

A=76. This work is in collaboration with Dr. A. Farhan of Kuwait group. This mass chain is expected to be completed by the end of 2009.

A=71. This work is in collaboration with Dr. K. Abusaleem of university of Jordan. This mass chain is expected to be completed by the end of 2009.

A=139. This work is in collaboration with Dr. P. Joshi at TIFR, Mumbai and Dr. J. Tuli at NNDC. This mass chain is expected to be completed by the end of 2009.

A=58, 78, 182 (post-review stages; complete by Dec 2008)
A=85, 89 (pre-review stage; complete by June 2009)

XUNDL compilation work will continue during 2008-2009.

NDS: development of codes for Band drawings and Tables in NDS.

Mentoring and Training
of New Data Evaluators through Collaborative work

- **A=31, 32:** Dr. Christian Ouellet joined our group as post-doctoral fellow in September 2007. Chris worked on A=31 evaluation according to ENSDF procedures. This mass chain has already been submitted to NNDC. It is currently at pre-review stage. In September 2008, he started working on A=32 nuclides, some of which are of interest in "island of inversion" region.

- **A=58**: Work in collaboration with Dr. Caroline Nesaraja at ORNL. The mass chain has gone through detailed review by Murray Martin. This mass chain is currently going through editing for reviewer's comments and further updating.

- **A=71**: This collaborative work started in August 2008 with Dr. Khalifeh Abu-saleem, Asstt. Professor in Physics at University of Jordan. He attended the ICTP-IAEA workshop for ESNDF training in April 2008 at Trieste. Dr. Abu-saleem is expected to visit McMaster for about one week in January 2009 and for about 3 weeks in summer 2009.

- **A=139**: This collaborative work is in early stages with Dr. Paresh Joshi at TIFR, Mumbai. He attended the ICTP-IAEA workshop for ESNDF training in April 2008 at Trieste. Dr. Joshi is expected to visit McMaster for about 3 weeks in summer 2009.

Other Related Activities

- **Review of M1 transition probabilities in ENSDF:**
  (See a separate presentation of Nov 5).
  Other multipolarities (E2, E1, etc.) planned

Atomic mass compilations since AME-2003.
2003-2008: ~45 primary papers compiled
Masses for about 450 nuclides, mostly far off the stability where less accurate and precise values were known earlier.
See under compilations status report (by Singh)
2008 Jan-July compilation available on ORNL webpage.

NDS software development: Band drawings already implemented in NDS in Sept 2008 issue.
Other items in progress. See presentation by Geraedts.

Personnel and Funding

- A. Chen: Assoc. Professor, Principal Investigator of Data Project.
- J. C. Waddington: Emeritus-Professor, Co-PI of Data Project.
- J. A. Cameron: Emeritus-Professor: Volunteer work since 1999 on ENSDF evaluation of A=35-44 region (A=38-44 published; A=36, 37 in progress)
- B. Singh: Research Scientist/Nuclear Data Evaluator.
- C. Ouellet: Post-doctoral Fellow: since September 2007
- S. Geraedts: Undergraduate Student; since March 2007.

- Financial support from DOE, USA and from NSERC, Canada.

Part 2: Astrophysics Data

Prepared by: C. Ouellet and A. Chen

Astrophysics Data Evaluation

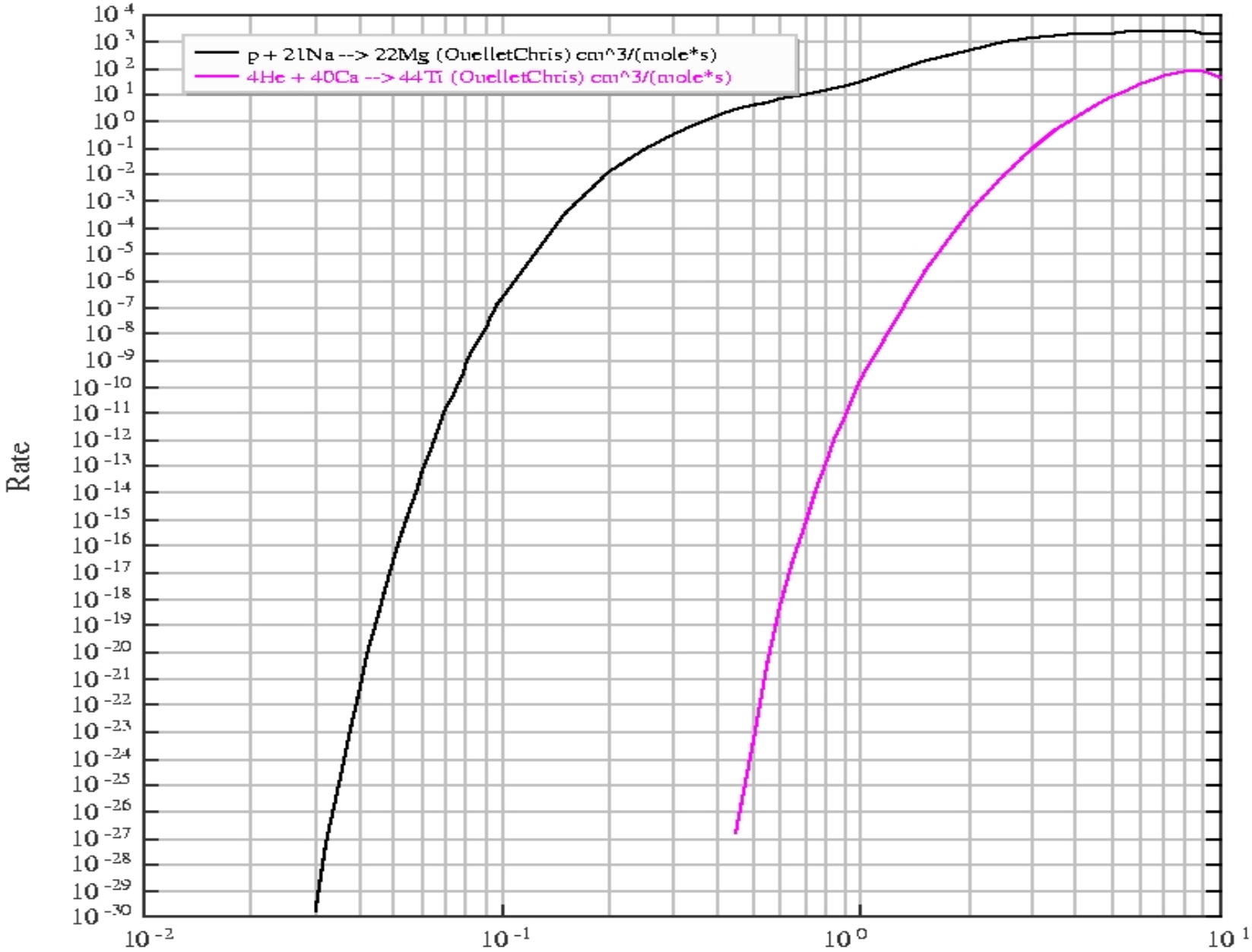
- ***Two reactions evaluated relevant to nuclear astrophysics***
- ***$^{40}Ca(\alpha,\gamma)^{44}Ti$ and $^{21}Na(p,\gamma)^{22}Mg$, both closely tied to Alan Chen's research program***
- ***Rates submitted using the Computational Infrastructure for Nuclear Astrophysics at www.nucastrodata.org at ORNL***
- ***Both new rates represent an improvement over existing datasets***

$^{40}Ca(\alpha,\gamma)^{44}Ti$ Evaluation

- This reaction is critical to the production of radioactive ^{44}Ti in supernova during the alpha-rich freezout phase
- ^{44}Ti is one of the very few important radionuclides which can be detected in space - allows for an absolute supernova yield of nucleosynthesis
- Longstanding controversy over Cassiopeia A remains unresolved – remnant appears to have produced much more ^{44}Ti than the measured reaction rate would indicate
- Early (1976-1981) γ-ray measurements pinned down many resonance strengths
- Isreali (+Argonne) AMS technique (2001-2006) discovered greatly enhanced yield compared to earlier studies
- DRAGON (2007) data found many previously unresolved resonances and combined with previous measurements gave the final evaluated reaction rate over the range T=1.0-7.0 GK

$^{21}Na(p,\gamma)^{22}Mg$ Evaluation

- This reaction is very important in many aspects of nuclear astrophysics from the hot CNO cycle to the rp-process in X-ray bursts to impacting the abundance of ^{21}Na
- ^{21}Na like ^{44}Ti is also one of a handful of very important radionuclides which can be detected in space – however the controversy surrounding this nuclide is that it remains to this date undetected
- Many potential explanations have been proposed, most recently (2007) electron screening in the hot plasma environment would perhaps modify the reaction rate formalism
- Similar to the $^{40}Ca(\alpha,\gamma)^{44}Ti$ evaluation direct methods of measuring resonance strengths were favored in the evaluation
- Rate is dominated by two proton resonances, one at 206 keV which dominates Nova temperatures (~0.1 GK) and one at 825 keV which dominates above 1.1 GK


p + 21Na --> 22Mg (OuelletChris) cm^3/(mole*s)
4He + 40Ca --> 44Ti (OuelletChris) cm^3/(mole*s)
Rate
10 4
10 3
10 2
10 1
10 0
10 -1
10 -2
10 -3
10 -4
10 -5
10 -6
10 -7
10 -8
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