

International Atomic Energy Agency

The 7th DAE-BRNS Theme Meeting on

EXFOR Compilation of Nuclear Data

Department of Physics, North-Eastern Hill University, Shillong, India

6–10 March 2017

Introduction to IAEA Nuclear Data Services

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Department of Nuclear Sciences and Applications



Nuclear Data for Safe Rice

Sinosphere
Dispatches From China



After 'Cadmium Rice,' now 'Lead' and 'Arsenic Rice'

By DIDI KIRSTEN TATLOW APRIL 25, 2014 7:48 AM 56



A farmer works her land near a lead smelter in Hunan Province. Sim Chi Yin for The New York Times

Rice absorb poisonous heavy metallic elements like Cd, As more than other vegetables.

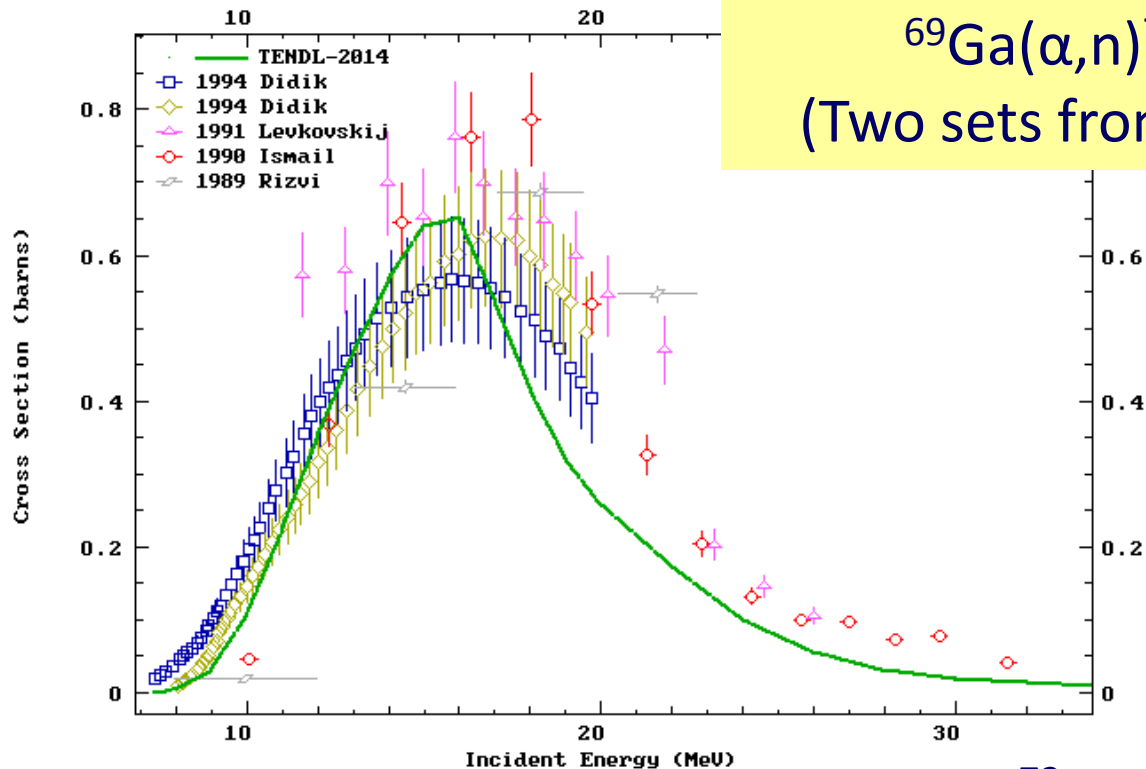
An improved rice against Cd absorption is developed in Japan.

However this improved rice absorbs more As 😞



Nuclear Data for ^{72}As (26 hrs) Tracer Production

31-GA-69(A,N)33-AS-72,,SIG



- None of these experientialists are interested in ^{72}As production for application.
- Nevertheless we can estimate yield and best beam energy without a new experiment **thanks to EXFOR**.

IAEA Nuclear Data Services

EXFOR (experimental reaction data)

ENDF (evaluated reaction data)

→ We will discuss them later.

CD/DVD with documentation, data, codes, etc.

Quick Links

ADS-Lib
Atomic Mass Data Centre
CINDA
Charged particle reference cross section
DROSG-2000
EMPIRE-3.2

ENSDF programs
EXFOR
Electron and Photon Interaction Data

IRDF - International Reactor Dosimetry and Fusion File v1.03 [page] [archive] [retrieve]
CD/DVD-ROMs available for on-line downloading [page]
Portable Empire-3.2.2 for Windows - nuclear reaction model code system for data evaluation [page] [download]

Main All Reaction Data Structure & Decay by Applications Doc & Codes NDS-Internal Index Events Links News

EXFOR
Experimental nuclear reaction data

ENDF
Evaluated nuclear reaction libraries

LiveChart of Nuclides
Interactive Chart of Nuclides

ENSDF
evaluated nuclear structure and decay data (+XUNDL) **

CINDA
Nuclear reaction bibliography

NSR
Nuclear Science References *

NDS, June 2014

↑ Mirrors

Nuclear Data Services
International Atomic Energy Agency
Vienna, Austria

BARC, India
Nuclear Data Services
Bhabha Atomic Research Centre
Mumbai, India

CNDC, China
Nuclear Data Services
China Institute of Atomic Energy
Beijing

↑ Partners

NNDC
National Nuclear Data Center
Brookhaven, USA

NEA

LiveChart of Nuclides
(evaluated structure and decay data)

NSR (Bibliography)

<http://www-nds.iaea.org/> : primary server (Vienna)
<http://www-nds.indcentre.org.in/>: mirror server (India)

NSR (Nuclear Science References)

Nuclear Science References (NSR)

NSR Reference Paper NIM A 640, 213 (2011)

Database version of January 14, 2015

The NSR database is a bibliography of nuclear physics articles, indexed according to content and spanning more than 100 years of research. Over 80 journals are checked on a regular basis for articles to be included. For more information, see the [help page](#). The of the NSR Web

- ~200,000 references (~150,000 from journals)
- Database maintained at NNDC.
- Compiled at NNDC and McMaster Univ. (Canada).

Quick Search

Nuclide
³¹Na or ca-38

Reaction
n,g or (n,g) or (16O,16O)

Publication Year from to

Reference Type All Experiment Theory

Output Format HTML BibTex Text

Search

Reset

<http://www.nndc.bnl.gov/nsr/>



NSR (cont.)

Nuclear Science References (NSR)

NSR Reference Paper NIM A 640, 213 (2011)

Database version of December 18, 2014

Very easy to use!

Just provide

- Author and/or
- Nuclide (Target) and/or
- Reaction

and search.

ysics articles, indexed according to content and spanning more than 100 years. For more information, see the [help page](#). The NSR database schema is available in the NSR Web Interface.

Number Search | Combine View | Recent References

Author
Brown or B.A.Brown

Nuclide
³¹Na or ca-38

Reaction
n,g or (n,g) or (16O,16O)

Publication Year from to

Reference Type All Experiment Theory

Output Format HTML BibTex Text

NSR – Exercise 1

Nuclear Science References (NSR)

NSR Reference Paper NIM A 640, 213 (2011)

Database version of December 18, 2014

Question

Search articles where
“Ganesan” is an author.

ysics articles, indexed according to content and spanning more than 100 years. For more information, see the [help page](#). The NSR database schema is available in the NSR Web Interface.

Number Search | Combine View | Recent References

Author
Brown or B.A.Brown

Nuclide
³¹Na or ca-38

Reaction
n,g or (n,g) or (16O,16O)

Publication Year from to

Reference Type All Experiment Theory

Output Format HTML BibTex Text

NSR – Exercise 2

Nuclear Science References (NSR)

NSR Reference Paper NIM A 640, 213 (2011)

Database version of December 18, 2014

Question

Search articles reporting experimental results of $^{78}\text{Se}(n,p)^{78}\text{As}$.

Physics articles, indexed according to content and spanning more than 100 years. For more information, see the [help page](#). The NSR database schema is available in the NSR Web Interface.

Number Search | Combine View | Recent References

Author
Brown or B.A.Brown

Nuclide
31Na or ca-38

Reaction
n,g or (n,g) or (16O,16O)

Publication Year from to

Reference Type All Experiment Theory

Output Format HTML BibTex Text

NSR – Exercise 2 (cont)

Not all articles report the $^{78}\text{Se}(n,p)$ reaction.

1995BI16 Phys.Rev. C52, 2546 (1995)

I.-G.Birn, B.Strohmaier, H.Freiesleben, S.M.Qaim

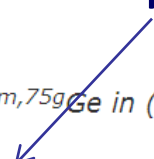
Isomeric Cross Section Ratios for the Formation of $^{75m,75g}\text{Ge}$ in (n, p) , (n, α) , and $(n, 2n)$ Reactions from 6 to 15 MeV

NUCLEAR REACTIONS $^{75}\text{As}(n, p)$, $^{78}\text{Se}(n, \alpha)$, $^{76}\text{Ge}(n, 2n)$, $E=6-15$ MeV; measured $\sigma(E)$; deduced isomeric cross-section ratio. Activation technique, hyperpure Ge detector. Statistical, precompound model analyses.

doi: [10.1103/PhysRevC.52.2546](https://doi.org/10.1103/PhysRevC.52.2546)

Data from this article have been entered in the **EXFOR** database. For more information, access X4 [dataset22291](#).

No $^{78}\text{Se}(n,p)$ in keywords



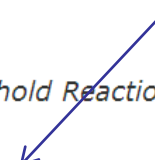
1994BI01 Nucl.Sci.Eng. 116, 125 (1994)

I.Birn, S.M.Qaim

Excitation Functions of Neutron Threshold Reactions on Some Isotopes of Germanium, Arsenic, and Selenium in the 6.3- to 14.7-MeV Energy Range

NUCLEAR REACTIONS ^{75}As , $^{74,76,78}\text{Se}$, $^{72,73,74}\text{Ge}(n, p)$, ^{75}As , $^{78,80}\text{Se}(\alpha, \alpha)$, ^{75}As , $^{70,76}\text{Ge}(n, 2n)$, $E=6.3-14.7$ MeV; measured $\sigma(E)$. Activation technique, high resolution γ -spectroscopy. Statistical multi-step model analysis.

$^{78}\text{Se}(n,p)$ in keywords!



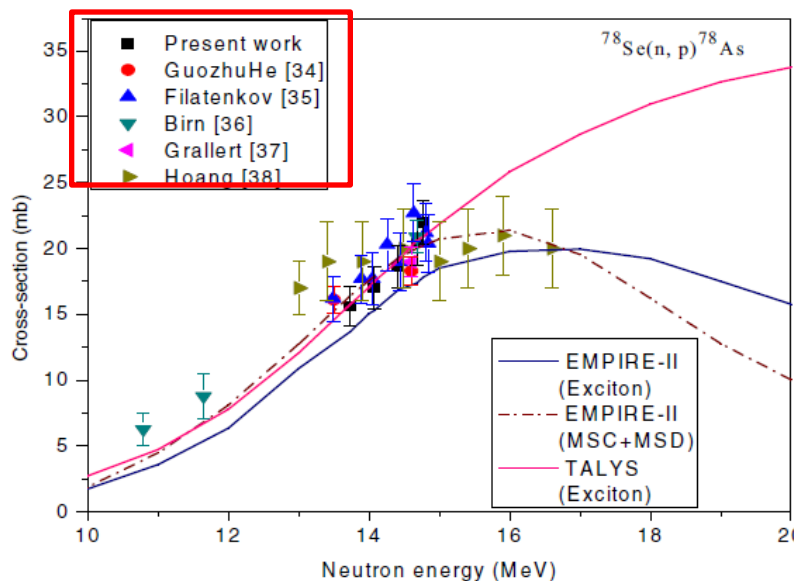
NSR – Exercise 2 (cont)

Compare NSR output for

“Nuclide = ^{78}Se and Reaction = n,p reaction”
with Fig.3 of the 33080 article.

Five past experiments plotted in Fig.3.

Are they also in the NSR output?



[34] Guozhu He, Zhongjie Liu, Junhua Luo, and Xiangzhong Kong, Indian J. Pure Appl. Phys. **43**, 729 (2005).

Not in NSR

[35] A. A. Filatenkov and S. V. Chuvaev, Khlopin Radiev. Inst., Leningrad Reports No. 258 (2001).

Not in NSR

[36] I. Birn, S. M. Qaim, B. Strohmaier, and H. Freiesleben, Nucl. Sci. Eng. **116**, 125 (1994).

in NSR

[37] A. Grallert, J. Csikai, Cs. M. Buczko, and I. Shaddad, IAEA Nucl. Data Section report to the I.N.D. C. No.286, 131 (1993).

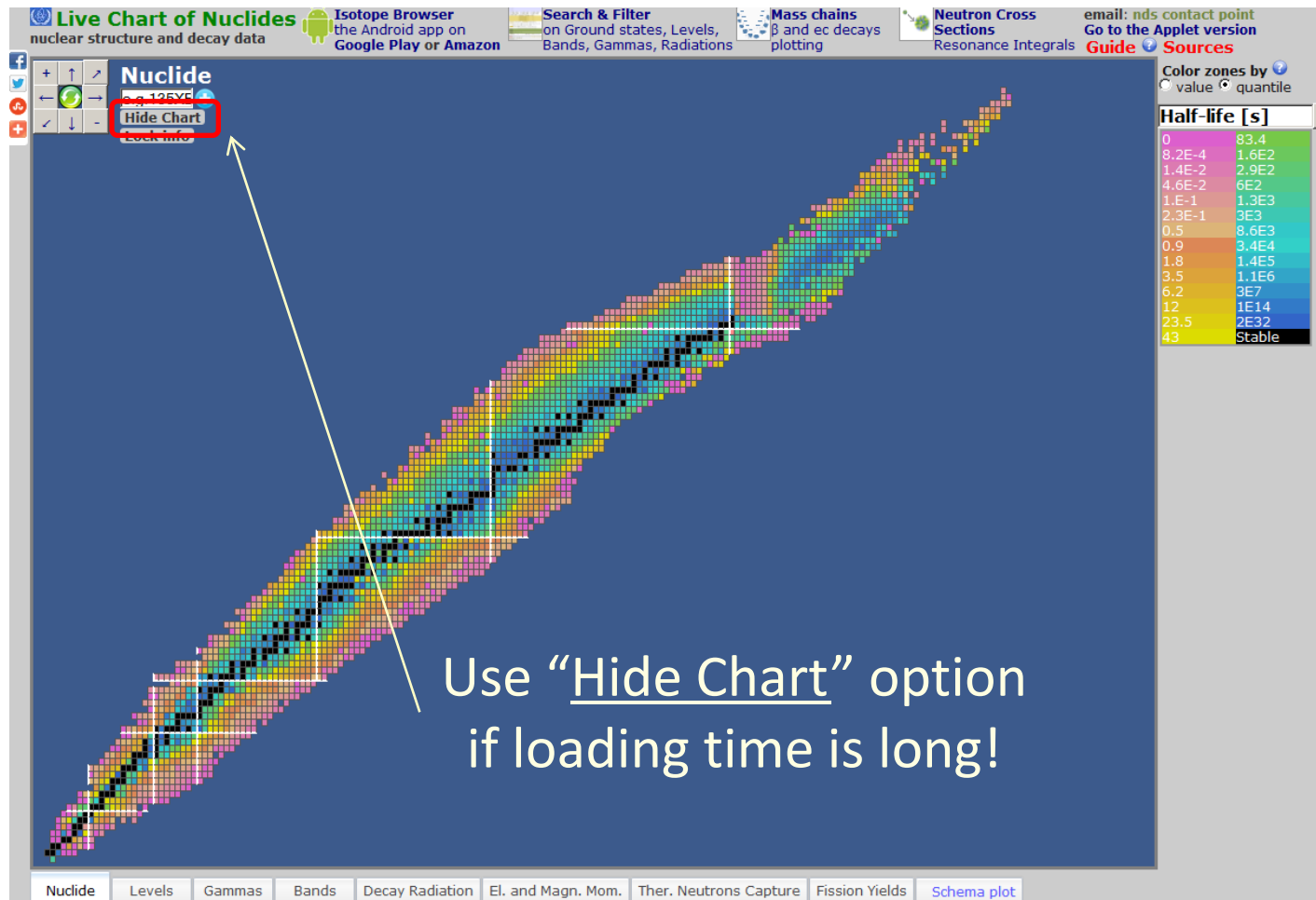
Not in NSR

[38] H. M. Hoang, U. Garuska, A. Marcinkowski, and B. Zwiegliniski, Zeitschrift fuer Physik A, Hadrons and Nuclei **334**, 285 (1989).

in NSR

FIG. 3. (Color online) Cross sections for $^{78}\text{Se}(n, p)^{78}\text{As}$ reaction

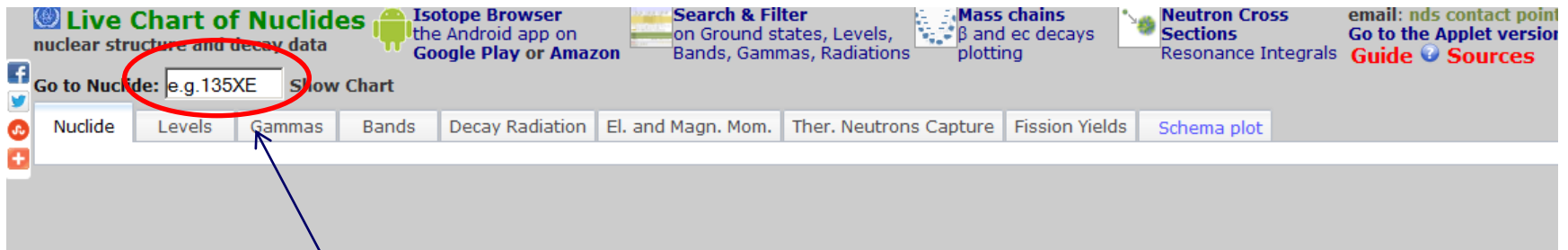
LiveChart of Nuclides



<http://www-nds.iaea.org/livechart/> (No mirror available)

LiveChart of Nuclides (cont.)

The query page becomes very simple if you select “Hide Chart” option.





The screenshot shows the top navigation bar of the Live Chart of Nuclides website. The main title is "Live Chart of Nuclides" with the subtitle "nuclear structure and decay data". There are several navigation links: "Isotope Browser the Android app on Google Play or Amazon", "Search & Filter on Ground states, Levels, Bands, Gammas, Radiations", "Mass chains β and ec decays plotting", and "Neutron Cross Sections Resonance Integrals". On the right, there is an email contact point and links to "Go to the Applet version", "Guide", and "Sources". Below the navigation bar, there is a search bar labeled "Go to Nuclide:" with the placeholder text "e.g. 135XE". To the right of the search bar is a "Show Chart" button. Below the search bar, there is a row of tabs: "Nuclide", "Levels", "Gammas", "Bands", "Decay Radiation", "El. and Magn. Mom.", "Ther. Neutrons Capture", "Fission Yields", and "Schema plot". The "Gammas" tab is highlighted in blue. A red circle is drawn around the search bar, and a blue arrow points from the text below to the "Gammas" tab.


Just type a nuclide symbol
(e.g., 1H, 12C, 238U)


LiveChart of Nuclides – ^{135}Xe

Nuclide tab


Live Chart of Nuclides
 nuclear structure and decay data


Isotope Browser
 the Android app on
[Google Play](#) or [Amazon](#)


Search & Filter
 on Ground states, Levels,
 Bands, Gammas, Radiations


Mass chain
 β and ec de
 plotting

Go to Nuclide: Show Chart

Nuclide
 Levels Gammas Bands Decay Radiation El. and Magn. Mom. Ther. Neutrons Capture Fissi

Click on a nuclide symbol to show the level schema and ENSDF dataset

Nuclide	J^π	G.S. $T_{1/2}$ Abundance	G.S. Decays	Q_{β^-} [keV]	Q_α [keV]
^{135}Xe 54 81	3/2+	9.14 h 2	β^- 100	1165.048 4070	-3630.67 415

Metastable states

Nuclide	Energy (keV)	J^π_{order}	Band	$T_{1/2}$	$T_{1/2}$ [s]	Decays
$^{135\text{m}}\text{Xe}$ 54 81	526.551 13	11/2-		15.29 min 5	9.17E2	β^- < 0.6 IT > 99.4

ENSDF datasets related to ^{135}Xe

Ground state

Metastable state

LiveChart of Nuclides - ^{135}Xe (cont.)

Levels tab

Live Chart of Nuclides nuclear structure and decay data

Isotope Browser the Android app on Google Play or Amazon

Search & Filter on Ground states, Levels, Bands, Gammas, Radiations

Mass chains β and ec decays plotting

Neutr Section Resor

Go to Nuclide: Show Chart

Nuclide **Levels** Gammas Bands Decay Radiation El. and Magn. Mom. Ther. Neutrons Capture Fission Yields Schem

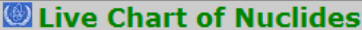

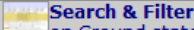

Click on a nuclide symbol to show the level schema and ENSDF dataset

Nuclide	Energy (keV)	J^{π}_{order}	Band	$T_{1/2}$	$T_{1/2}$ [s]	Decays	I
^{135}Xe 54 81	0.0	3/2+		9.14 h 2	3.29E4	β^- 100	
^{135}Xe 54 81	288.455 15	1/2+					
^{135}Xe 54 81	526.551 13 m	11/2-		15.29 min 5	9.17E2	β^- < 0.6 IT > 99.4	————— 7/2+
^{135}Xe 54 81	1131.512 11	7/2+					————— 11/2+
^{135}Xe 54 81	1260.416 13	5/2+					————— 1/2+
^{135}Xe 54 81	1448.36 3	(3/2+)					————— 3/2+

^{135}Xe

LiveChart of Nuclides - ^{135}Xe (cont.)

Decay Radiation tab

nuclear structure and decay data the Android app on Google Play or Amazon on Ground states, Levels, Bands, Gammas, Radiations β and ec decays plotting

Go to Nuclide: Show Chart

Nuclide Levels Gammas Bands **Decay Radiation** El. and Magn. Mom. Ther. Neutrons Capture Fission Yields

Parent	$T_{1/2}$	Level E [keV]	Jp order	Decay	Q decay <small>note on Q values</small>	Daughter
^{135}Xe 54 81	9.14 h 2	0.0	3/2+	β^- 100 %	1165.048 4070	^{135}Cs 55 80

see the ENSDF source

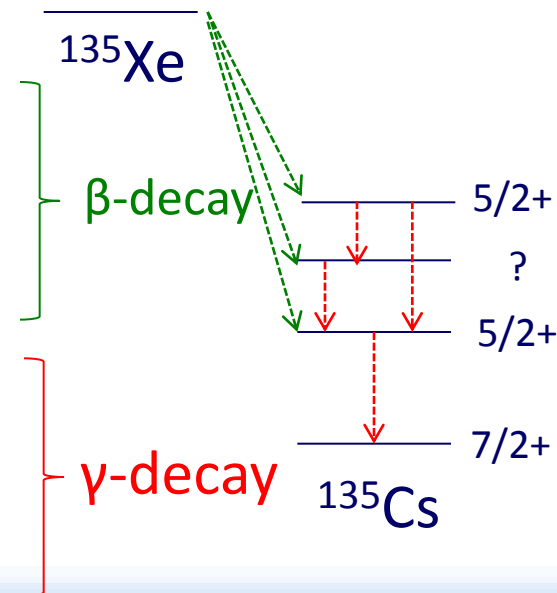
Note: Q-value used in ENSDF to determine displayed decay data is: 1165.4 keV - see [note on Q values](#)

Beta

Fed level [keV]	Jp	End Point [keV]	Avg Energy [keV]	Intens. per decay [%]
1062.420 14		103 4	26.9 11	0.123 6
981.315 22		184 4	50.0 12	0.075 5
608.186 14	5/2+	557 4	173.3 15	3.11 14
407.989 13		757 4	248.1 16	0.59 3
249.793 12	5/2+	915 4	310.2 16	96 4

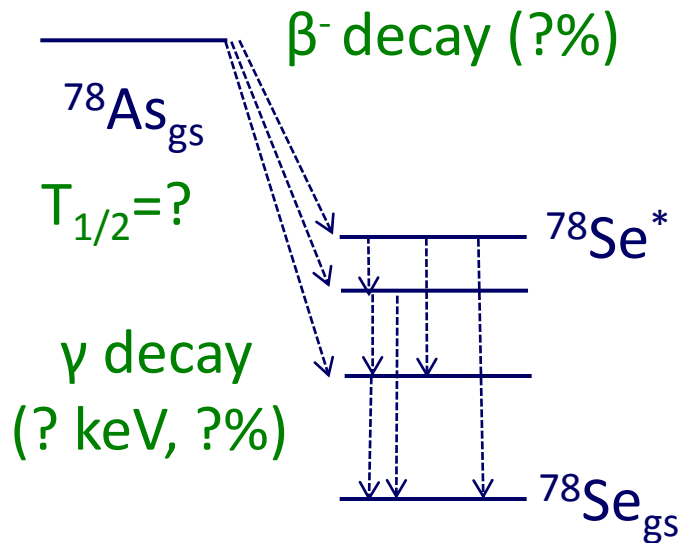
Gamma

Start level [keV]	Jp	Final Level [keV]	Jp	γ Energy [keV]	Intens. per decay [%]
407.989 13		249.793 12	5/2+	158.197 18	0.289 14
608.186 14	5/2+	407.989 13		200.19 10	0.012 5
249.793 12	5/2+	0.0	7/2+	249.794 15	90 3
608.186 14	5/2+	249.793 12	5/2+	358.39 3	0.221 11
981.315 22		608.186 14	5/2+	373.13 10	0.015 3



LiveChart of Nuclides - Exercise

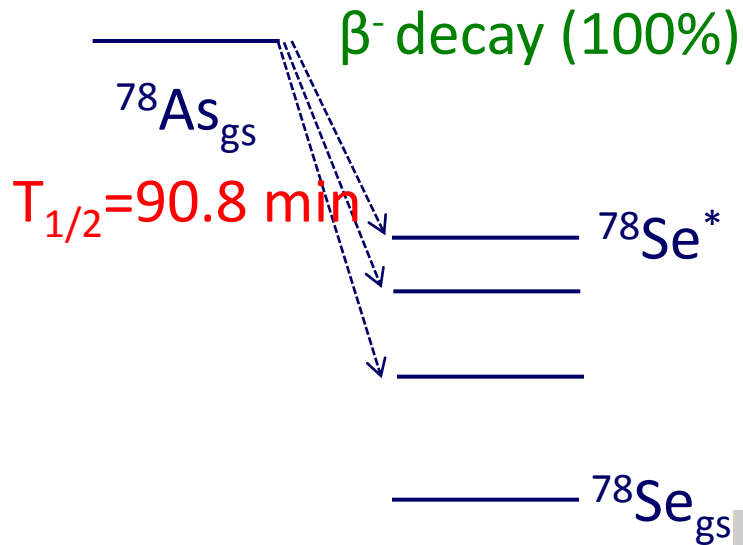
One determined the $^{78}\text{Se}(n,p)^{78}\text{As}$ cross section by detection of γ from $^{78}\text{As} - \beta^- \text{ decay} \rightarrow ^{78}\text{Se}^* - \gamma \text{ decay} \rightarrow ^{78}\text{Se}_{\text{gs}}$.



Questions:

1. Half-life of ^{78}As
2. Branching ratio of $^{78}\text{As} \beta^- \text{ decay}$
3. Energy of strongest decay γ radiation and its intensity

LiveChart of Nuclides – Exercise (cont)



Questions:

1. Half-life of ^{78}As
2. Branching ratio of ^{78}As β^- decay
3. Energy of strongest decay γ radiation and its intensity

Live Chart of Nuclides
nuclear structure and decay data

Go to Nuclide: Show Chart

Nuclide	J π	G.S. $T_{1/2}$ Abundance	G.S. Decays	Q_{β^-} [keV]	Q_{α} [keV]
^{78}As 33 45	2-	90.7 min 2	β^- 100	4208.949 9813	-7192.26 1026 -

ENSDF datasets related to ^{78}As
Evaluated Nuclear Structure Data File

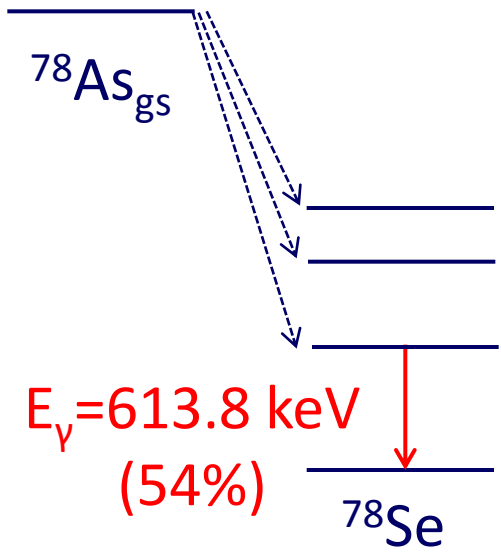
- ADOPTED LEVELS, GAMMAS
- 78GE B- DECAY (88 M)
- 76GE(A,PNG)
- 78AS B- DECAY (90.7 M)
- 78SE(T,3HE)

XUNDL datasets related to ^{78}As
Experimental Unevaluated Nuclear Data List

- 76GE(A,PNG):XUNDL-1



LiveChart of Nuclides – Exercise (cont)



Questions:

1. Half-life of ^{78}As
2. Branching ratio of ^{78}As β^- decay
3. Energy of strongest decay γ radiation and its intensity

Live Chart of Nuclides nuclear structure and decay data

Go to Nuclide: Show Chart

Decay Radiation

Start level [keV]	Jp	Final Level [keV]	Jp	γ Energy [keV]	Intens. per de
2838.58 9	(2+)	2682.09 9	4+	156.6 3	0.092 24
2682.09 9	4+	2507.72 10	3-	174.2 3	0.18 4
1854.00 9	3+	1502.64 11	4+	351.1 2	0.162 24
2682.09 9	4+	2327.34 13	2+	354.3 2	1.9 3
1758.91 11	0+	1308.66 7	2+	449.8 4	0.08 3
3144.52 13	3-	2682.09 9	4+	462.2 2	0.59 9
1995.78 10	2+	1498.76 18	0+	497.0 3	0.18 3
2838.58 9	(2+)	2334.87 19	0+	503.7 2	0.42 6
1854.00 9	3+	1308.66 7	2+	545.3 1	3.0 4
613.84 7	2+	0.0	0+	613.8 1	54 6
3144.52 13	3-	2507.72 10	3-	637.1 2	0.21 3

LiveChart of Nuclides – Exercise (cont)

Half-lives and decay gamma intensities are important inputs to derive Activation cross sections.

Extractions from the 33080 article ($\lambda = \ln 2 / T_{1/2}$, f_d : decay γ intensity)

$$\sigma = \sigma_M \frac{A \varepsilon_M f_d \lambda N_M}{A_M \varepsilon f_d \lambda M} \frac{N_M (1 - e^{-\lambda M t_1}) e^{-\lambda M t_2} (1 - e^{-\lambda M t_3})}{N (1 - e^{-\lambda t_1}) e^{-\lambda t_2} (1 - e^{-\lambda t_3})}$$

We extracted these data from LiveChart.

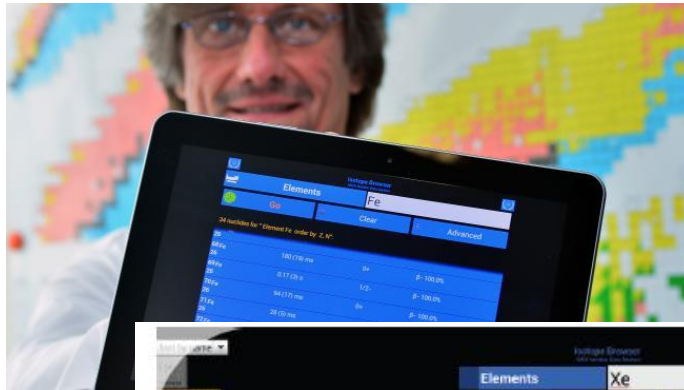
TABLE I. The decay data of the radioisotopes produced

Nuclear Reaction	Abundance (%)	Half life	E_γ (MeV)	f_d (%)
$^{78}\text{Se}(n, p)^{78}\text{As}$	23.77 ± 0.28	90.7 ± 0.2 m	0.614	54 ± 0.6
$^{80}\text{Se}(n, p)^{80}\text{As}$	49.61 ± 0.41	15.2 ± 0.2 s	0.666	42 ± 0.5
$^{56}\text{Fe}(n, p)^{56}\text{Mn}$	91.75 ± 0.36	2.578 ± 0.0001 hr	0.847	99 ± 0.3
$^{19}\text{F}(n, p)^{19}\text{O}$	100	26.91 ± 0.08 s	0.197 1.357	96 ± 2.1 50.4 ± 1.1

LiveChart of Nuclides – Data Source

- **Q-value, S-value, atomic masses:** 2012 Atomic Mass Evaluation (G. Audi et al., Chin.Phys.C**36**(2012)1287; M. Wang et al., Chin.Phys.C**36**(2012)1603)
- **Natural isotopic abundances:** M.Berglund and M.E.Wieser, Pure.Appl.Chem.**83**(2011)397.
- Other data are mainly from the **ENSDF library** which evaluation results are also published in “Nuclear Data Sheets” which is good for citation.
- Similar data can be also available through **NuDat (NNDC)**.

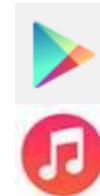
Isotope Browser (Mobile app for iOS and Android)



Free!

Android: Search for “isotope browser” on “Google Play”.

Apple: Search for “isotope browser” on “iTunes”.



Send your **feedback** to the developer (Dr Marco VerPELLI)!

