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

Naohiko OTSUKA

Nuclear Data Section

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

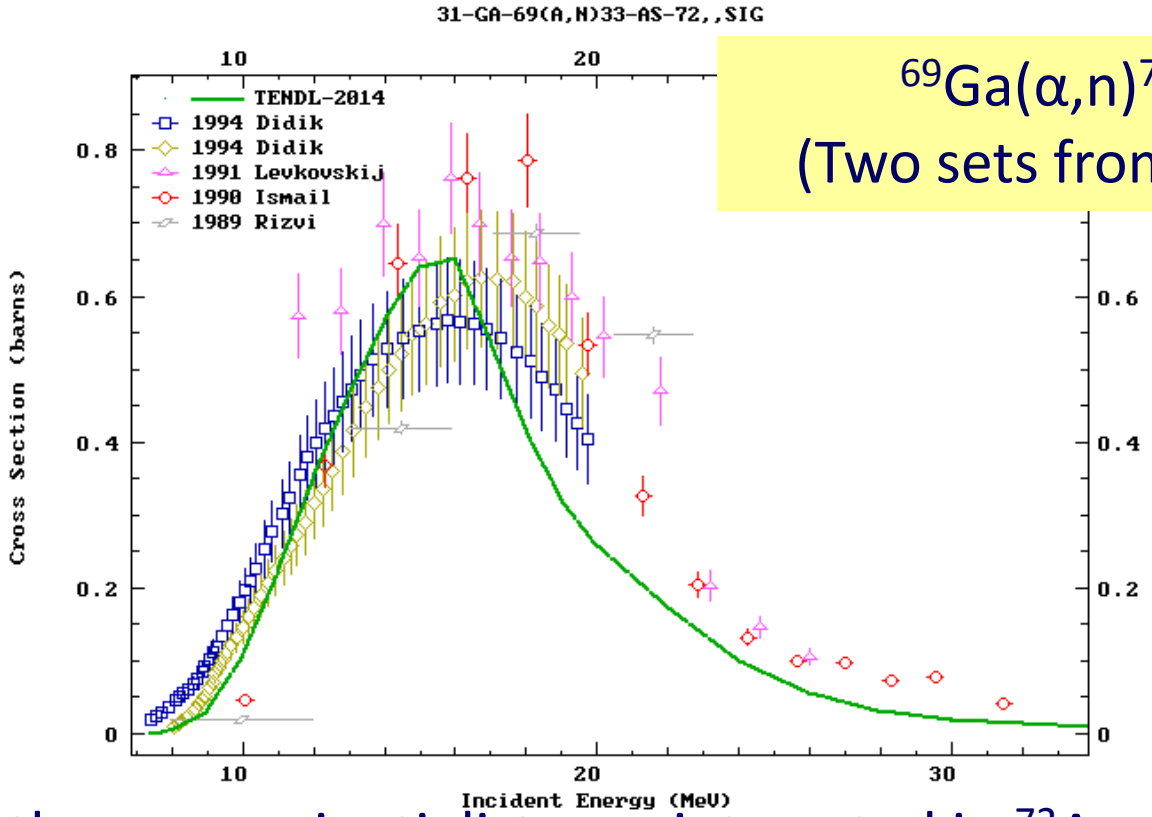
A farmer works her land near a lead smelter in Hunan Province. Sim Chi Yin for The New York Times

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



^{69}Ga(α,n)^{72}As
(Two sets from VECC)

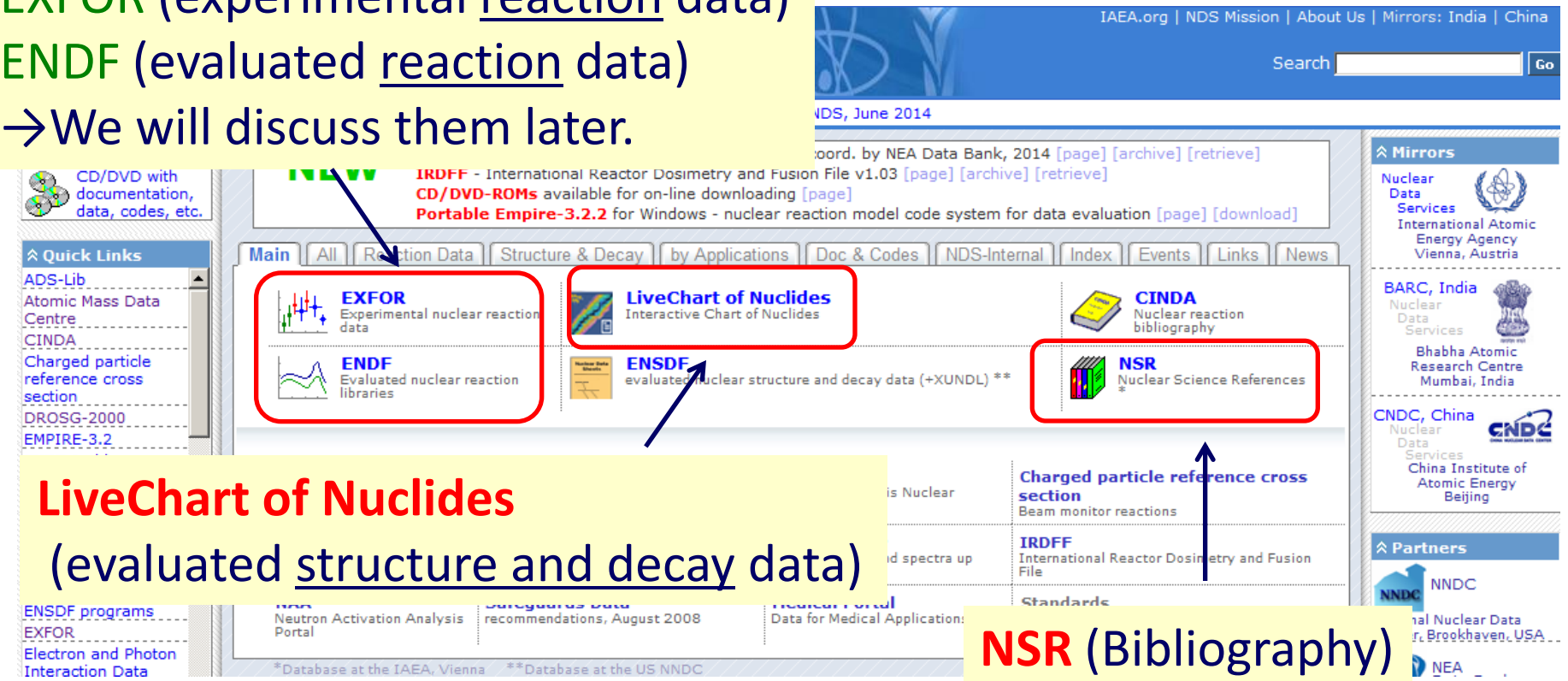
- None of these experientialists are interested in ^{72}As production for application.
- Nevertheless we can estimate yield and best beam energy without a new experiment thanks to EXFOR.

IAEA Nuclear Data Services

EXFOR (experimental reaction data)

ENDF (evaluated reaction data)

→We will discuss them later.



LiveChart of Nuclides

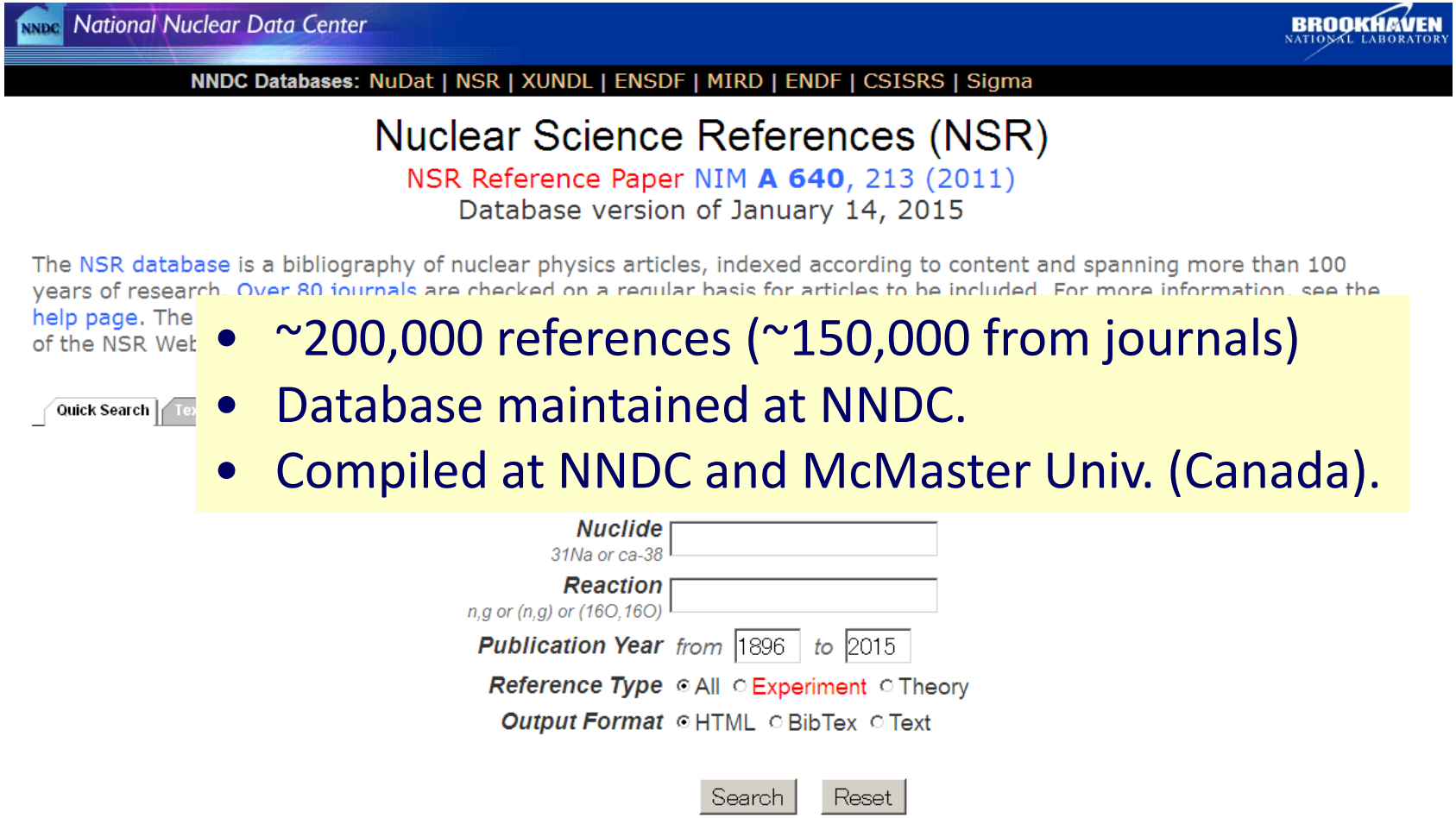
(evaluated structure and decay data)

NSR (Bibliography)

http://www-nds.iaea.org/ : primary server (Vienna)

http://www-nds.indcentre.org.in/: mirror server (India)

NSR (Nuclear Science References)



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

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

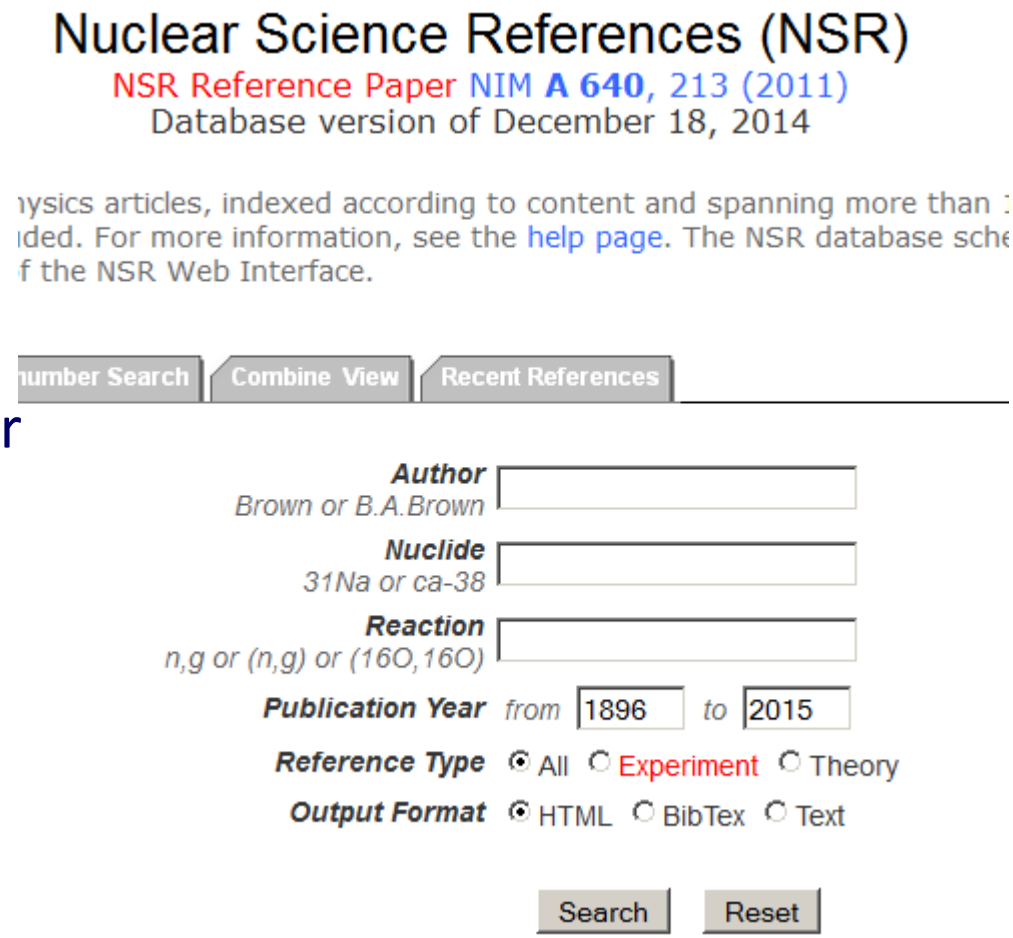
NSR (cont.)

Very easy to use!

Just provide

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

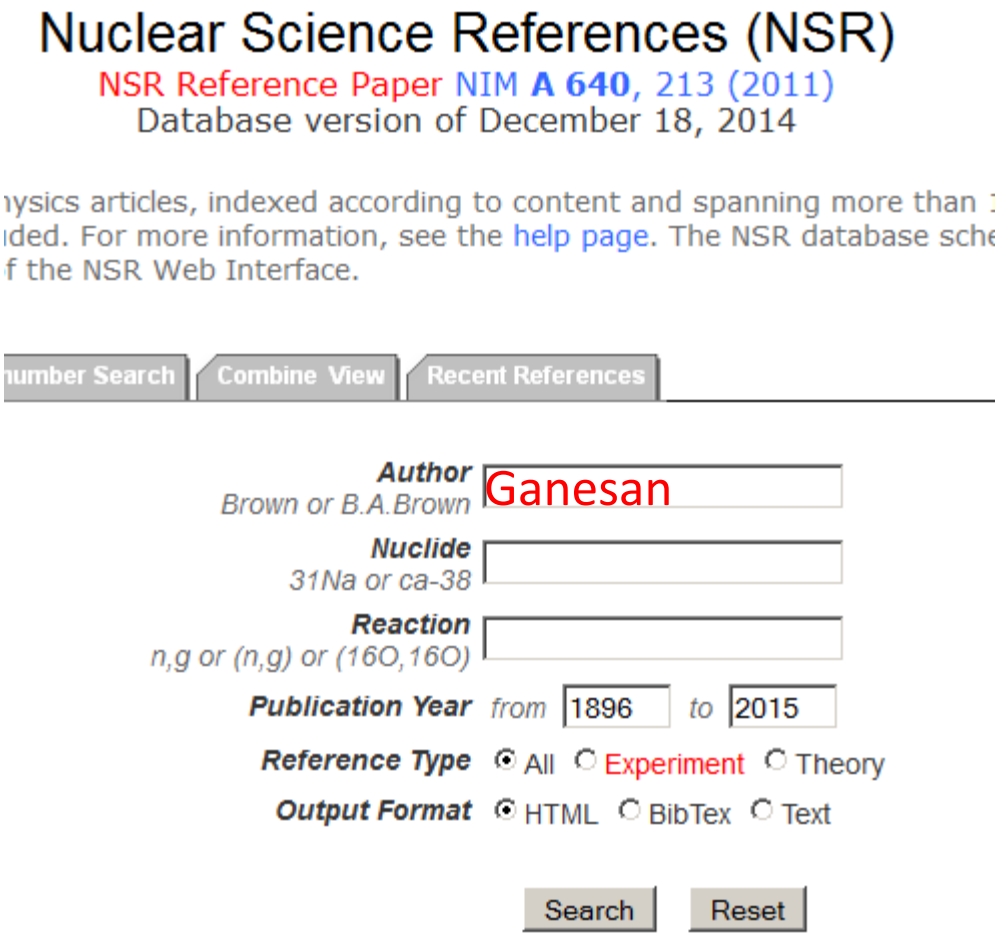
and search.



NSR – Exercise 1

Question

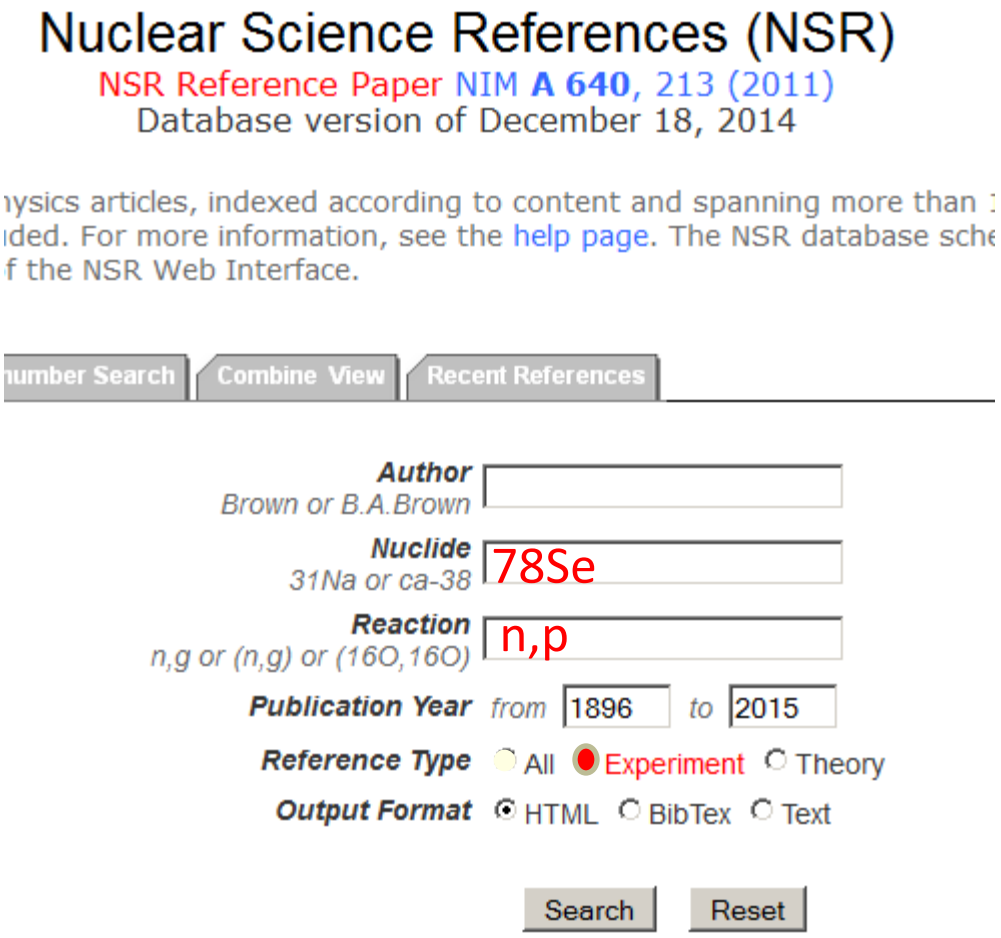
Search articles where "Ganesan" is an author.



NSR – Exercise 2

Question

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



NSR – Exercise 2 (cont)

Not all articles report the ^{78}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}Ge in (n, p), (n, α), and (n, 2n) Reactions from 6 to 15 MeV

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

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

doi: 10.1103/PhysRevC.52.2546
*Data from this article have been entered in the **EXFOR** database. For more information, access X4 dataset22291.*

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

I.Birn, S.M.Qaim

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

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

NSR – Exercise 2 (cont)

Compare NSR output for

"Nuclide =78Se 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?

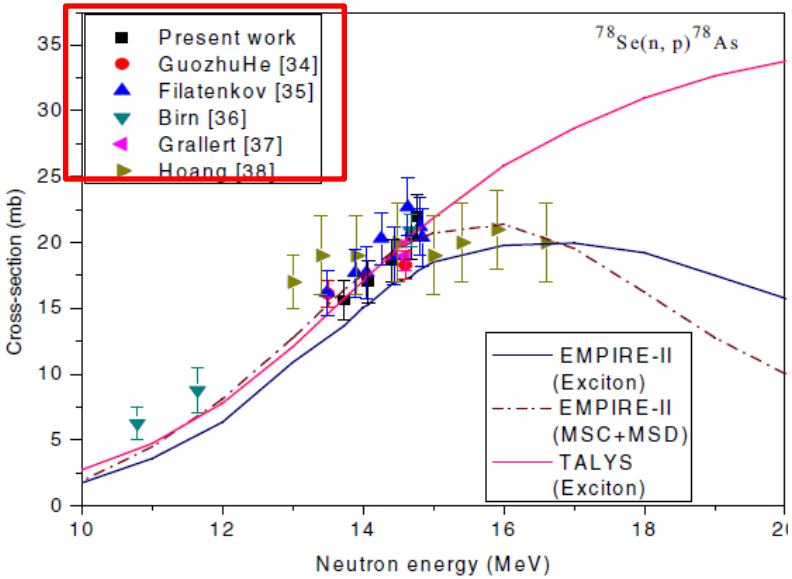


FIG. 3. (Color online) Cross sections for ^{78}Se(n, p)^{78}As reaction

[34] Guozhu He, Zhongjie Liu, Junhua Luo, and Xiangzhong Kong, Indian J. Pure Appl. Phys. **43**, 729 (2005). — Not in NSR

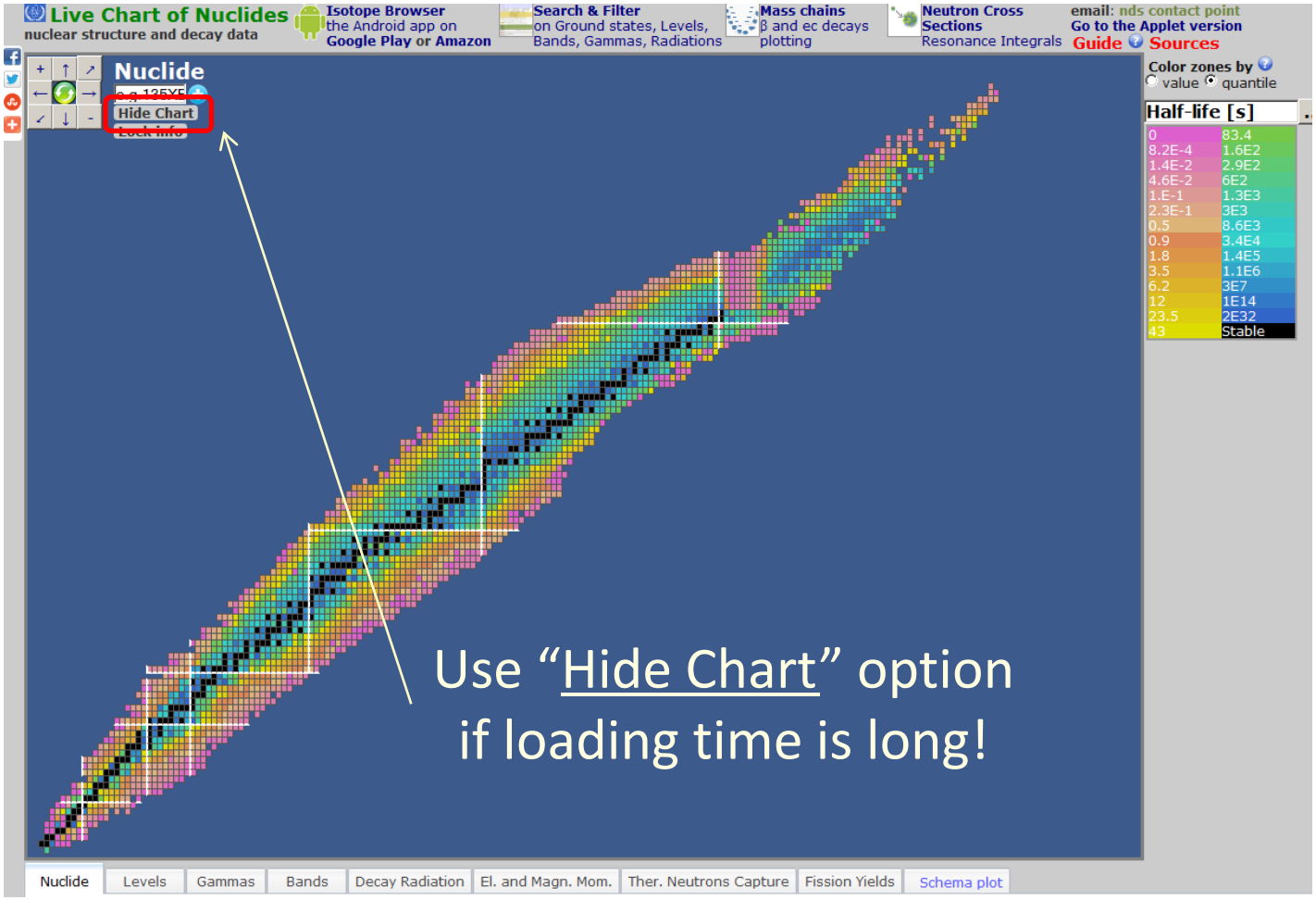
[35] A. A. Filatenkov and S. V. Chuvaev, Khlopin Radiev. Inst., Leningrad Reports No. 258 (2001). — Not in NSR

[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. Zwieglinski, Zeitschrift fuer Physik A, Hadrons and Nuclei **334**, 285 (1989). — **in NSR**

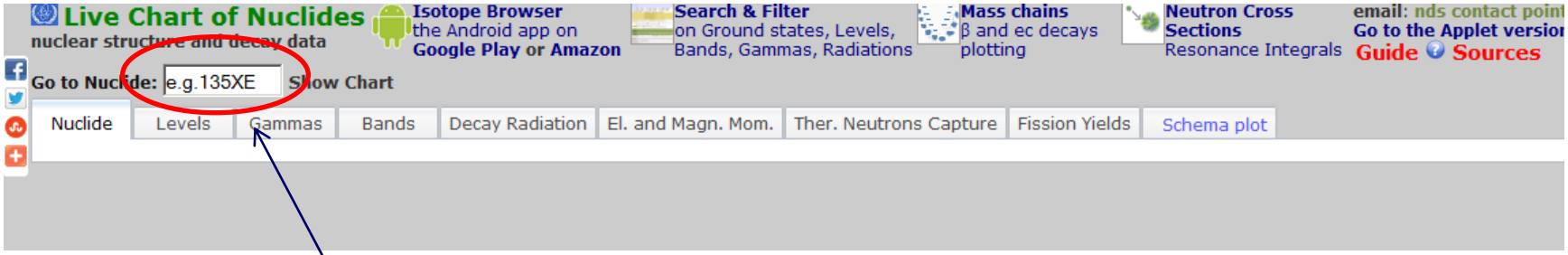
LiveChart of Nuclides



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

LiveChart of Nuclides (cont.)

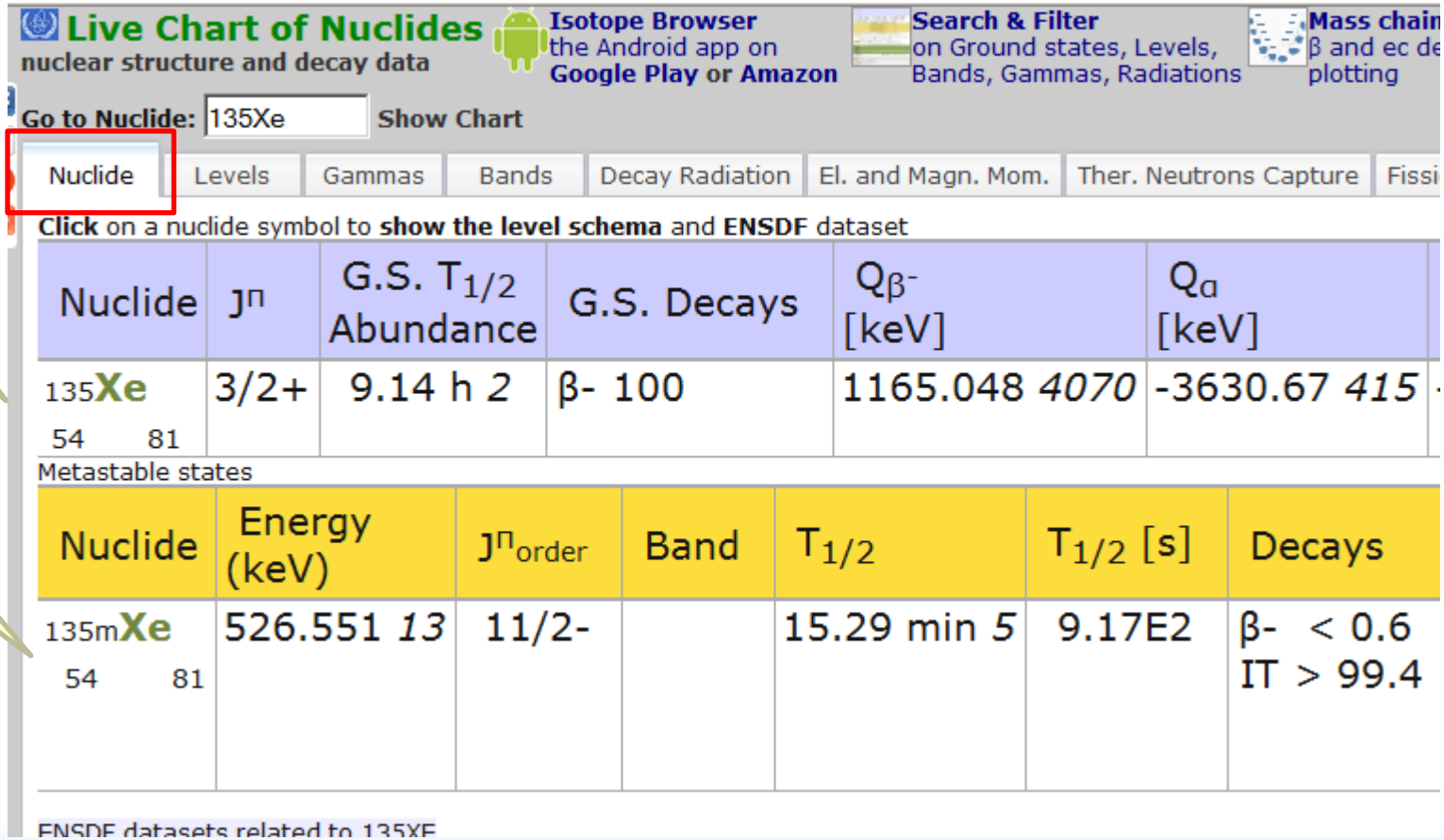
The query page becomes very simple if you select "Hide Chart" option.



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: 135Xe 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	Jπ	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
^{135m}Xe 54 81	526.551 *13*	11/2-		15.29 min *5*	9.17E2	β- < 0.6 IT > 99.4

ENSDF datasets related to 135XE

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

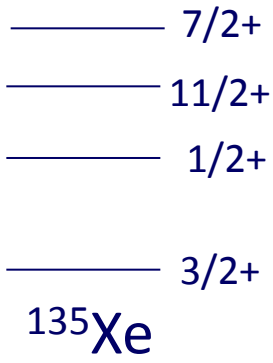
Neutr
Secti
Resor

Go to Nuclide: 135Xe 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
$^{135}_{54}$Xe $_{81}$	0.0	3/2+		9.14 h *2*	3.29E4	β- 100	
$^{135}_{54}$Xe $_{81}$	288.455 *15*	1/2+					
$^{135}_{54}$Xe $_{81}$	526.551 *13* m	11/2-		15.29 min *5*	9.17E2	β- < 0.6 IT > 99.4	
$^{135}_{54}$Xe $_{81}$	1131.512 *11*	7/2+					
$^{135}_{54}$Xe $_{81}$	1260.416 *13*	5/2+					
$^{135}_{54}$Xe $_{81}$	1448.36 *3*	(3/2+)					



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

Decay Radiation 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

Go to Nuclide: 135Xe 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 note on Q values	Daughter
$^{135}_{54}$Xe $_{81}$	9.14 h *2*	0.0	3/2+	β- 100 %	1165.048 *4070*	$^{135}_{55}$Cs $_{80}$

see the ENSDF source

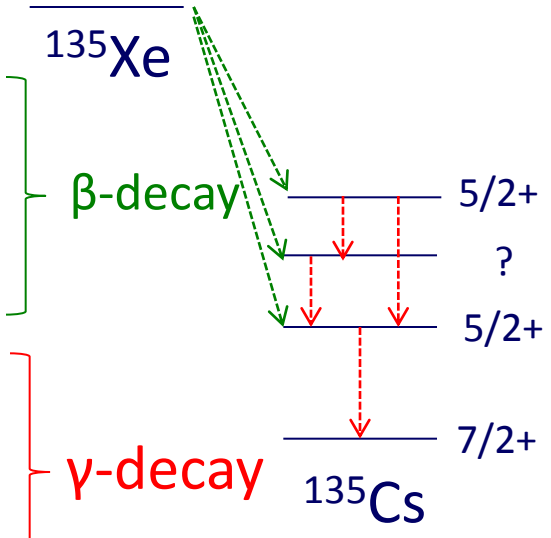
Note: Q-value used in ENSDF to determine displayed decay data is: 1165 *4* keV - see note on Q values

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*

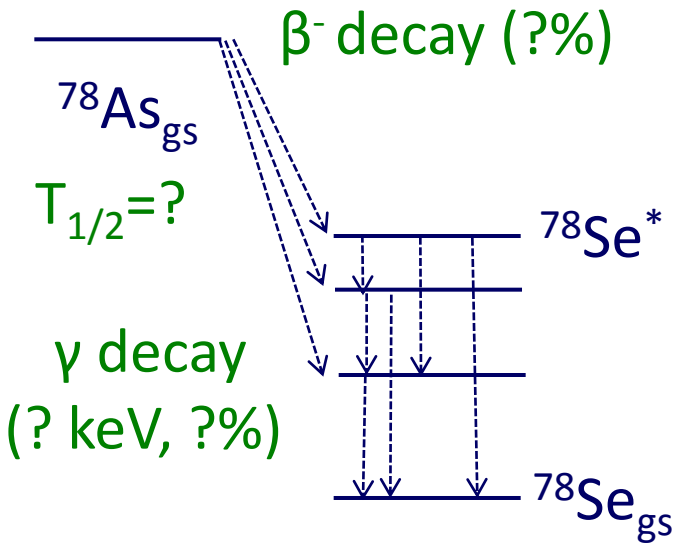
Gamma

Start level [keV]	Jp	Final Level [keV]	Jp	γ Energy [keV]	Intens. per de
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

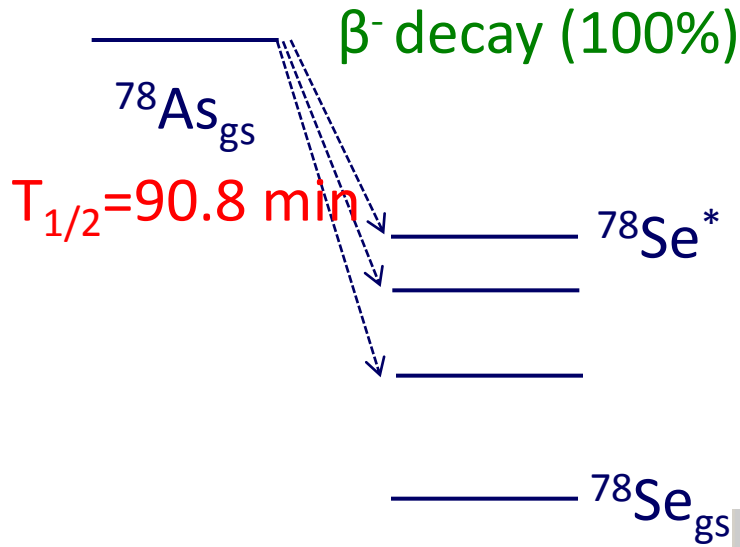
One determined the $^{78}Se(n,p)^{\mathbf{78}}\mathbf{As}$ cross section by detection of γ from ^{78}As - β^- decay → $^{78}Se^*$- γ decay→$^{78}Se_{gs}$.



Questions:

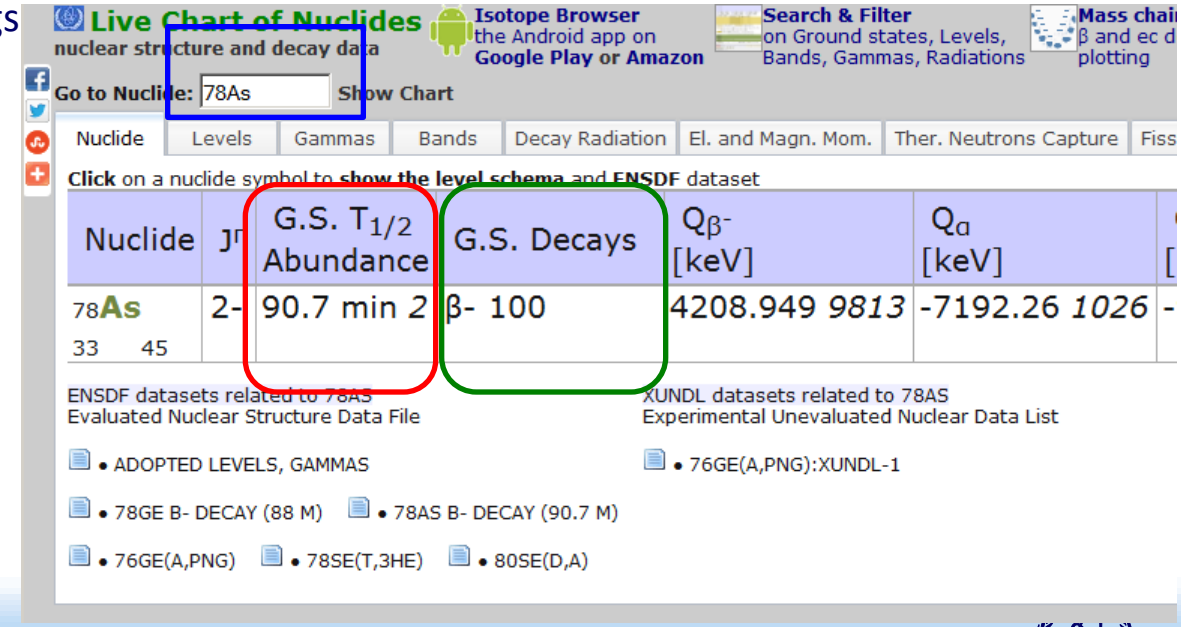
1. Half-life of ^{78}As
2. Branching ratio of ^{78}As β^- decay
3. Energy of strongest decay γ radiation and its intensity

LiveChart of Nuclides – Exercise (cont)

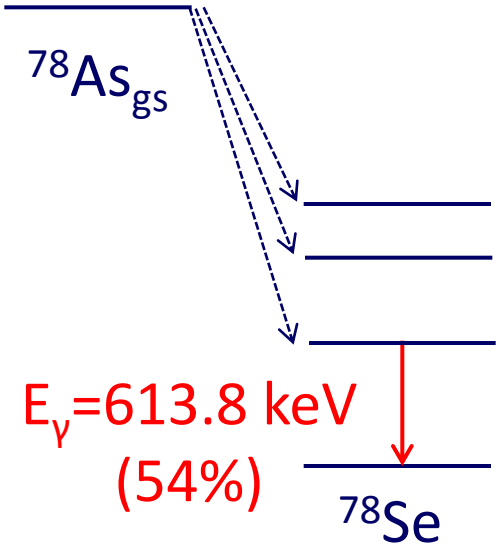


Questions:

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



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

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

Go to Nuclide: 78As Show Chart

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

Level | Jp | note on

Gamma

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)

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

We extracted these data from LiveChart.

TABLE I. The decay data of the radioisotopes produced i

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

LiveChart of Nuclides – Data Source

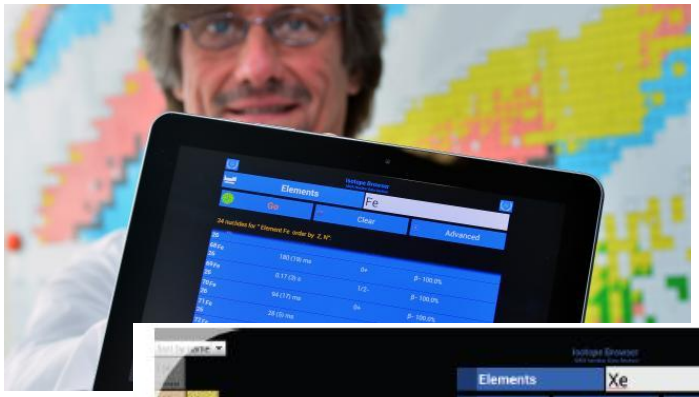
- Q-value, S-value, atomic masses: 2012 Atomic Mass Evaluation (G. Audi et al., Chin.Phys.C**36**(2012)1287; M. Wang et al., Chin.Phys.C**36**(2012)1603)

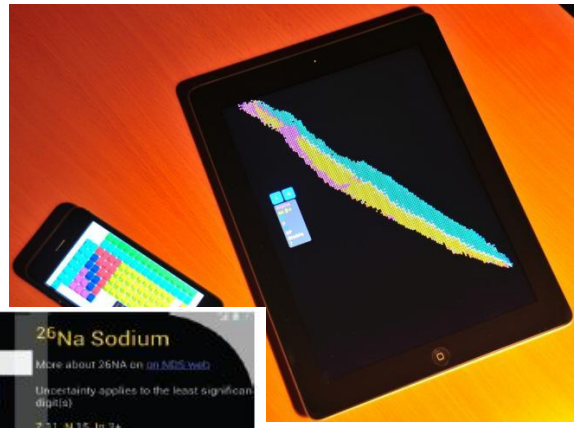
- Natural isotopic abundances: M.Berglund and M.E.Wieser, Pure.Appl.Chem.**83**(2011)397.

- 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)!