Practical Work for ENSDF Evaluation

A=218 (October 22-26, 2018)

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A=218

Why A=218?

Practical reasons:

-Current data in ENSDF / NDS (2006) ~13 years old: Jan 25, 2006.

-Short mass chain i.e. not a huge amount of experimental data.

-Mixture of radioactive decays and reactions.

-Although, not many new papers since 2006, still each mass chain in ENSDF needs to be updated every 10 years or so

1. Update of new Q values from 2016-AME (2017Wa10) from previous AME-2003 (2003Au03) values

2. Update of internal conversion coefficients using BrIcc code, replacing previous values from Hager-Seltzer (HSICC) coefficients. May need to renormalize decay schemes for I(gamma)/100 decays.

3. Hindrance Factors in α decays, LOGFT values in beta decays based on new Q values and perhaps updated half-lives of A=218 and relevant A=222 nuclides.

A=218

Nuclear Structure Physics aspects:

- As of today, experimentally known Nuclides of A=218: Z=82-92, N=136 126: ^{218}Pb, ^{218}Bi, ^{218}Po, ^{218}At, ^{218}Rn, ^{218}Fr, ^{218}Ra, ^{218}Ac, ^{218}Th, ^{218}Pa, ^{218}U.
- Sub-shell closures in ^{218}Pb with Z=82 and in ^{218}U with N=126.
- Several nuclei are away from Z=82, N=126 magic numbers, thus collective excitations are expected
- Evidence of stable Octupole deformation e.g. in ^{218}Rn and ^{218}Ra; a 1- state in ^{218}Ra discovered recently from ^{222}Rn by 2016Pa28.
- Observation of reflection-asymmetric (alternating-parity) structures, e.g. in ^{218}Fr and ^{218}Ac
- Comparisons with model calculations possible

Practical applications:

^{218}Po and ^{218}At are of interest in monitoring environmental radioactivity as they are daughter products of ^{222}Rn and its predecessor ^{238}U.

A=218

Current experimental information about A=218 nuclides:

^{218}Pb: Z=82, N=136: only the ground state and half-life known: updated.

^{218}Bi: Z=83, N=135: only the ground state and half-life known: updated.

^{218}Po: Z=84, N=134: ^{218}Bi β- decay; ^{222}Rn α decay: Libby McCutchan

^{218}At: Z=85, N=133: only the ground state and half-life known: updated.

^{218}Rn: Z=86, N=132: ^{218}At β- decay; ^{222}Ra α decay, (HI,Xγ): Libby McCutchan

^{218}Fr: Z=87, N=131: ^{222}Ac α decays (two activities), (HI,2αnγ): Balraj Singh

^{218}Ra: Z=88, N=130: ^{222}Th α decay, (HI,xnγ): Murray Martin

^{218}Ac: Z=89, N=129: ^{222}Pa α decay, (HI,xnγ): Shamsu Basunia

^{218}Th: Z=90, N=128: ^{222}U α decay, (HI,xnγ): Balraj Singh

^{218}Pa: Z=91, N=127: only the ground state and half-life known: updated.

^{218}U: Z=92, N=126: only the ground state and a high-spin isomer with half-lives known; no gamma-ray data exist: updated.

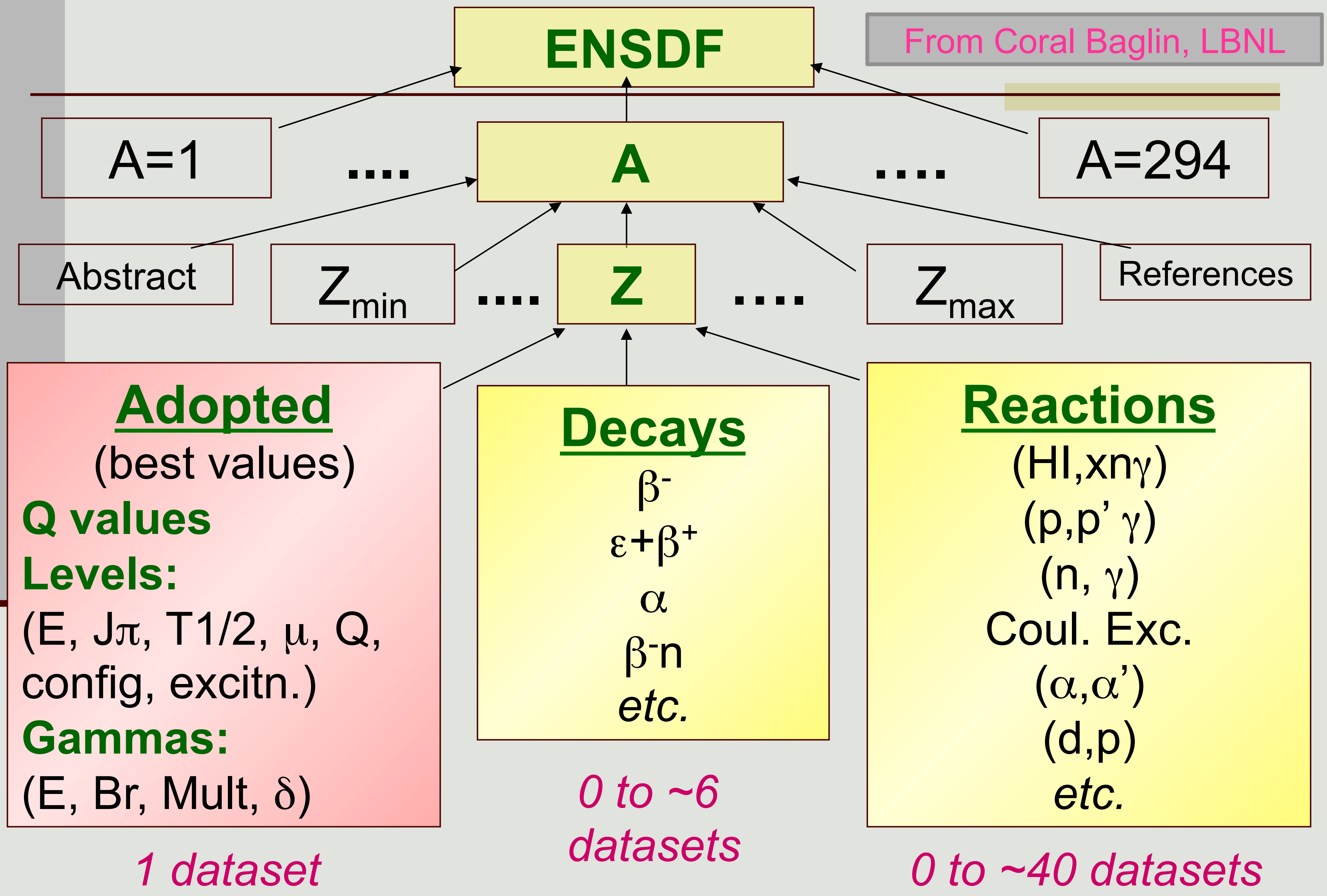
Relevant α-decay parents: ^{222}Rn, ^{222}Ra, ^{222}Ac, ^{222}Th, ^{222}Pa, ^{222}U.

Relevant α-decay daughters: ^{214}Pb, ^{214}Bi, ^{214}Po, ^{214}At, ^{214}Rn, ^{214}Fr, ^{214}Ra, ^{214}Ac, ^{214}Th.

A bit more about ENSDF database and formats

- ENSDF database organization
- Record types: most frequently used
- Some examples
- How to start a mass chain update / evaluation

ENSDF Database Structure



A dataset in ENSDF: collection of 80-column records, as needed for a particular decay or reaction. ID: a must

ENSDF Standard 80-character Formated Records

Record	1–5	6	7	8	9	10–19	20–21	22–29	30–31	32–39	40–41	42–49	50–55	56–62	63–64	65–74	75–
IDENT	NUCID	&	blank			←DSID→					DSREF					←PUB→	
XREF	NUCID	blank		X	!	←DSID→					blank						
REF	AAA	blank		R	bl	KEYNUMBER	REFERENCE										
HIST	NUCID	&	bl	H	bl	←HTEXT											
Q-VALUE	NUCID	blank		Q	bl	Q-	DQB	SN	DSN	SP	DSP	QA	DQA	QREF			
G COMM	NUCID	&	†	#	bl	CTEXT											
F/R COMM	NUCID	&	†	#	‡	SYM(FLAG)	CTEXT										
PARENT	NUCID	blank		P	§	E	DE	←J→			←T→		DT	blank		QP	
NORM	NUCID	blank		N	§	NR	DNR	NT	DNT	BR	DBR	NB	DNB	NP	DNP	blank	
P NORM	NUCID	&	P	N	§	NR*BR	UNC	NT*BR	UNC	blank		NB*BR	UNC	NP	DNP	blank	
LEVEL	NUCID	&	bl	L	bl	E	DE	←J→			←T→		DT	←L→		←S→	
BETA	NUCID	&	bl	B	bl	E	DE	IB	DIB	blank		LOGFT	DFT	blank			
EC	NUCID	&	bl	E	bl	E	DE	IB	DIB	IE	DIE	LOGFT	DFT	blank			
ALPHA	NUCID	&	bl	A	bl	E	DE	IA	DIA	HF	DHF	blank					
PART	NUCID	&	bl		¶	E	DE	IP	DIP	ED	←T→		DT	←L→		blank	
GAMMA	NUCID	&	bl	G	bl	E	DE	RI	DRI	←M→		MR	DMR	CC	DCC	TI	

Each data set must have at least two records:
First: Data set identification record (DSID).
Last: a blank record

Body of a data set:

1. Header comments: references (as NSR key-numbers), with brief descriptions.

2. General and footnote comments on particular quantities such as Beta or Alpha energy, beta feedings, alpha intensities, log *ft,* alpha HF, gamma energy, gamma intensity, gamma multipolarity, gamma mixing ratio, level energy, level spin-parity, level half-life, etc.

Should preferably be ordered as:

1. Comments on particle records, beta, alpha, delayed neutrons, etc.

2. Comments on gamma-ray transitions

3. Comments on Level properties.

Note: comments often also appear with individual levels and gamma rays or particles.

Body of a data set

Level Record: energy and uncertainty, spin-parity, half-life and uncertainty, L-transfer and spectroscopic factors in particle-transfer reactions, (isomer label if needed, ? In column 80 if tentative level).

Pertinent comment on a certain level property follow Level record.

B-, EC+B+, or Alpha records for radioactive decay data sets:

Particle energy and uncertainty only when precisely measured; beta intensity, Log *ft* or HF, EC+B+ intensity (LOGFT code outputs separated B + and EC intensities), label for forbidden unique beta transitions, ? In column 80 if tentative.

Pertinent comment on a certain particle emission follow Particle record.

Gamma Record: energy and uncertainty, photon intensity and uncertainty, multipolarity, mixing ratio with sign (if valid) and uncertainty, conversion coefficient (generally from BrIcc), transition intensity (Ig+Ice) if needed, gamma-gamma-coin label if valid, ? In column 80 if tentative.

Pertinent comment on a certain property of gamma follow Gamma record

Data set ID records, ordering of data sets for a nuclide: examples

200HG	ADOPTED LEVELS, GAMMAS	
200HG	200AU B- DECAY (48.4 M)	NSR# (up to 3)
200HG	200AU B- DECAY (18.7 H)	NSR#
200HG	MUONIC ATOM	
200HG	200TL EC DECAY	
200HG	198PT(A,2NG)	
200HG	198PT(9BE,A3NG)	
200HG	199HG(N,G) E=TH:PRIMARY	
200HG	199HG(N,G) E=TH:SECONDARY	
200HG	199HG(N,G) E=33.5 EV RES	
200HG	200HG(N,N’G)	
200HG	200HG(A,A’)	
200HG	COULOMB EXCITATION	
200HG	202HG(P,T)	

Creating data sets

Compilation and evaluation of nuclear structure data from 1935:

A=21-44: P. Endt: Utrecht: evaluation work from1950-1998:

pencil and slide rule. Submitted to NP-A written in pencil, type setting by publishers. Endt's evaluations were well respected in nuclear physics community.

A>45: NDS: from 1960- present: hand written, 80-column computer cards until 1980, mono-chrome screen editors until 2000 or so, color monitors,……

Text editors

Semi-automatic procedures for large data tables in .pdf in papers: since 1998 at McMaster, we have been using internal .pdf scanners, then convert to spreadsheet, and through a computer code translate .excel to .ENSDF format.

EVP editor from NNDC: lot more advanced, but need to learn.

190W 190W IT DECAY (166 US) 2011ST21,2010LA16
190W H TYP=FUL$AUT=BALRAJ SINGH AND JUN CHEN$CIT=ENSDF$CUT=15-OCT-2018$
190W c 2011St21 (also 2012Al05,2009Al30,2009Al16,2009Fa06,2008StZY,2005Ca02,
190W 2c 2003Po14,2000Po26): {+190}W nuclide formed by in-flight
190W 3c fragmentation of {+208}Pb beam at 1 GeV/nucleon
190W 4c from the GSI UNILAC and SIS-18 accelerator complex. Target thickness
190W 5c of 2.526 g/cm{+2}, backed by {+93}Nb foil of thickness 0.223 g/cm{+2}.
190W 6c Fragments separated and identified in flight by the Fragment Separator
190W 7c (FRS) operated in achromatic mode, based on time of flight, B|r and
190W 8c energy loss. Transmitted ions slowed in Al degraders and stopped in a
190W 9c plastic catcher. The stopper was surrounded by the RISING |g-ray
190W Ac spectrometer. Measured E|g, I|g, delayed |g rays, isomer lifetime.
190W Bc {+190}W beam was fully-stripped or mixture of H- or He-like nuclei.
190W d 2001MaZV, 2000ScZY, 2000PoZY: superseded by 2000Po26
190W c 2010La16: E=840 MeV. Measured E|g, I|g, |g|g, delayed |g spectra
190W 2c using Gammasphere array at Atlas-ANL facility. In reference 24,
190W 3c authors mentioned that full details of this study are to be published
190W 4c elsewhere. But in evaluators' search of literature, no further
190W 5c publication from this group seems to have appeared.
190W cG E$From 2011St21 unless otherwise stated. Uncertainty of 0.5 keV
190W 2cG for E|g assigned in consultation (in January 2012) with Zs. Podolyak
190W 3cG (one of the authors of 2011St21)
190W cG RI$From 2010La16
190W P 1840.4 14 (10-) 166 US 6
190W N 1
190W PN 6
190W L 0.0 0+
190W L 206.8 5 (2+)
190W G 206.8 5
190W L 565.1 7 (4+)
190W G 358.3 5
190W L 1049.4 9 (6+)

```
190W S G KC=0.00766 11 $ LC=0.001509 22$ MC=0.000351 5 $ NC=8.41E-5 12
190W S G OC=1.313E-5 19$ PC=7.19E-7 11
190W   L 1840.4    14  (10-)           166 US  6                         M2
190W 2 L %IT=100
190W  cL T$from |g(t) (2010La16). Others: 108 |ms {I9} (2011St21, from |g(t);
190W 2cL earlier values: 106 |ms {I18} in 2009Al30, 105 |ms {I22} in 2009Fa06,
190W 3cL 0.06 ms {I+150-3} in 2005Ca02 and |<3.1 ms or 0.39 ms {I+|@-26} in
190W 4cL 2000Po26)
190W  cL $Interpreted by 2010La16 as yrast-trap isomer, not a K-isomer
190W  cL $Configuration=|n9/2[505]~#|n11/2[615], K|p=10-
190W 2cL (2010La16,2005Ca02,2000Po26)
190W   G 97          100       [M2]                  48.1 21
190W  cG $Others: 46-keV, (E1), |g ray to 2335, (10+) level in 2000Po26,
190W 2cG with I|g=60 {I30} relative to I|g=62 {I21} for 484|g from (6+) state;
190W 3cG 58.5 keV {I5} with I|g=60 {I13} relative to I|g=21 {I7} for 484|g
190W 4cG (2005Ca02). In later work 58.5-keV peak was assigned to x rays by
190W 5cG 2009Fa06
190W B G BM2W=0.0134 5 (2010La16)
190W S G KC=33.2 14 $ LC=11.3 6$ MC=2.80 13 $ NC=0.68 4
190W S G OC=0.108 5$ PC=0.0064 3
```

Starting an evaluation of a mass chain for ENSDF: collection of data files and evaluations

- -Retrieve the previous evaluation from the ENSDF database in the .ensdf format data file from www.nndc.bnl.gov/ensdf/. This is the file that will be edited as guided by the new literature, as well as possible revisions in the previous data file.
- -Collect previous published NDS evaluations, even the earlier ones are sometimes useful. Download from NDS webpage.
- -Collect available evaluations by the Decay Data Evaluation Project (DDEP) from www.nucleide.org/DDEP.htm.
- -Collect compilation and evaluation in the 1978-Table of Isotopes by John Wiley & Sons (Independent work; 1996 edition from ENSDF)
- -Download copies of 2017Wa10 (AME-2016), 2017Au03 (NUBASE-2016), 2014StZZ (compiled magnetic dipole and electric quadrupole moments), 2016St14 (evaluated Q-moments), 2013An02 (evaluation of nuclear radii).

Evaluating a mass chain: collection of literature

-Download data files in .ensdf format from the XUNDL database: www.nndc.bnl.gov/xundl/. for A=218 and relevant A=222 nuclides. Also look for relevant A=214 datasets. These are compiled (**not evaluated**) data sets from current papers. These data sets give you an idea as to what is new since the previous evaluation in ENSDF, however, not all new literature may be covered in XUNDL, especially, the publications in conference proceedings, lab reports, theses, etc.

-Consult the Nuclear Science References (NSR) database: www.nndc.bnl.gov/nsr/ and retrieve and collect new experimental references for each nuclide in a mass chain related to nuclear structure published since about a year before the literature cut-off stated in the previous ENSDF evaluation. Example: for A=218, should search literature from about January 2005. In heavy mass regions, where alpha-decays are dominant modes of decay, one needs to search for parent nuclides as well, for example, for alpha decays of relevant A=222 nuclides.

Evaluating a mass chain: collection of literature

-Download (collect) copies of references that are used in the previous ENSDF evaluation. Consult NSR database for all the references prior (and up to the cut-off date of previous evaluation) to make sure if all the older references are covered. All experimental structure-related references pertaining to a certain nuclide should be cited. If no data are taken from certain references for a nuclide, these can be listed under others.

-Secondary references (conference proceedings, theses, lab reports, private communications, etc.) should also be consulted, especially, when not superseded by formal publications, in which case evaluators may wish to check with the original authors whether such data (generally, but not always, of a preliminary nature) should be used in ENSDF evaluations.

-Structure theory articles: papers with model calculations of levels, spins and parities, transition probabilities, etc. for a relevant nuclide should also be consulted. Examples: 2017Ib01, 2001Za04 for ^{218}Rn; 2005Bo18, 2005Za02, 1998Ra05 for ^{218}Ra; 2003Ca21 for ^{218}U, etc.

Evaluating a mass chain: computer codes

-Familiarity with the use of the following computer codes:

-Analysis codes: GTOL, GABS, BrIcc, BrIccMixing, LOGFT, ALPHAD, RULER, RADLST, V-AVELIB, (ALPHAD-NEW), (J-GAMUT).

-Format and physics checking codes: FMTCHK, PANDORA.

-ENSDF format to Tables/drawings in .PDF: JAVA-NDS.

-The ENSDF format is 80-column text-based. Use a text editor or much more advanced EVP screen editor (from NNDC). The EVP editor automatically keeps track of column-based .ensdf format. In addition, it offers running all the analysis and utility codes within its features, including calculation of weighted averages.

Evaluating a mass chain: updating data sets

- Each nuclide must have an “ADOPTED” data set, followed by individual decay data sets for each type of decay (α decay, β^-, $\varepsilon+\beta^+$, IT), and each (or in some cases combined) type of reaction, whatever studies are available in literature for a nuclide.

-The decay data sets require special attention, as quite often these are of importance in applications, need evaluation of absolute photon intensities (i.e. per 100 decays of the parent). Special procedures are used in ENSDF evaluations to deduce gamma-normalization factors, and decay branching ratios when a nuclide decays by more than one decay mode, e.g. a $(29/2)^+$ isomer in ^{217}Ac at 2 MeV decays 95.7% by IT and 4.3% by α.

-Update / revise all the individual data sets first. In each data set, listing available of angular distribution / correlation coefficients, DCO and/or angular asymmetry ratios (ADOs), polarization coefficients, measured internal conversion coefficients, sub-shell ratios, etc. need to be listed in support of multipolarity assignments and multipole mixing ratios. If mixing ratios are from internal conversion data, make sure these are consistent with conversion coefficients from BrIcc; use BrIccMixing code.

Example: ^{218}Fr nuclide: individual data sets

Current **ENSDF database** (Jan 2006):

^{222}Ac α decay (5.0 s); decay of ground state

^{222}Ac α decay (63 s); decay of an isomer (energy not known)

^{209}Bi(^{18}O,2αnγ): high-spin study up to (24+)

Note: no separate data sets for half-lives, decay modes and other structure properties such as magnetic dipole moments, electric quadrupole moments, etc. for ground states and long-lived isomers. These quantities are compiled, discussed and evaluated in the Adopted data sets.

Current **XUNDL database**, dataset after Jan 2006:

U(p,X): measurement of magnetic dipole moment, radius, and half-life of an isomer at 86 keV in ^{218}Fr: information available from this work for the isomer will be discussed only in the Adopted data set

NSR search of experimental papers after Jan 2005 shows 7 references, out of which 3 seem relevant. Check also reference lists in papers in case NSR is missing some paper.

Example: ^{218}Fr nuclide: ^{222}Ac α decay (5.0 s)

^{222}Ac α decay (5.0 s) **1982Bo04,1972Es03,1964Mc21**

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Ashok K. Jain, Balraj Singh	NDS 107, 1027 (2006)	25-Jan-2006

Parent: ^{222}Ac: E=0.0; $J^{\pi}=1^{-}$; $T_{1/2}$=5.0 s *5*; Q(α)=7137.4 *20*; %α decay=99.0 *10*

^{222}Ac-$T_{1/2}$: from measured values of 5.5 s *5* (1952Me13) and 4.2 s *5* (1958To25). Other: 5 s *1* (1972Es03).

^{222}Ac-%α decay: %α=99 *1*. Possible ε branching was estimated by 1966Wa23 as 1-2% from Iα(7.13-MeV α) of ^{218}Rn shown in ^{222}Ac α spectrum by 1964Mc21. Calculated partial $T_{1/2}$>100 s for ^{222}Ac β decay (1997Mo25) gives (%ε+%β^{+})<5.

Other: 1991Ga28: $\alpha\alpha$ correlations from successive α decays.

Q(α)=7137.4 *20* from Eα=7008.6.

^{218}Fr Levels

E(level)	J^{π}	Comments
0	1^{-}	J^{π}: from 'Adopted Levels'.
46 *11*		

α radiations

Eα	E(level)	Iα†#	HF‡	Comments
6963 *10*	46	6 *1*	28 *6*	Eα: from 1964Mc21. Original energy has been increased by 11 keV, as recommended by 1991Ry01.
7008.6 *20*	0	94 *1*	2.6 *3*	Eα: recommended by 1991Ry01 from energies measured by 1982Bo04, 1972Es03 and 1964Mc21. The original energies were changed because of changes in calibration energies used. The original energies and the changes (+ for increased energies, and - for decreased Eα's) are 7013 *2* (−4.4) (1982Bo04), 7010 *20* (+1.4) (1972Es03), 6998 (−1.6) (1964Mc21). Others: 1988Hu08, 1968Ha14, 1958To25, 1951Me10.

† α intensity per 100 α decays. These Iα's are the values recommended by 1991Ry01 from Iα's measured by 1964Mc21.

‡ $r_0(^{218}$Fr)=1.5401 *20* is used in calculations.

For absolute intensity per 100 decays, multiply by 0.99 *1*.

Decay data sets: special treatment

When possible, need to normalize the decay scheme for determination of photons/100 decays of the parent.

The following quantities and assignments need to be the same as in the Adopted data set: level spins and parities, level half-lives, gamma-ray multipolarities and mixing ratios, and as far as possible theoretical conversion coefficients. Measurements made in the decay data sets in support of these quantities should be detailed in comments.

When possible RADLST code should be run to compare the total decay energy deduced from the given decay scheme with the decay Q value; indicating completeness of the decay scheme.

A=218

All work will not get completed by October 26, 2018.
Some additional work will be required in the next few weeks.

Please correspond with the group leader of the nuclide assigned to you.

Expected completion of first draft by December 21, 2018

Final draft to send for review by February 28, 2019.

Possible joint publication in Nuclear Data Sheets journal ~ July 2019 under the authorship of group leaders, and participants who contribute effectively to this evaluation.