

# ALPHAD\_RadD-v1.0

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This ALPHAD\_RadD-v1.0 code is an extension of original ALPHAD program, based on Preston's spin-independent formalism [1]. The extended code automatically deduces radius parameter ( $r_0$ ) for odd-A and odd-odd alpha emitters by employing interpolation or extrapolation procedures [2] using a recent data file of evaluated  $r_0$  parameters, as given in 2020Si16 [3] for ground-state to ground-state alpha transitions in 186 even-even nuclei, followed by deduction of alpha hindrance factors [1]. Additionally, the ALPHAD\_RadD code has an option of inputting user-supplied radius parameter. 2020Si16 evaluation [3], an update to 1998Ak04 [4] evaluation, presents updated  $Q_\alpha$  values (primarily from AME2016) half-lives, and other relevant quantities required for the deduction of  $r_0$  parameters of even-even alpha emitters, with literature cutoff date of June-2020, with no new relevant references up to November 2020. In the ALPHAD\_RadD code, some bugs in the original ALPHAD code, as pointed at some data meetings, were resolved by Tim Johnson at NNDC and by us.

## Features of the ALPHAD\_RadD code

### Case 1: Even-Even Alpha emitters

The value of deduced radius parameter for ground-state to ground-state transition is automatically inserted by ALPHAD\_RadD code in the ENSDF-formatted data file.

### Case 2: Odd-Odd and Odd-A Alpha emitters

The ALPHAD\_RadD code automatically deduces radius parameter, using an interpolation procedure for  $r_0$  parameters for the neighboring nuclides [2], employing our recent evaluation of  $r_0$  parameters of even-even nuclides, followed by deduction of HFs for alpha transitions. The deduced radius parameter for a particular alpha decay dataset is inserted in the corresponding ENSDF -formatted data file, together with appropriate comments. Additionally, the code has an option of accepting user-supplied  $r_0$  parameter (*Note: If the ALPHAD\_RadD code is executed multiple times on a particular alpha decay data set,  $r_0$  statement is added to the output file each time the code is executed. A user needs to remove the multiply inserted  $r_0$  parameter statements*).

## Handling of asymmetric and large fractional uncertainties in $T_{1/2}$ and other quantities:

ALPHAD\_RadD and ALPHAD codes do not handle asymmetric, and large (>30% or so) fractional uncertainties correctly. These codes read only the first uncertainty in half-life that appears in a parent record of input file in the .ensdf format. Users can consider running the code(s) multiple times to estimate the uncertainty in  $r_0$  parameter for such cases, as for example, with the input of mean value, mean value + the upper limit, and mean value - the lower limit. Non-numeric uncertainties such as LT, LE, GT, GE and AP are ignored in ALPHAD\_RadD and ALPHAD codes. User should consider assigning (reasonable) numeric uncertainties in such cases.

### Input files:

#### (1) 2020\_r0\_EE.DAT

This is the main input file containing  $r_0$  parameters of 186 nuclei listed in our recent evaluation of radius parameters of even-even alpha emitters (2020SI16) [3]. The data values listed in this file are appearing as per following format:

Column No.	Details of Input value
1-5	Parent Z
6-9	Parent N
10-18	Daughter radius parameter ( $r_0$ )
19-27	Uncertainty in daughter radius parameter

#### (2) ELE.IN

This file contains nuclide symbols along with their atomic numbers. This file is used to list nuclide symbols of alpha parent and alpha daughter nuclei.

### Some sample input, report and output ENSDF Files provided in ALPHAD\_RadD package

Input ENSDF	Report File	Output ENSDF	$r_0$ parameter (fm)
210Ra.ens	210Ra.rpt	210Ra.out	1.4989(56)
217Po.ens	217Po.rpt	217Po.out	1.55206(14)
194Bi.ens	194Bi.rpt	194Bi.out	1.5187(42)

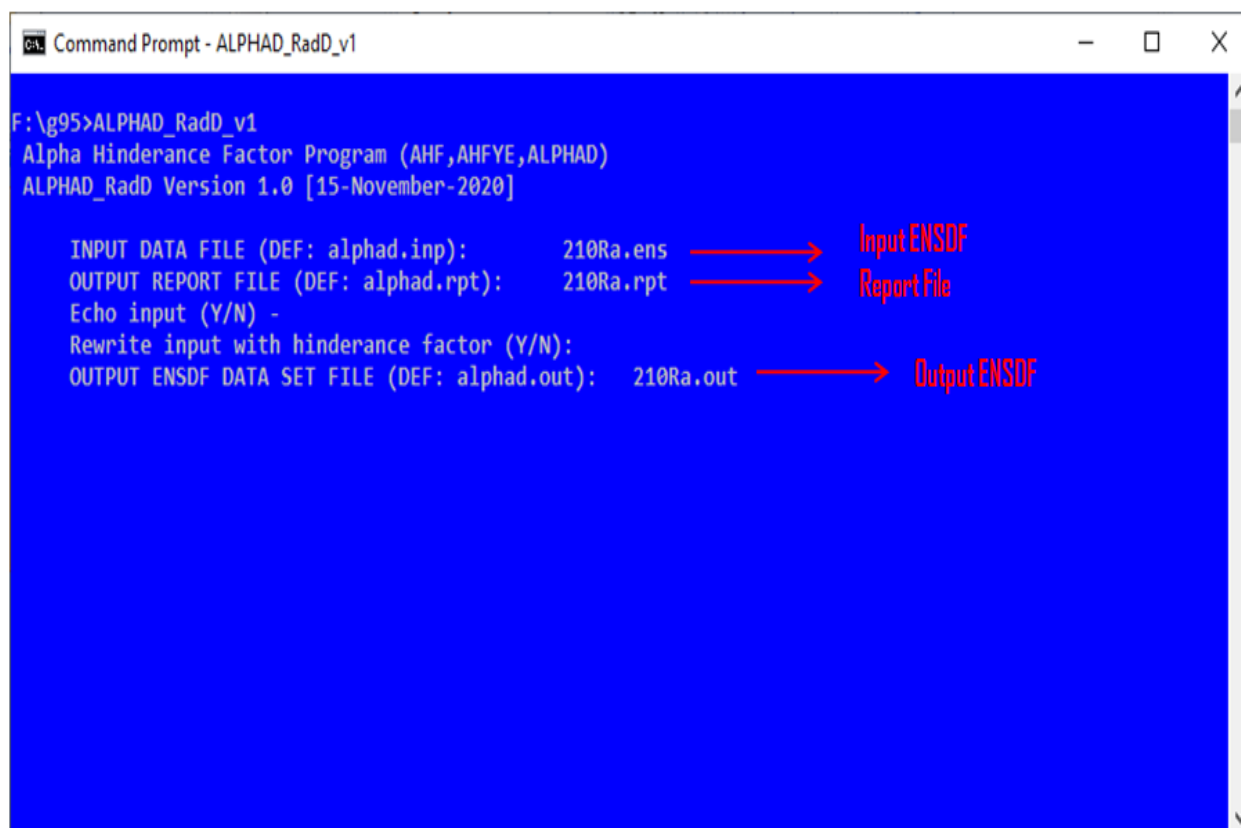
### References

- [1] M.A. Preston. Phys. Rev. 71, 865 (1947).
- [2] M. J. Martin, *Guidelines for Evaluators*, Appendix E, page 73 (October 2019).
- [3] Sukhjeet Singh, Sushil Kumar, Balraj Singh, and A.K. Jain, Nuclear Data Sheets 167, 1 (2020).
- [4] Y.A. Akovali, Nuclear Data Sheets 84, 1 (1998).

## Step by step execution of ALPHAD\_RadD for even-even, odd-odd and odd-A nuclides

### Even-even nuclide (example: $^{210}\text{Ra}$ )

Typical input consol for  $^{210}\text{Ra}$  is shown in Fig. 1. The code writes the value of radius parameter in output file with appropriate comment (see Fig.: 2).



```
Command Prompt - ALPHAD_RadD_v1

F:\g95>ALPHAD_RadD_v1
Alpha Hinderance Factor Program (AHF,AHFYE,ALPHAD)
ALPHAD_RadD Version 1.0 [15-November-2020]

INPUT DATA FILE (DEF: alphad.inp):      210Ra.ens  —————> Input ENSDF
OUTPUT REPORT FILE (DEF: alphad.rpt):    210Ra.rpt  —————> Report File
Echo input (Y/N) -
Rewrite input with hinderance factor (Y/N):
OUTPUT ENSDF DATA SET FILE (DEF: alphad.out):  210Ra.out  —————> Output ENSDF
```

Fig. 1: Console of ALPHAD\_RadD for  $^{210}\text{Ra}$

TextPad - F:\g95\210Ra.out

File Edit Search View Tools Macros Configure Window Help

Find incrementally

210Ra.out x

```

210RA 214TH A DECAY 14NDS 201408
210RA H TYP=FUL$AUT=M. SHAMSUZZOHA BASUNIA$CIT=NDS 121, 561 (2014)$
210RA2 H CUT=31-Mar-2014$
210RA c {+214}Th |e branch was estimated by 1995E107 as |<0.2% from the |b
210RA2c gross theory of 1973Ta30. The r{-0} parameter, calculated by using
210RA3c %|a=99.9 {I1}, fits the local r{-0} trend.
210RA D NO CALCULATION FOR T1/2(EC) OF 214TH IS GIVEN IN 1997MoZW.
210RA c The partial half-life for {+214}Th |b{++} decay was
210RA2c calculated by 1997Mo25 as 19.4328 s, which gives %|b{++}=0.51.
210RA cA HF$The nuclear radius parameter r{-0}({+210}Ra)=1.4989 {I56}
210RA2cA is deduced by assuming HF=1.0 for the ground-state to
210RA3cA ground-state alpha decay branch.
214TH P 0.0 0+ 87 MS 10 7827 5
210RA N 0.999 1
210RA L 0.0 0+ 3.7 S 2
210RA cL T$From Adopted Levels
210RA A 7678 10 1.0
210RA cA E Weighted average of 7680 {I10} (1968Va18), 7677 {I10}
210RA2cA (1980Ve01) and 7670 {I20} (1984Sc13). Uncertainty - lowest
210RAxcA experimental value.
210RA cA IA only one |a group has been observed. Upper limit on
210RA2cA intensity of an unobserved 7090-keV |a to 2+ state
210RA3cA is estimated as <0.93 per 100 |a decays by assuming
210RA4cA its hindrance factor to be <1 (the 2+ level energy of E(2+)|?600
210RA5cA is used which is obtained by extrapolation from 2+ level energies in
210RA6cA heavier radium isotopes). Possible |a transitions to higher level
210RA7cA are neglected.

```

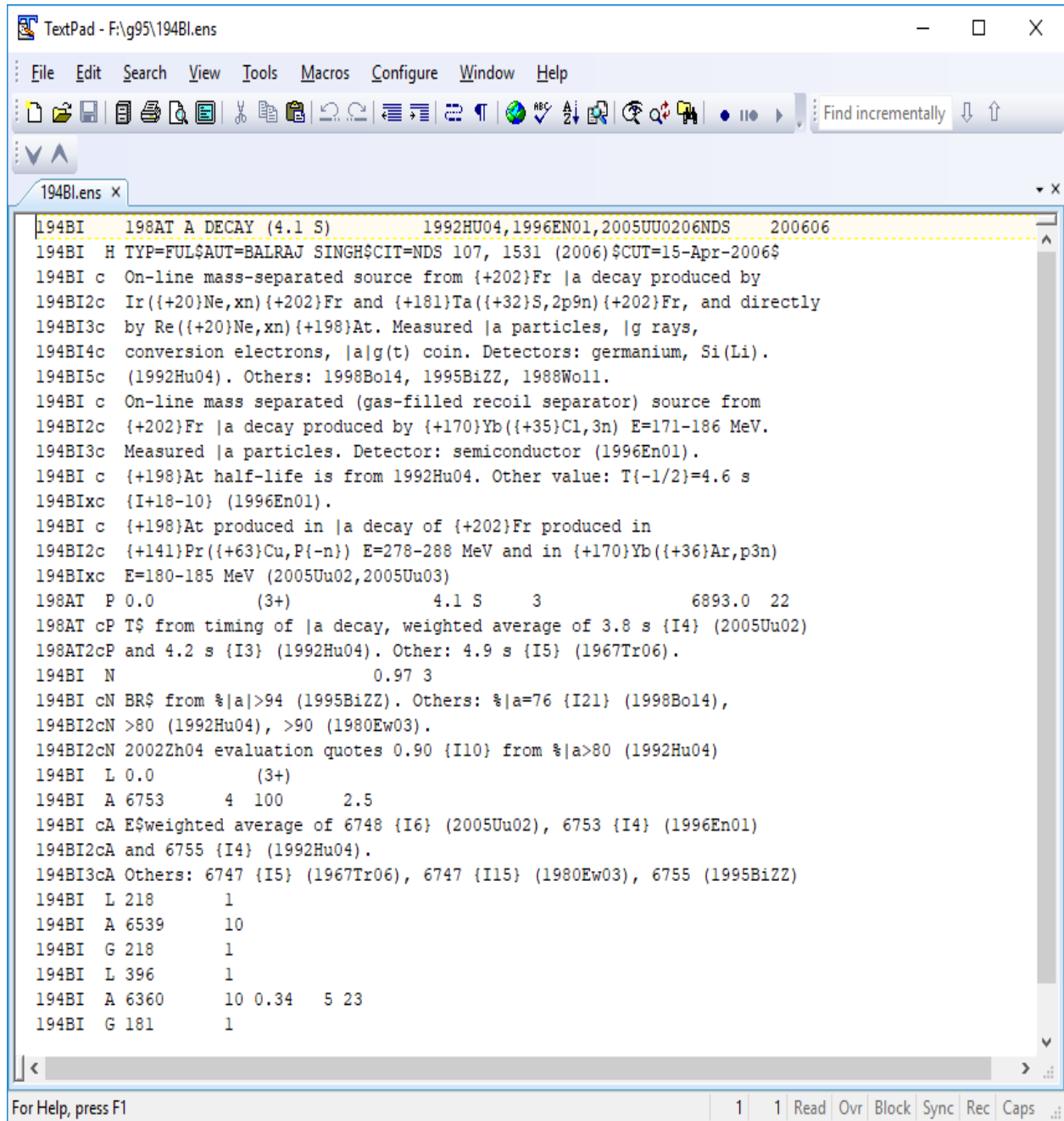
Comment inserted by ALPHAD\_RadD

For Help, press F1 29 1 Read Ovr Block Sync Rec Caps

Fig.:2 Output file of ALPHAD\_RadD

## Odd-odd nuclide (example $^{194}\text{Bi}$ )

The code automatically deduces  $r_0$  parameter, followed by deduction of HFs.



```

194BI 198AT A DECAY (4.1 S) 1992HU04,1996EN01,2005UU0206NDS 200606
194BI H TYP=FUL$AUT=BALRAJ SINGH$CIT=NDS 107, 1531 (2006)$CUT=15-Apr-2006$
194BI c On-line mass-separated source from (+202)Fr |a decay produced by
194BI2c Ir((+20)Ne,xn){+202}Fr and (+181)Ta((+32)S,2p9n){+202}Fr, and directly
194BI3c by Re((+20)Ne,xn){+198}At. Measured |a particles, |g rays,
194BI4c conversion electrons, |a|g(t) coin. Detectors: germanium, Si(Li).
194BI5c (1992Hu04). Others: 1998Bo14, 1995BiZZ, 1988Wo11.
194BI c On-line mass separated (gas-filled recoil separator) source from
194BI2c (+202)Fr |a decay produced by (+170)Yb((+35)Cl,3n) E=171-186 MeV.
194BI3c Measured |a particles. Detector: semiconductor (1996En01).
194BI c (+198)At half-life is from 1992Hu04. Other value: T(-1/2)=4.6 s
194BIxc {I+18-10} (1996En01).
194BI c (+198)At produced in |a decay of (+202)Fr produced in
194BI2c (+141)Pr((+63)Cu,P{-n}) E=278-288 MeV and in (+170)Yb((+36)Ar,p3n)
194BIxc E=180-185 MeV (2005Uu02,2005Uu03)
198AT P 0.0 (3+) 4.1 S 3 6893.0 22
198AT cP T$ from timing of |a decay, weighted average of 3.8 s {I4} (2005Uu02)
198AT2cP and 4.2 s {I3} (1992Hu04). Other: 4.9 s {I5} (1967Tr06).
194BI N 0.97 3
194BI cN BR$ from %|a>94 (1995BiZZ). Others: %|a=76 {I21} (1998Bo14),
194BI2cN >80 (1992Hu04), >90 (1980Ew03).
194BI2cN 2002Zh04 evaluation quotes 0.90 {I10} from %|a>80 (1992Hu04)
194BI L 0.0 (3+)
194BI A 6753 4 100 2.5
194BI cA E$weighted average of 6748 {I6} (2005Uu02), 6753 {I4} (1996En01)
194BI2cA and 6755 {I4} (1992Hu04).
194BI3cA Others: 6747 {I5} (1967Tr06), 6747 {I15} (1980Ew03), 6755 (1995BiZZ)
194BI L 218 1
194BI A 6539 10
194BI G 218 1
194BI L 396 1
194BI A 6360 10 0.34 5 23
194BI G 181 1

```

Fig.3: Input file of  $^{194}\text{Bi}$  containing no record corresponding to  $r_0$  parameter

The typical input console and executions of ALPHAD\_RadD for  $^{198}\text{Bi}$  is shown in figures below. After specifying the name of input, report and output files, program gives two options i.e. user can give his own radius parameter OR let the program deduce the value of radius parameter using even-even radius parameters as input:

```
Command Prompt - ALPHAD_RadD_v1
F:\g95>ALPHAD_RadD_v1
Alpha Hinderance Factor Program (AHF,AHFYE,ALPHAD)
ALPHAD_RadD Version 1.0 [15-November-2020]

INPUT DATA FILE (DEF: alphad.inp):      194Bi.ens
OUTPUT REPORT FILE (DEF: alphad.rpt):    194Bi.rpt
Echo input (Y/N) -
Rewrite input with hinderance factor (Y/N):
OUTPUT ENSDF DATA SET FILE (DEF: alphad.out):  194Bi.out

Computations proceeding
Report will be written to file: 194Bi.rpt
Processing ==> 194BI    198AT A DECAY (4.1 S)

Do you want to give your own radius parameter?
Type yes or YES to give it otherwise type no or NO
```

Option through which program can accept radius parameter given by user

Case (a): If user wants to give his own radius parameter then he/she has to type “yes” or “YES”. The snapshot after typing “YES” is shown below:

```
Command Prompt - ALPHAD_RadD_v1
F:\g95>ALPHAD_RadD_v1
Alpha Hinderance Factor Program (AHF,AHFYE,ALPHAD)
ALPHAD_RadD Version 1.0 [15-November-2020]

INPUT DATA FILE (DEF: alphad.inp):      194Bi.ens
OUTPUT REPORT FILE (DEF: alphad.rpt):    194Bi.rpt
Echo input (Y/N) -
Rewrite input with hinderance factor (Y/N):
OUTPUT ENSDF DATA SET FILE (DEF: alphad.out):  194Bi.out

Computations proceeding
Report will be written to file: 194Bi.rpt
Processing ==> 194BI 198AT A DECAY (4.1 S)

Do you want to give your own radius parameter?
Type yes or YES to give it otherwise type no or NO
YES
Enter your own radius parameter defined in the following format
(for example: 1.4568 0.0025)
```

After typing “YES” program ask for the value of radius parameter. The format in which radius parameter should be supplied to program is shown below:

Suppose in case  $^{198}\text{Bi}$  the values for radius parameter and its uncertainty deduced by user are 1.4568 and 0.0025, respectively. The user has to enter the value of radius parameter and its uncertainty separated by one blank space. In present case, the program will accept following number:

1.4568 0.0025

When the radius parameter is supplied in the above said format, then program will do the calculations of HFs and theoretical half-lives and will also insert the value of radius parameter in the output file. The snapshot of output file is shown below:



```

194BI 198AT A DECAY (4.1 S) 1992HU04,1996EN01,2005UU0206NDS 200606
194BI H TYP=FUL$AUT=BALRAJ SINGH$CIT=NDS 107, 1531 (2006)$CUT=15-Apr-2006$
194BI c On-line mass-separated source from (+202)Fr |a decay produced by
194BI2c Ir((+20)Ne,xn)(+202)Fr and (+181)Ta((+32)S,2p9n)(+202)Fr, and directly
194BI3c by Re((+20)Ne,xn)(+198)At. Measured |a particles, |g rays,
194BI4c conversion electrons, |a|g(t) coin. Detectors: germanium, Si(Li).
194BI5c (1992Hu04). Others: 1998Bo14, 1995BiZZ, 1988Wo11.
194BI c On-line mass separated (gas-filled recoil separator) source from
194BI2c (+202)Fr |a decay produced by (+170)Yb((+35)Cl,3n) E=171-186 MeV.
194BI3c Measured |a particles. Detector: semiconductor (1996En01).
194BI c (+198)At half-life is from 1992Hu04. Other value: T(-1/2)=4.6 s
194BIxc (I+18-10) (1996En01).
194BI c (+198)At produced in |a decay of (+202)Fr produced in
194BI2c (+141)Pr((+63)Cu,P(-n)) E=278-288 MeV and in (+170)Yb((+36)Ar,p3n)
194BIxc E=180-185 MeV (2005Uu02,2005Uu03)
194BI cA HF$The nuclear radius parameter r(-0)((+194)Bi)=1.4568 {I25}
194BI2cA as specified by the user.
198AT P 0.0 (3+) 4.1 S 3 6893.0 22
198AT cP T$ from timing of |a decay, weighted average of 3.8 s {I4} (2005Uu02)
198AT2cP and 4.2 s {I3} (1992Hu04). Other: 4.9 s {I5} (1967Tr06).
194BI N 0.97 3
194BI cN BR$ from %|a>94 (1995BiZZ). Others: %|a=76 {I21} (1998Bo14),
194BI2cN >80 (1992Hu04), >90 (1980Ew03).
194BI2cN 2002Zh04 evaluation quotes 0.90 {I10} from %|a>80 (1992Hu04)
194BI L 0.0 (3+)
194BI A 6753 4 100 0.66 6
194BI cA ESweighted average of 6748 {I6} (2005Uu02), 6753 {I4} (1996En01)
194BI2cA and 6755 {I4} (1992Hu04).
194BI3cA Others: 6747 {I5} (1967Tr06), 6747 {I15} (1980Ew03), 6755 (1995BiZZ)
194BI L 218 1
194BI A 6539 10
194BI G 218 1
194BI L 396 1
194BI A 6360 10 0.34 5 5.8 10
194BI G 181 1

```

Comment inserted by ALPHAD\_RadD

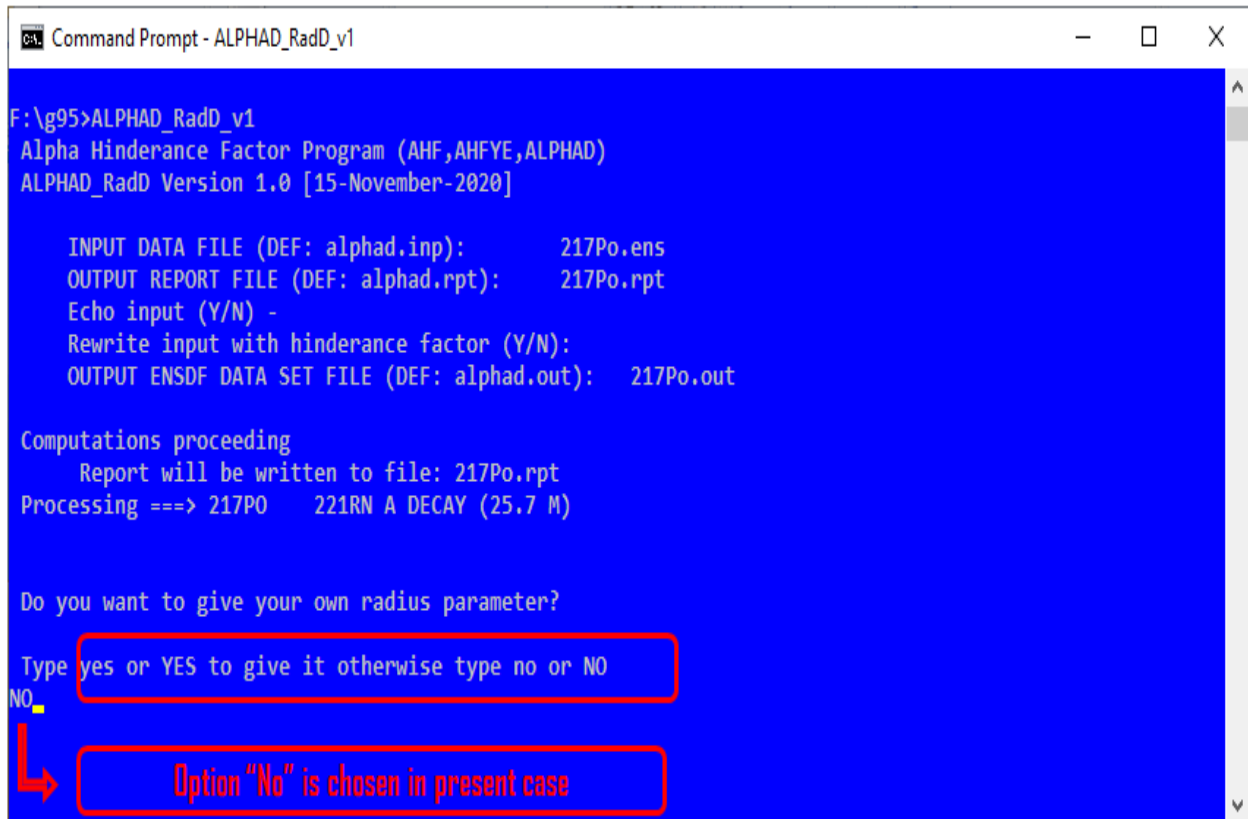
For Help, press F1 1 1 Read Ovr Block Sync Rec Caps

Case (b): If user type “no” or “NO”, it means program will first deduce the value of radius parameter by using the radius parameter of adjacent even-even nuclides listed in *2020\_r0\_EE.DAT*. Then, it will perform calculations of HFs and theoretical half-lives. The deduced value of radius parameter will also be inserted in output file with suitable comment. The snapshot corresponding to this situation is shown for <sup>217</sup>Po nuclide whose case is discussed below.



### Odd-A nuclide (example $^{217}\text{Po}$ )

The execution of the program for this case is same as odd-odd  $^{194}\text{Bi}$ . Again, there are two options for user.



```
Command Prompt - ALPHAD_RadD_v1

F:\g95>ALPHAD_RadD_v1
Alpha Hinderance Factor Program (AHF,AHFYE,ALPHAD)
ALPHAD_RadD Version 1.0 [15-November-2020]

INPUT DATA FILE (DEF: alphad.inp):      217Po.ens
OUTPUT REPORT FILE (DEF: alphad.rpt):    217Po.rpt
Echo input (Y/N) -
Rewrite input with hinderance factor (Y/N):
OUTPUT ENSDF DATA SET FILE (DEF: alphad.out):  217Po.out

Computations proceeding
Report will be written to file: 217Po.rpt
Processing ==> 217PO    221RN A DECAY (25.7 M)

Do you want to give your own radius parameter?
Type yes or YES to give it otherwise type no or NO
NO
Option "No" is chosen in present case
```

Option (a): If the user type “no”, the program will deduce radius parameter by using the radius parameter of adjacent even-even nuclides.

Option (b): User can supply his/her own radius parameter; this situation is already described in case of  $^{194}\text{Bi}$  above.

If user chooses option (a) then following output file will appear. Please note that, the deduced value of radius parameter will be inserted at appropriate place with suitable comment.

TextPad - [F:\Res. Work\DATA EVALUATION\ALPHAD+RadD\Alphad\_RadD\_v1.1-25.07.2020\IAEA\217Po.out]

File Edit Search View Tools Macros Configure Window Help

Find incrementally

217Po.out

```

217PO 221RN A DECAY (25.7 M) 1977VY02,1997LI23,2004LI2818NDS 201802
217PO H TYP=FUL$AUT=B. SINGH, T. ROY, K. BANERJEE$CIT=NDS 147, 382 (2018)$
217PO2 H CUT=1-DEC-2017$
217PO c 1977Vy02: measured E|a, I|a, E|g, I|g, ce
217PO c 1997Li23, 2004Li28: measured E|a, I|a, E|g, I|g, |a|g-coin, half-lives
217PO2c of decays of (+221)Rn and (+217)Po, decay branching ratios.
217PO c Based on configurations of the parent and daughter state fed by
217PO2c 6037|a and corresponding HF, 2004Li28 tentatively propose 6037|a to an
217PO3c 11/2+ state, and the (9/2+) ground state below it at an energy of 9.5
217PO4c or 19.8 keV, and the 254|g and 264|g feeding the 11/2+ state rather
217PO5c than the 9/2+ g.s. However, from (+217)Bi |b(+)- decay studies by
217PO6c 2003Ku25 and 2014Mo02, there does not seem to be any evidence of such a
217PO7c scenario of (+217)Po level scheme
217PO cA E$From 1997Li23 and 1977Vy02, with uncertainties from 1997Li23.
217PO2cA 1977Vy02 quoted uncertainty of 3 keV for each E|a value. Values in
217PO3cA 1977Vy02 were adjusted downward by 2 keV by 1991Ry01 in a
217PO4cA re-calibration procedure
217PO cA IA$Intensities per 100 |a decays, uncertainties are not available.
217PO cG E,RI$From 1977Vy02. The authors normalized I|g values to I|g(218|g
217PO2cG of (+221)Fr decay)=10.7% (I6). The relative Ice values measured by
217PO3cG 1977Vy02, were normalized to Ice(K 218|g)=1.5% (I2).
217PO cL E$From E|g values
217PO cL J,T$From Adopted Levels
217PO cA HF$The nuclear radius parameter r(-0)((+217)Po)=1.55206 (I14)
217PO2cA is deduced from interpolation (or unweighted average) of radius
217PO3cA parameters of the adjacent even-even nuclides.
221RN P 0.0 7/2(+) 25.7 M 5 6148 2
221RN cP J$Spin measured by 1987Bo29, laser spectroscopy. Parity from possible
221RN2cP allowed |b transition to a 294, (9/2)+ level in (+221)Fr. Note that
221RN3cP J|p is 7/2+ in the January 2007-update of ENSDF database for (+221)Rn.
221RN cP T$From 1997Li23 and 2004Li28. Note that in the January 2007-update of
221RN2cP ENSDF database for (+221)Rn, value is 25 min (I2), taken from 1956Mo15,
221RN3cP where 1997Li23 and 2004Li28 references were not included.
221RN cP QP$From E|a=6037 (I2), assuming that this |a feeds the g.s.
221RN2cP rather than a level at 9.5 or 19.8 keV as tentatively proposed
221RN3cP in 2004Li28. Based on the proposal by 2004Li28, 2017Wa10 deduced
221RN4cP 6163 keV (I3)
217PO N 4.3 5 0.20 2
217PO cN NR$Absolute intensities were obtained by 1977Vy02 by normalizing

```

Comment inserted by ALPHAD\_RadD

For Help, press F1

1 1 Read Ovr Block Sync Rec Caps

Odd-odd and odd-A nuclide for which deduction of radius parameter is not possible through ALPHAD\_RadD (example  $^{216}\text{Ac}$ )

There are certain cases for which deduction of radius parameter is not possible. This situation occurs when  $r_0$  parameters for one or both neighboring even-even alpha emitters are not available in the input file. In such cases, an appropriate message will be displayed on screen and user has to give his/her own radius parameter as shown below for  $^{216}\text{Ac}$ :

```

F:\g95>ALPHAD_RadD_v1
Alpha Hinderance Factor Program (AHF,AHFYE,ALPHAD)
ALPHAD_RadD Version 1.0 [15-November-2020]

INPUT DATA FILE (DEF: alphad.inp):      216Ac.ens
OUTPUT REPORT FILE (DEF: alphad.rpt):    216Ac.rpt
Echo input (Y/N) -
Rewrite input with hinderance factor (Y/N):
OUTPUT ENSDF DATA SET FILE (DEF: alphad.out):  216Ac.out

Computations proceeding
Report will be written to file: 216Ac.rpt
Processing ==> 216AC    220PA A DECAY

Do you want to give your own radius parameter?
Type yes or YES to give it otherwise type no or NO
NO

=====
CALCULATION FOR RADIUS PARAMETER
=====

Alpha Parent      Daughter      Radius (fm)
=====
Ele  Z  N  A      Ele  Z  N  A
-----

The radius parameter could not be deduced as one of the even-even input radius parameter does not exist in the
2020_r0_EE.DAT data file.

Enter your own radius parameter defined in the following format
(for example: 1.4568 0.0025)

```

In such cases, if option “no” is selected, the code prints the following message: “*the radius parameter could not be deduced as one of the even-even input radius parameter does not exist in the 2020\_r0\_EE.DAT data file.*”