

KC02.HIVA.TEXT(INFO)

**HIVAP**

**Status 20-6-90**

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### **Use of logic units**

#### **1. Required datasets and their logic unit number**

5 standard input  
6 standard output  
9 mass table 'MASSES'  
10 POPP1 buffer arrays for E-J population, dynamic. allocated by ALLOCH  
11 POPP2 buffer arrays for E-J population, dynamic. allocated by ALLOCH  
12 POPA1 buffer arrays for E-J population, dynamic. allocated by ALLOCH  
13 POPA2 buffer arrays for E-J population, dynamic. allocated by ALLOCH  
23 SYSOUT(A) output print, lists input data, dynamic. allocated by ALLOCH

#### **2. Conditionally required datasets**

14 yrast lines 'IYR', needed if 'IRAST' not=0 for reading (not tested)  
16 dataset results from 'ROT', needed only if TSTROT not=0  
19 dataset for calculated AM population fission channel or entry J dist.  
    required if JFIS > 0  
21 dataset for transmission coefficients, dynamically allocated by TRANSM  
    required only if IOWKB = 0 and IOVER > 0  
22 dummy dataset, when less print-out is desired (LPRINT>3)  
    dynamically allocated by ALLOCH  
25 dataset for results in format compatible with plotting package  
    required if IDISC > 0

### 3. Allocating outside GSI

The routines ALLOCH and TRANSM use GSIALC and GSIFRE (GSI-specific) for dynamic allocation of the logic units 10,11,12,13,15,21,22. Outside GSI ALLOCH,GSIALC,GSIFRE must be replaced by dummy routines and the allocations must be done by JCL(job control language).

As a help for the space needed:POPP1,POPP2,POPA1,POPA2 (units 10 to 13) are real arrays (dimension 4096), there must be space for at least NA such arrays in each one. NA is an input parameter explained below. All these are buffer arrays, that are only needed during the calculation

### 4. New load module(at GSI)

When source program has been changed, a new load module is created in the following way:

- a) Change in HIVAP (main) the version number
- b) Compile source HIVA.FORT(AA) under ISPF menu 4.12 with HIVA.FORT as INCLUDE library

there may be B37 problems, check if enough space for HIVA.OBJ or AA.LIST or use NOLIST,NOSOURCE option

- c) use EX LINK(HIVA) 'name'  
creates load module HIVA.LOAD(name)  
at the time the programme size is ca .75 Mbytes

## HIVAP INPUT PARAMETER SUMMARY

All parameters are in free input format, subject to a few limitations. There can be any text in between the parameter values ('numbers'). However numbers must be distinguishable from the text: they must be either at the beginning of a line or preceded by a blank or an equal sign =. A consequence of this rule is that numbers in parentheses are not recognized as numbers. There must be a number for each required parameter. Each 'group' of parameters can be written on one or several lines, but a new group must start with a new line. In the following input summary we have indicated by the separation lines(-----) which parameters belong to a 'group'. On input these separation lines are optional(as is the text between the 'numbers'). None of the lines should exceed column 72;

### Abbreviations:

LD	liquid drop
AM,J	angular momentum
CN	compound nucleus
N	neutron
P	proton
A	alpha
F	fission
G	gamma
GDR	giant dipole resonance
default(or def) means the value actually used if zero was inputted	
EP,JP	parent excitation, spin
ED,JD	(or EF,JF) daughter excitation, spin

Please avoid using options marked 'do not use' or 'not tested'

TITLE /\*Comment line\*/

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IAP, IZP, IAT, IZT, ISHELL, ISHELF, IPAIR, MC, MP, IBF, IFISRT, NOFISS, NON, NOP, NOA,  
NOG, IDISC, IGAM

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NA, NZ, MASSES, NUMB, IOVER, INERT, INERF, FINERT, ILIM, LPRINT, LOGUN, ICOR, NUMISO  
LDBM, IRAST, IOWKB , ITRANS, JFJI

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Required only if 'JFJI'=1: 'ALICE' approximation  
DJ(2), DJ(3), DJ(4)

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Required only if 'IGAM' not=0: (non-standard gamma emission)  
EG1WU, EG2WU, EG1MIN, EG1MAX, EG2MIN, EG2MAX, JFACTOR

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Required only if 'IGAM' not=0: (non-standard gamma emission)  
CGIANT, EGIANT, WGIANT, STRIPE, IOPT

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CST, CLD, BARFAC, ESHELL, BARO, SHELLO, DELT, QVALUE

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Required only if 'ILIM' not=0: (non-standard cut parameters)  
CUT, FRACT2, ABSMIN, PRCN, SIGLOW, DEL1, NOLEP, NOLJI, NOLJF

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Required only if IOVER<0: (non-standard transmission coeffic.)  
IOVER, IOWKB, ITRANS, SIGLOW, TLLOW, DEL(2), Q0(FM2), OMN, OMP, OMA, IPTR

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Required only if IOVER<0 and if OMN not zero: neutron potential  
VRN, RORN, ADIFRN, VIN, ROIN, ADIFIN

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Required only if IOVER<0 and if OMP not zero: proton potential  
VRP, RORP, ADIFRP, VIP, ROIP, ADIFIP, RCOULP, CBFACP

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Required only if IOVER<0 and if OMA not zero: alpha potential  
VRA, RORA, ADIFRA, VIA, ROIA, ADIFIA, RCOULA, CBFACA

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If 'NUMISO' not 0: (Isomers)  
(ISOZ ISOA ISOJ) /\*NUMISO TIMES CONTINUOUS\*/

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If 'INERT' not 0: (exp yrast)  
ENERGY SPIN ENERGY SPIN ENERGY SPIN

---

Only if 'IFISRT' =1:  
A2MS,ROMS,C3MS,RKAPPA,NOROTF,FINERF,RKAPA4

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IF NUMB>0:  
QVALUE

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IF NUMB>0:  
IZ,IA,K,BE(IZ,IA,K) /\* 3 PER LINE, SEVERAL OPTION\*/

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IF IBF=2:  
BF(1,1) (9F8.3)

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IF IBF=3:  
(BF(IZ,IA),IA=1,NA),IZ=1,NZ) (9F8.3)

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Elab loop(repeat following lines every energy):  
E,IEXC,IFUS,LIMBAR,JLOWER,JUPPER,NEWFIS,ITESTROT,JFIS,E1

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If NEWFIS=1: (do not use)  
CLD,BARFAC

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If IFUS=1:  
FLCRIT,DELTAL

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If IFUS=2:  
RATIO

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If IFUS=3:  
FLCRIT

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if IFUS=5:  
SIGFUS,DELTAL

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if IFUS=7 and IAP >4:  
V0,RO,D

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if IFUS=8:  
V0,RO,D,Q0(FM2),CRED,NOCURV,NOPROX,IOPT,ITEST

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If IFUS=9:  
SIGMAJ(J) J=JLOWER to JUPPER

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if IFUS=10:  
V0,RO,D,Q0(FM2),CRED,NOCURV,NOPROX,IOPT,ITEST,SIGRO

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if IFUS=11:  
V0,RO,D,Q0(FM2),CRED,NOCURV,NOPROX,IOPT,ITEST,SIGRO,CUTOFF,XTH,APUSH,FPUSH

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Last line above ends Elab loop

-1.000

one blank

one blank or new case

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#### PARAMETER DESCRIPTION

TITLE any comment fitting into one line(72 columns)

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IAP projectile mass, alias 'AP'

IZP nuclear charge of projectile, alias 'ZP'

IAT target mass, alias 'AT'

IZT nuclear charge of target, alias 'ZT'

ISHELL shell correction control for level density in equilibrium configuration, alias 'SHELL'

0 no shell correction

1 shell correction, shell energies are calculated analytically using formulas from Myers-Swiatecki(MS67)  
recommended if no mass table available

② shell correction, shell energies are obtained by subtracting from the experimental masses the LD masses (MS67)  
recommended if mass table available  
is reset to 1 if MASSES not equal 9 (i.e. exp mass table)

ISHELF shell correction control for level density in saddle point configuration, alias 'SHELF'

0 no shell correction

1 the shell correction at saddle is equal to the shell correct. at equilibrium (technical)

③ the shell correction is inferred from the zero angular mom. fission barrier that is actually used(recommended)  
 $Shsd = Bf(0) - BfLD(0) + Shgs$   
 $BfLD(0) = BfLD(0, FISROT) * BARFAC$

IPAIR alias 'PAIR'  
is set zero internally if ISHELL=0  
pairing correction control for level density, see also DELT

0 no pairing correction

1 standard pairing correction, odd mass nuclei are the reference

2 shifted pairing correction, even-even nuclei are the reference  
recommended if no mass table available

4 shifted pairing correction, even-even nuclei are the reference  
pairing is determined from mass tables  
recommended if mass table available(i.e. MASSES=9)

is reset to 2 if MASSES not=9

MC for Myers-Swiatecki masses(MS67);  
is set =1 internally if ISHELL=0  
    0 with shell corrections, recommended  
    1 without shell corrections

MP for Myers-Swiatecki masses(MS67);  
is set =1 internally if ISHELL=0  
    0 with pairing corrections, recommended  
    1 without pairing corrections

IBF fission barrier control for l=0 barriers:  
    0 barrier = BARFAC\*BfLD(FISROT) + BAR0  
    ① barrier = BARFAC\*BfLD(FISROT) + BAR0 - Shellgs, recommended  
    2 user barriers at l=0, same for all nuclei, will be entered  
    3 user barriers at l=0, one for each nuclei, will be entered

IFISRT alias 'FISROT'  
    0 use CPS 1974 liquid drop barriers (FISROT)  
    1 non-standard parameters for FISROT(calc of BfLD) will be used  
    → 2 use Sierk 1984 liquid drop barriers (BARFIT)

NOF 1 fission is suppressed, default(0) is recommended

NON 1 neutron emission is suppressed, default(0) is recommended

NOP 1 proton emission is suppressed, default(0) is recommended

NOA 1 alpha emission is suppressed, default(0) is recommended

NOG 1 gamma emission is suppressed, default(0) is recommended

IDISC alias DISC  
    0 no action  
    1 put ER cross sections on disc (log.unit=25 )  
        (for individual nuclei)  
    2 put on disc (log.unit=25) excitation functions for  
        fusion, total evaporation, and fission cross sections,  
        sum xn,pxn,2pxn etc  
        (compatible with FITER)  
    3 combined action of IDISC=1 and 2

IGAM alias 'GAMMAS'  
    1 non-standard gamma emission(recommended)  
    0 standard is E1: GDR and E2: 10 Weisskopf units/MeV  
        EGR=80/A\*\*.3333, width= 5 MeV

NA maximum number of neutrons emitted + 1, DEFAULT=14  
 NZ maximum number of protons emitted+1, default=1(no protons)  
 the CPU time is roughly proportional to NA\*NZ  
 MASSES where to get masses from:  
     0 MS 1967 mass formula (obligatory if no mass table availab)  
     not 0: is set=9, will read masses from LOG UNIT 9(on disc)  
 NUMB number of separation energies entered explicitly by user  
     these will override those obtained from the mass table  
 IOVER parameter for transmission coeffs TL of N P A, alias 'INVER'  
     =0: calculate transmission coefficients, no read or write disc  
         recommended together with WKB=1  
     =1: read from disc or else calculate then write on disc  
         does not read or write if WKB=1  
     =2: no read from disc, calculate, then write on disc  
     <0: non-standard transmission coefficients  
 INERT 1: flag telling there will be exp yrast line data inputted  
 INERF not used for the moment  
 FINERT macroscopic rigidity of nuclei, default is 1  
     also affects saddle point rotation  
 ILIM alias 'LIMITS'  
     0: nothing (normal)  
     1: wants to read non standard cut off parameters, see 'CUT' etc  
 LPRINT alias 'PRINT'  
     concerns amount of printout(most output for smallest 'LPRINT')  
     0: maximum output(lots of trees to cut)  
     1: less parent J-E distributions, less emission tables  
     2:  
     3: no sequence printout(sequence=one evaporation step)  
     4: no sequence and no row print out (only energy and case)  
     5: only case printout(case is one given reaction)  
 LOGUN dummy parameter, set zero  
 ICOR 0: print X-sections in F format(in mb)(> 1 microbarn)  
     1: print X-sections in E format  
 NUMISO number of isomers (zero normally)  
 LDBM level density parameter (recommended value is 1)  
     0: use conventional formula for level density, see CST and CLD  
     >0: use Töke-Swiatecki formula for level density, see CST

and CLD

for 1 the ratio  $a_f/a_n$  reaches 1 as function  
of AM

as fission barrier reaches zero, for 2 or 4 this ratio  
does not vary as function of AM, for 3 or 4 the  
shell corrections are not J-dependent and the  
exp. yrast energies, if any, are ignored

IRAST	0: normal use	
	1: will get yrast lines directly from disc, log unit 14	
IOWKB	alias WKB	
	0: get transmission coeff. with optical model(OVER2)	
	1: " " " with <u>WKB</u> approx.(OWKB), recommended	
	2: OM for N,P; WKB for alphas	
ITRANS	0: calc.transm.coeff once per Z, recommended	
	1: calc.transm.coeff every 3rd mass (do not use)	
JFJI	0: exact angular momentum coupling	0
	1: averaged AM coupling('ALICE' option, less CPU)	
	recommended for most cases, unless AP+AT<130	

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Required only if 'JFJI'=1:

DJN	average AM taken away by N, recommended: 1
DJP	average AM taken away by P, recommended: 1
DJA	average AM taken away by A, recommended: 3

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Non standard gamma emission('IGAM' not =0):

EG1WU	gamma strength E1 in Weisskopf units/MeV, default is pure GDR recommended:0.01, together with JFACTOR=1 for CN masses > 150; for lighter nuclei this may be too large by a factor 2 to 5; more experience on this is needed; also see under 'Further explanations' below
EG2WU	gamma strength E2 in Weisskopf units/MeV recommended:10
EG1MIN	min.energy of E1 gammas, default is 1 MeV
EG1MAX	max.energy of E1 gammas, default is 20 MeV
EG2MIN	min.energy of E2 gammas, default is 1 Mev
EG2MAX	max.energy of E2 gammas, default is 4 MeV

JFACTOR 1: gamma strength will be multiplied by 2J+1

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Non-standard gamma emission('IGAM' not =0):

CGIANT GDR strength(for cross section in mb), default(0) (no GDR)

EGLANT GDR energy,default is  $80/A^{**0.333}$  MeV

WGLANT GDR width, default is 5 MeV

STRIPE technical, set zero

IOPTG technical, set zero

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CST alias LEVELPAR

for LDBM = 0:

quantity for level density parameter 'a'=(AP+AT)/CST,def=10.

for LDBM = 1 or 2:

scaling parameter for level dens. r0, default=1.16 (TS) )

1.153 (WR)

CLD alias AF/AN

for LDBM = 0:

$a_f/a_n$ ,ratio of level density parameters at saddlept

and for ground state configuration, default=1

\* for LDBM = 1 or 2:

any value not 1 Töke-Swiatecki 1981 formula

1 WR formula for levdens

BARFAC factor with which LD fission barriers will be multiplied,  
see also 'NOROTF', default is 1

ESHELL shell damping energy, default is 18.5 (MeV),alias EDAMP

BARO overall(constant) shell correction energy at saddle point  
normally zero

SHELLO overall(constant) shell correction energy in ground state  
configuration, normally zero

DELT pairing correction parameter, default=11.,gap=DELT/SQRT(A)

QVALUE program normally calculates Q-value from mass table, but if  
any non zero value is inserted here, it will be substituted

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This only if 'ILIM' = 1:

CUT default is 0.001  
fraction of parent population that can be neglected;  
this is used in CUTOFF (which is called by GRIDS which is  
called by HIVAP) before each evaporation step(SEQUENCE) in  
order to 'trim' the parent population array; the J and E  
dimensions are trimmed down so that for each no more than  
the given fraction is lost

FRACT2 default is 0.001

ABSMIN default is 0 (in mb)  
these parameters determine when the calculation is to be broken  
off in N and Z direction; when going along a certain isotope row  
(Z=const), the calculation is broken off when the last population  
count gives less than SUMLOW; SUMLOW is the larger of the 2  
quantities(in mb): ABSMIN resp. FRACT2 times maximum isotope  
cross section found so far in the current isotope row;  
FRACT2 also determines the last Z to be included (Z<=NZ) in a  
similar way;

PRCN fraction in % that can be cut off in parent population by  
'level' trimming(see CUTOFF subroutine); the default is to use  
a percentage that is compatible with CUT

SIGLOW inverse cross section(mb) cutoff, default: 0.001 mb  
only operative if transmission coeff. are recalculated

DEL(1) lowest gamma ray energy, default is 1 MeV, technical,

NOLEP always use 1, technical

NOLJI always use 1, technical

NOLJF always use 1, technical

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Non-standard transmission coefficients('IOVER'<0):

IOVER parameter for transmission coefficients N P A ,alias 'INVER'  
see above, must be > 0 here

IOWKB alias 'WKB'  
0: get transmission coeff. with optical model(OVER2)  
will require log.unit 21  
1: " " " with WKB approx.(OWKB),no read-write  
2: OM for N,P; WKB for alphas

ITRANS 0: calc.transm.coeff once per Z

1: calc.transm.coeff every 3rd mass  
SIGLOW inverse cross section(mb) cutoff, default: 0.001 mb  
TLOW cut off for inverse transmission coefficients, default: none  
DEL(2) lowest energy of emitted neutrons, minimum and default=0.1MeV  
Q0(FM2) average quadrupole moment(fm2) of emitting nuclei  
in testing stage  
OMN 1: flag for non-standard neutron potential  
OMP 1: flag for non-standard proton potential  
OMA 1: flag for non-standard alpha potential  
IPTR 1: print out transmission coeff and inverse sigmas

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if OMN = 1 neutron potential  
VRN real potential depth(MeV)  
RON radius parameter  
ADIFRN diffuseness  
VIN imaginary potential depth  
ROIN radius parameter  
ADIFIN diffuseness

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if OMP = 1 proton potential  
VRP real potential depth(MeV)  
ROP radius parameter  
ADIFRP diffuseness  
VIP imaginary potential depth  
ROIP radius parameter  
ADIFIP diffuseness  
RCOULP Coulomb radius parameter  
CBFACP factor allowing to change Coulomb barrier(default=1)

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if OMA = 1 alpha potential  
VRA real potential depth(MeV)  
ROA radius parameter  
ADIFRA diffuseness  
VIA imaginary potential depth  
ROIA radius parameter  
ADIFIA diffuseness  
RCOULA Coulomb radius parameter

CBFACA factor allowing to change Coulomb barrier(default=1)

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Isomers(NUMISO>0):

ISOZ Z location : Z of compound nucleus minus Z of isomer nucleus+1  
ISOA N location : N of compound nucleus minus N of isomer nucleus+1  
ISOJ Ang.Mom. of isomer(rounded to integer)

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Required only if 'IFISRT' not=0:

A2MS surface parameter for 'FISROT', default=17.9439  
R0MS Coulomb radius parameter for 'FISROT', default=1.2249  
C3MS Coulomb parameter for 'FISROT', default=0.7053  
Dahlinger value is 0.72913  
RKAPPA isospin dependence parameter of surface energy in 'FISROT',  
default=1.7826, Dahlinger value is 0.38033  
NOROTF 0: NOOP  
1: BARFAC operates on J=0 part of macroscopic fission barriers  
2: shape changes in macroscopic rotation are neglected  
(constant moment of inertia)  
FINERF macroscopic rigidity of nucleus at saddle point, def=FINERT  
(divisor of rotational part of saddlepoint yrast line)  
RKAPA4 isospin\*\*4 dependence parameter of surface energy in 'FISROT'  
default=0, Dahlinger value is 20.489

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This card only if 'NUMB'>0:

QVALUE user supplied Q-value

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This line only if 'NUMB'>0: repeat four variables 'NUMB' times

IZ ZCN-Zresidual+1  
IA ACN-Aresidual+1  
K 1: neutron, 2: proton, 3: alpha  
BE separation energy(MeV)

---

Required only if IBF=2 (not tested so far)

BF(1,1) ground state(J=0) fission barrier ; WILL BE THE SAME FOR ALL  
NUCLEI

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Required only if IBF=3 (not tested so far)  
((BF(IA,IZ),IA=1,NA),IZ=1,NA) J=0 fission barriers for all nuclei in  
evaporation residua-array

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\*\*\*\*\* FOLLOWING LINES ARE ENERGY LOOP : \*\*\*\*\*

SIGR0, CUTOFF, XTH, APUSH, FPUSH additionally  
 allows for fluctuating barrier with truncated Gaussian,  
 and for extrapush, see above

LIMBAR 0: standard  
 1: LCRIT is limited by fission barrier  $BF(LCRIT) > 0.1 \text{MEV}$   
 used in 'PARAP' or 'FUSION'(IFUS=0,8)

JLOWER angular momentum of lowest partial wave, default=0

JUPPER " " highest " " , default is determined  
 internally by program

NEWFIS 0: standard  
 1: will read new values for the parameters 'CLD' and 'BARFAC'  
 at every energy(not recommended)

TSTROT 1: will write results from ROT (yrast lines on disc, log unit  
 16 must be allocated by JCL

JFIS >0: log.unit 19 must be allocated by JCL  
 1: will write fission J-distribution on disc for each fission  
 step  
 2: will write entry J-distribution for each evaporation step  
 3: as 1 + 2  
 4: writes J distr. of CN and of fission(summed over all steps)  
 recommend to use DJN=DJP=DJA=0 or JFJI=0  
 recommend also high accuracy (see LIMITS)  
 if used to obtain survival to fission as function of J,  
 then recommend option IFUS=9 with partial cross sections=1  
 5: as 4, but 1-Jdistr., i.e. Per if partial x-sect were=1

EN only operative if IFUS=8 or 10  
 allows to calculate cross sections averaged over target;  
 E and EN correspond to the energy upstream and downstream  
 of the target

Only if, 'NEWFIS' not=0: (do not use)

CLD SEE ABOVE

BARFAC SEE ABOVE

if 'IFUS'=1: (use only well above the barrier)

LCRIT critical angular momentum for fusion

DELTAL diffuseness of partial waves distribution

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if 'IFUS'=2: (use only well above the barrier)

RATIO ratio of X-section for fusion to reaction

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if 'IFUS'=3: (use only well above the barrier)

LCRIT critical angular momentum for fusion

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if 'IFUS'=5: (use only well above the barrier)

SIGFUS fusion cross section in mb

DELTAL diffuseness of partial waves distribution

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if 'IFUS'=7:

V0,R0,D depth, radius parameter and diffuseness(fm) of potential  
for inverted parabola for partial fusion x-sections, AP>4;  
for alphas,protons, neutrons uses opt.model(OM) and requires

V0,R0,D,W,RI,DI,RCOUL i.e. in addition to real pot also imag.pot

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if 'IFUS'=8 or 10: (recommended)

V0 strength parameter of nuclear potential, see also 'NOCURV'  
recommended: 40

R0 radius parameter(recommended: 1.12)

R=R0\*AT\*\*0.3333 for n,p

R=1.6+R0\*AT\*\*0.3333 for alphas

R=R0\*(AT\*\*0.3333+AP\*\*0.3333) for HI

D diffuseness parameter,recommended: 0.75

Q2 quadrupole moment of target nucleus in fermi squared  
or BETA value of quadrupole deformation (if <1)

CRED barrier thickness parameter, default=1.(<1 more transparency)

NOCURV 0: nuclear pot V is prop. to reduced curvature radius:

V=V0\*RCURV, recommended

1: reduced curvature radius is not used(set=1.), V=V0

NOPROX 0: minimum distance between nuclear surfaces is calc. exactly  
recommended

1: minimum distance between nuclear surfaces is taken along  
the center line

IOPT -1: nuclear pot is Woods-Saxon

0: nuclear pot is exponential(recommended)  
1: nuclear pot is exponential with central radii correction  
2: full proximity pot with central radii correction  
3: full proximity pot without central radii correction  
4: exp proximity pot with central radii correction  
5: Bass potential, V0, R0, D will be changed internally

ITEST  
-1: parabolic barrier, no print  
0: WKB , no print  
1: WKB , small print(recommended)  
2: WKB , full print  
3: parabolic barrier, full print

SIGR0 required if IFUS=10 or IFUS=11  
percent fluctuation of parameter R0 (standard deviation)  
recommend 4 to 5 (spherical target nuclei)  
recommend 6 to 6.5 (deformed target nuclei)

CUTOFF required only if IFUS=11, integration limit for fluctuations  
in units of SIGR0, default is 2.5

XTH required if IFUS=11, threshold x value in extrapush theory,  
0 is no extrapush, typical value = 0.7

APUSH required if IFUS=11, slope coefficient in extrapush theory  
typical values 10 to 18

FPUSH required if IFUS=11, angular momentum coefficient in extrap.  
theory, default is 0.75

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If 'IFUS'=9:

SIGML(I) partial fusion cross sections from JLOWER to JUPPER

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\*\*\*\*\* ENERGY LOOP ENDS HERE, THERE CAN BE SEVERAL ENERGY LOOPS,

last energy must be -1.0

last input line must be blank,unless a new case (see TITLE) is  
started

OPTICAL MODEL FOR NEUTRON, PROTON, ALPHA

AT, ZT mass and charge of residual nucleus

the following are default values

C----- NEUTRON

c Wilmore-Hogdson NP55(64)673

c as cited in Perey ADNDT13(74)293

V=47.01 - 0.267\*E

RV=1.322-7.6E-4\*AT +4.E-6\*AT\*AT -8.E-9\* AT \*\*3.

AV=.660

C

S=1.00 ! surface absorption flag

W=9.520 -0.053\*E

RW=1.266-3.7E-4\*AT +2.E-6\*AT\*AT -4.E-9\*AT \*\*3.

AW=0.48

C

VSO=7.00 ! spin orbit as recommended by Perey

RSO=RW

ASO=AW

RCLMB=.001

C ----- PROTON

C BECCHETTI-GREENLEES PR182(1969)1190

C as cited by Perey ADNDT13(74)293

C

V=54. + 24.\* (AT-2.\*ZT)/AT + 0.4\*ZT/AT\*\*0.33333 - 0.32\*E

RV=1.17

AV=.750

C

S=1.00 ! surface absorption flag

W=11.8 + 12.\* (AT-2.\*ZT)/AT - 0.25\*E

RW=1.32

AW=.51 + 0.7\*(AT-2.\*ZT)/AT

RCLMB=1.16

C

VSO=6.2 ! spin orbit

RSO=1.01

ASO=.75  
 C-----ALPHA  
 c Satchler NP70(65)177  
 V=50.2  
 RV=1.2+1.5/AT\*\*0.33333 ! SATCHLER ORIGINAL  
 C RV=1.275+1.5/AT\*\*0.33333 ! MODIFIED, used in older versions  
 AV=.564  
 W=12.30  
 C  
 RW=1.2+1.5/AT\*\*0.33333 ! SATCHLER  
 C RW=1.25 ! modified, used in older versions  
 AW=.564  
 RCLMB=1.30

WKB parameters neutron,proton,alpha  
 C  
 HBAR=.65819E-21  
 AMU=1.03641E-44  
 ROFUS=0.  
 CRED=1. ! parameter of VLRO(reduced mass is nominal)  
 NORUTH=1 ! parameter of VLRO  
 NOPROX=1 ! parameter of VLRO  
 NOCURV=1 ! parameter of VLRO  
 ION=1 ! parameter of VLRO  
 ITEST=0 ! parameter of VLRO  
 IOPT=-1 ! parameter of VLRO (Woods-Saxon)

C-----  
 C NEUTRONS ,see Perey above  
 VO=VRN ! as inputted by user (OMN=1)  
 R0=RORN "  
 D=ADIFRN "  
 IF(V0.LE.0.) V0=47.01  
 IF(R0.LE.0.) R0=1.322 - 7.6E-4\*AT + 4.E-6\*AT\*AT - 8.E-9\*AT\*\*3.  
 ROT=R0

IF(D.LE.0.) D=0.660

C-----

C PROTONS OWN FIT

V0=VRP

R0=RORP

D=ADIFRP

C PEREY 1963 POT

C IF(V0.LE.0.) V0=53.3+27.\* ( AT-2.\*ZT)/AT +0.4\*ZT/AT\*\*0.33333

C IF(R0.LE.0.) R0=1.25

C Following WKB POT FITTED TO KURCEWICZ DATA TH232+P(1981), in use

IF(V0.LE.0.) V0=62

IF(R0.LE.0.) R0=1.254

ROT=R0

IF(D.LE.0.) D=0.750

C-----

C--ALPH-MODIFIED SATCHLER (IGO USE V0=1100.;R0=1.17-1.6/AT3;D=0.574)

C FITTED TO ALPHA FUSION DATA SEP 81

V0=VRA

R0=RORA

D=ADIFRA

IF(V0.LE.0.) V0=50.2 ! same as Satchler

IF(R0.LE.0.) R0=1.2067 ! satchler uses 1.2

ROT=R0+1.6/AT3 ! alpha radius 1.6, Satchler uses 1.5

IF(D.LE.0.) D=0.564 ! same as Satchler

## HIVAP LOOP STRUCTURE

There is a loop hierarchy which is the basis to understand the program.  
This hierarchy is as follows:

- 1) CASE loop (a given projectile-target system)
- 2) ENERGY loop (a given excitation energy of the initial compound nucleus or projectile energy)
- 3) ROW(Z) loop (a given Z of the residual nuclei, starting with the Z of the CN)
- 4) SEQUENCE(N) loop (a given A, or N, of the residual nuclei, starting with CN)
- 5) EP loop (a given 'parent' excitation)
- 6) JP loop (a given parent spin)
- 7) JD loop (a given 'daughter' spin)
- 8) ED loop (a given daughter excitation)

## HIVAP SUBROUTINE STRUCTURE(approximate)

HIVAP

Case loop

GAMMAS

SEPNENF (MSBEN, FISROT, BARFIT)

Energy loop

OM (TLD) or PARAP or FUSE(MYREAD, or FUSION (VLRO -VO-VL-VR,  
INVPAR) TWKB -WKB,  
PARABO,  
FISROT)

Row loop

Sequence or step loop

TRANSM (OVER2 (TLD) or OWKB (FUSION))

SEQIN (DROPB)

ROT (FISROT,  
BARFIT,  
DECOD,  
MYRD,  
IP2)

GRIDS (SUMPOP,  
GETPUT,  
CUTOFF,  
TOT)

DENSTY (FISROT,  
BARFIT,  
BETA,  
SLITE)

EVA (DENSTY,  
POPUL)

SEQOUT (OUT1,  
OUT2,  
GETPUT,  
FISROT,  
TOT)

```
    end sequence loop
    ROWOUT (OUT1)
    GETPUT
end row loop
ENGOUT (CASOUT)
end energy loop
CASOUT
end case loop
end HIVAP
```

## HIVAP subroutines

ALLOCH dynamical allocation units 10,11,12,13,22,23  
BETA gets most probable deformation as function of temperature  
free from D. Vermeulen 1983  
BARFIT liquid drop barriers according to Sierk  
free from Sierk, 1984  
CASOUT print output within case loop  
CUTOFF eliminates negligible elements in the E-J population (to save  
CPU time) and reassesses the optimal E and J dimensions  
DECODN input parameter reading routine  
DENSTY calculates level densities  
DROPB droplet model routine (free from Myers), calls DROPL  
serves to calculate surface ratio of saddlepoint and equilibrium  
configurations, which in turn influences  $a_f/a_n$

ENGOUT print output within energy loop  
EVA core of program, calculates daughter ED-JD population from  
parent EP-JP population, calls POPUL  
FISROT get CPS 1974 liquid drop barriers, free from Plasil  
FUSE gets fusion partial cross sections (various options, including  
Bass model)  
FUSION calculates fusion partial cross sections using WKB method,  
various nucleus-nucleus potentials, allowing for deformed  
target nuclei and increased sub-barrier transparency,  
calls VLRO(entries VO, VL, VR), TWKB(entry WKB), PARABO, FISROT  
more powerful version (FUSIO) is being developed  
GAMMAS calculate gamma strength functions  
GETPUT stores or reads buffer E-J populations (logic units 10 to 13)  
GRIDS routine preparing the E-J populations prior to the main calcul.  
(done in EVA), calls GETPUT, SUMPOP, TOT, CUTOFF  
GSIALC GSI-specific dynamic allocation routine  
GSIFRE GSI-specific routine for dynamic FREE of allocated datasets  
IP1 linear interpolation  
IP2 parabolic interpolation  
MSBEN gets separation energies using Myers-Swiatecki 1967 Lysekil

parameterisation  
 MYRD input parameter reading routine  
 OM calculates absorption cross sections (using optical model) for N,P,A; used for N,P,A induced reactions (at low energies)  
 OUT1 print out routine for 1-dimensional arrays, 'A' is maximum value, 9,8 etc are respectively a factor 2,4 etc less  
 OUT2 print out routine for 2-dimensional arrays, 'A' is maximum value, 9,8 etc are respectively a factor 2,4 etc less  
 OVER2 calculates N,P,A transmission coefficients for evaporation calculation, using optical model, calls TLD  
 OWKB same as OVER2, but using WKB method, calls FUSION  
 PARABO get location and value of maximum of a parabola  
 PARAP calculate fusion partial cross section using parabolic method (Hill-Wheeler)  
 POPUL used by EVA  
 ROT get or calculate yrast lines (also at saddle point)  
 ROWOUT print output within row(Z) loop  
 SEPENF calculate Q-value, separation energies for N,P,A, fission barriers, get shell correction energies calls MSBEN, FISROT, reads mass table log.unit.9  
 SEQIN routine initialising variables specific to a given current parent nucleus about to undergo evaporation (separation energies, level density parameters, etc)  
 SEQOUT print output within sequence(N) loop  
 SUMPOP adds up populations of different parent origin (via xn,pxn,αxn) but going to the same residual nucleus  
 TLD calculate transmission coefficients for N,P,A in double precision, called from OVER2 and OM  
 TOT get sum and first moments of E-J population  
 TRANSM gets transmission coefficients for N,P,A from disc (log.unit.21) or from calculations (calls OVER2 or OWKB) and optionally writes them on disc  
 TWKB calculates 'fusion transmission coefficients using WKB approximation, has entry WKB  
 VLRO calculates nucleus-nucleus potential has different entries V0, VL, VR

### A note on the accuracy

HIVAP is primarily a technical structure. The physics consists in a judicious choice of the input parameters and options. The defaults provided, though not meaningless, may be inadequate in specific cases. The modular structure allows to modify HIVAP and change its various parts concerning, say, fusion, level densities, yrast lines, fission barriers, transmission coefficients for emitted particles etc, and last but not least the desired print out. If physics changes have been made, they should be stated when citing HIVAP. Unfortunately HIVAP is not a nice 'black box' always yielding 'true' cross sections, no matter how it is used.

The reliability for a given decay channel in a given reaction is best investigated by 1)finding out to which input parameters the calculation is particularly sensitive (example: in heavy element production the fission barriers would be the most important parameter to watch). It was our philosophy to make every parameter that could conceivably influence the results a variable input parameter, just for the above purpose; 2)assessing how well the input parameters are fixed a priori by either a (supposedly) good theoretical prediction or some independent experimental piece of evidence (example: the fusion cross section, or the yrast line may be known experimentally).

Some statistical properties are still scantily known. For example, the  $\gamma$ strength function at high AM and excitation, or the level densities at high AM close to the yrast line. The latter are interconnected and the E1  $\gamma$ strength recommended here is likely to be 'effective', compensating for the lack of a realistic level density approach that works for the 'yrast stripe'.

For very high excitations ( $> 100$  MeV), the statistical theory itself is at question.

Unfortunately, for 'exotists', the more exotic a nucleus produced, the more likely the prediction for its (small) peak cross section is sensitive to even minor changes in the input assumptions.

In general the accuracy will be better for the main decay paths and the results least trustworthy either for a very rare decay path or an excitation function far off its maximum. The statistical theory contains many functions with essentially exponential behaviour. It is therefore on a logarithmic scale that one should look and compare with data: differences by less than a factor two are often 'excellent' agreement in cases where the predictions are very sensitive on certain input parameters. The 1 MeV by 1 h E-J grid also limits the accuracy. No details of the  $\gamma$ -deexcitation pattern can be expected on this grid level.

Please advise me if errors are found in the program( I am only human) and/or if unexplained or suspicious discrepancies experiment/calculation show up.

Input example (including JCL cards).

At GSI the JCL's (all lines starting with //) allocating FT10F001, FT11F001, FT12F001, FT13F001, FT22F001, and FT23F001 are not necessary since they are allocated dynamically by the program, some of the other allocations are only necessary if certain input parameters are set (see Use of logic units) At GSI, except for the line allocating MASSESLZ and KC02.PROG.LOAD, you must replace the account number KC02 by your own. A newer version is sometimes available as HIVAPN (see second JCL). Remember: except for the TITLE line, the text in the input (starting after the SYSIN JCL) is immaterial (use it for memory).

```
//KC02H      JOB  300
//S3       EXEC  PGM=HIVAP
//STEPLIB  DD   DSN=KC02.PROG.LOAD,DISP=SHR
//G.FT05F001 DD  DDNAME=SYSIN
//G.FT06F001 DD  SYSOUT=A
//G.FT09F001 DD  DSN=KC02.TABLES.DATA(MASSESLZ),DISP=SHR
//G.FT10F001 DD  DSN=KC02.POPP1.DATA,DISP=OLD
//G.FT11F001 DD  DSN=KC02.POPP2.DATA,DISP=OLD
//G.FT12F001 DD  DSN=KC02.POPA1.DATA,DISP=OLD
//G.FT13F001 DD  DSN=KC02.POPA2.DATA,DISP=OLD
//G.FT14F001 DD  DSN=KC02.ROT.DATA,DISP=SHR
//G.FT16F001 DD  DSN=KC02.TSTROT.DATA,DISP=OLD
//G.FT19F001 DD  DSN=KC02.JFISS.DATA,DISP=OLD
//G.FT22F001 DD  DUMMY
//G.FT23F001 DD  SYSOUT=A
//G.FT25F001 DD  DSN=KC02.HIDATA.DATA(TB153AH),DISP=OLD
//G.SYSIN    DD  *
```

12C +141PR(153TB) THIS IS THE TITLE LINE

31-7-81 AH

---

```
AP= 12      ZP=6          AT= 141      ZT= 59
ISHELL(GS)= 2  ISHELL(SADDLE)= 2  PAIRING= 4  MC= 0  MP= 0
IBF= 1  FISROT PARAMETERS= 0
NOFISSION= 0  NONEUTRONS= 0  NOPROTONS= 0  NOALPHAS= 0  NO GAMMAS= 0
```

DISC=0 GAMMA PARAMETERS(IGAM)= 1

NEUTRONS= 8 PROTONS= 2

MASSES LOG UNIT= 9 NUMB= 0 IOVER= 1 INERT= 0 INERF= 0 FINERT= 1  
LIMITS= 1 PRINT= 3 LOGUN= 0 ICOR= 0 ISOMERS= 0 LDBM= 1  
IRAST= 0 WKB= 1 ITRANS= 0 JFJI = 1

ONLY IF JFJI EQUAL (1)

ANG.MOM. LOSS NEUTRONS 1 PROTONS 1 ALPHAS 3

ONLY IF IGAM NOT ZERO

EG1WU= 0.01 EG2WU=10 EG1MIN= 1 EG1MAX= 7  
EG2MIN= 1 EG2MAX= 4 JFACTOR= 1

ONLY IF IGAM NOT ZERO

CGIANT= 0 EGIANT= 0 WGIANT= 0 STRIPE= 0 IOPT= 0

CST=1.153 CLD=1 BARFAC=0.8 EDAMP= 18.5 BARO= 0  
SHELL0= 0. DELT= 0. QVALUE= 0.

ONLY IF LIMITS NOT ZERO

CUT=0 FRACT2=0 ABSMIN=0 PRCN=0 SIGLOW=0 DEL1=0 NOLEP=1 = 1 = 1

ONLY IF OVER LESS ZERO

OVER= OWKB= TRANS= SIGLOW= TLLOW= DEL2= Q=  
OMN= OMP= OMA= IPTR=

ONLY IF OVER LESS ZERO AND OMN NOT ZERO OPT MODEL NEUTRONS

VRN= RORN= ADIFRN= VIN= ROIN= ADIFIN=

ONLY IF OVER LESS ZERO AND OMP NOT ZERO OPT MODEL PROTONS

VRP= RORP= ADIFRP= VIP= ROIP= ADIFIP=  
RCOULP= CBFACP=(1)

ONLY IF OVER LESS ZERO AND OMA NOT ZERO OPT MODEL ALPHAS

VRA= RORA= ADIFRA= VIA= ROI= ADIFIA=

RCOULA= CBFACA=(1)

---

ONLY IF ISOMERS NOT ZERO

ROW= STEP= SPIN= AND ROW= STEP= SPIN=

---

ONLY IF INERT NOT ZERO (LOWER PART YRAST LINE)

ENERGY(1.85) SPIN (6) ENERGY (4.25) SPIN(14) ENERGY(12.2) SPIN(36)

---

ONLY IF FISROT NOT ZERO

A2MS ROMS C3 KAPPA NOROTF FINERT KAPPA4

---

E= 65 EXC 1 FUS=5 LIMBAR=0 JLOW=0 JUP=0 0 TSTROT=0 JFIS=0 EN= 0  
SIGFUS 1000 DELTAL 1

---

E= 70 EXC 1 FUS=5 LIMBAR=0 JLOW=0 JUP=0 0 TSTROT=0 JFIS=0 EN= 0  
SIGFUS 1085 DELTAL 1

---

E= 80 EXC 1 FUS=8 LIMBAR=0 JLOW=0 JUP=0 0 TSTROT=0 JFIS=0 EN= 0  
VO 40 R0 1.12 D .75 Q .3 CRED 1 NOCURV 0 NOPROX 0 IOPT 0 ITEST 0

---

-1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0