Fusión Nuclear

Química Nuclear

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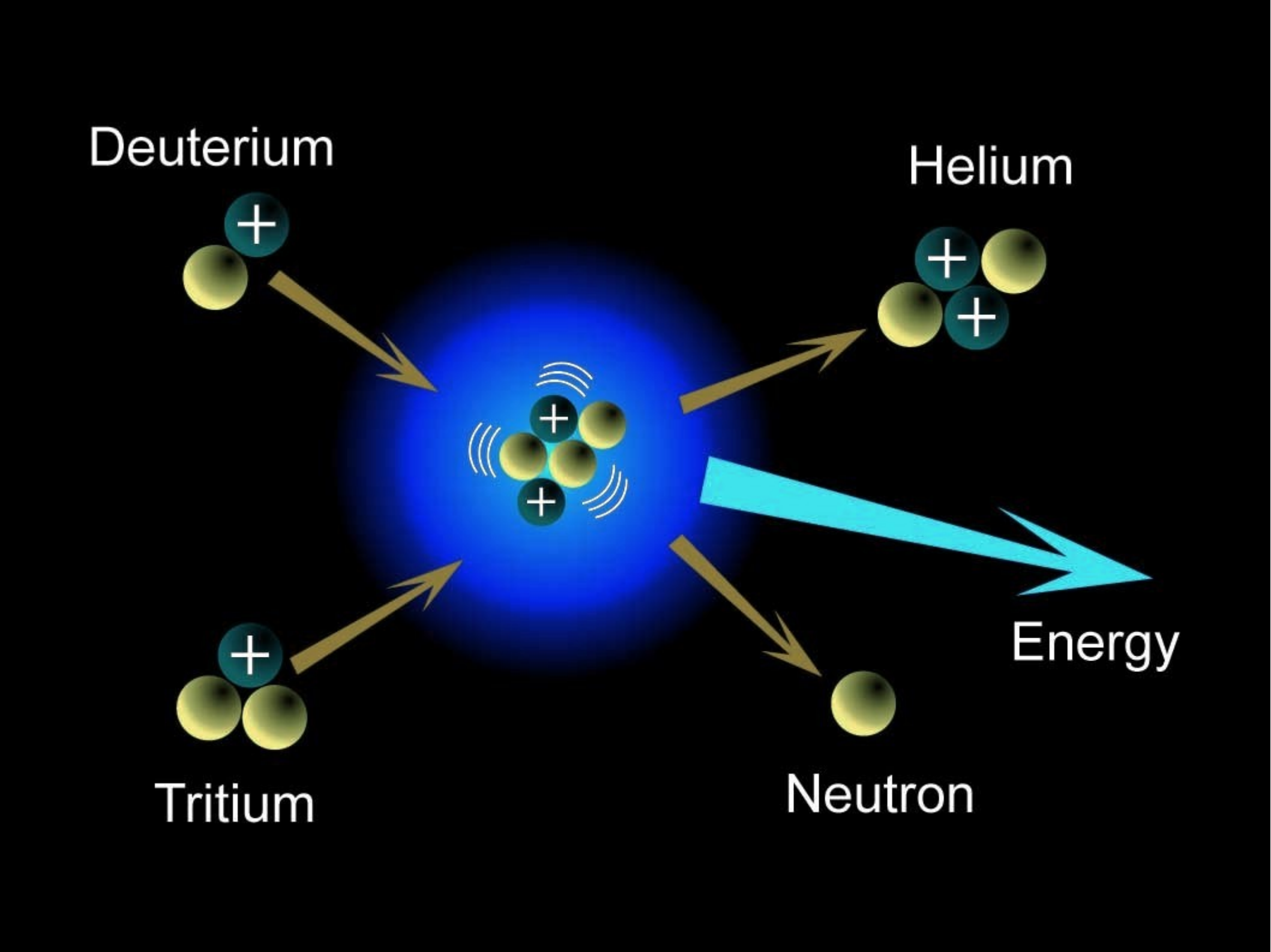
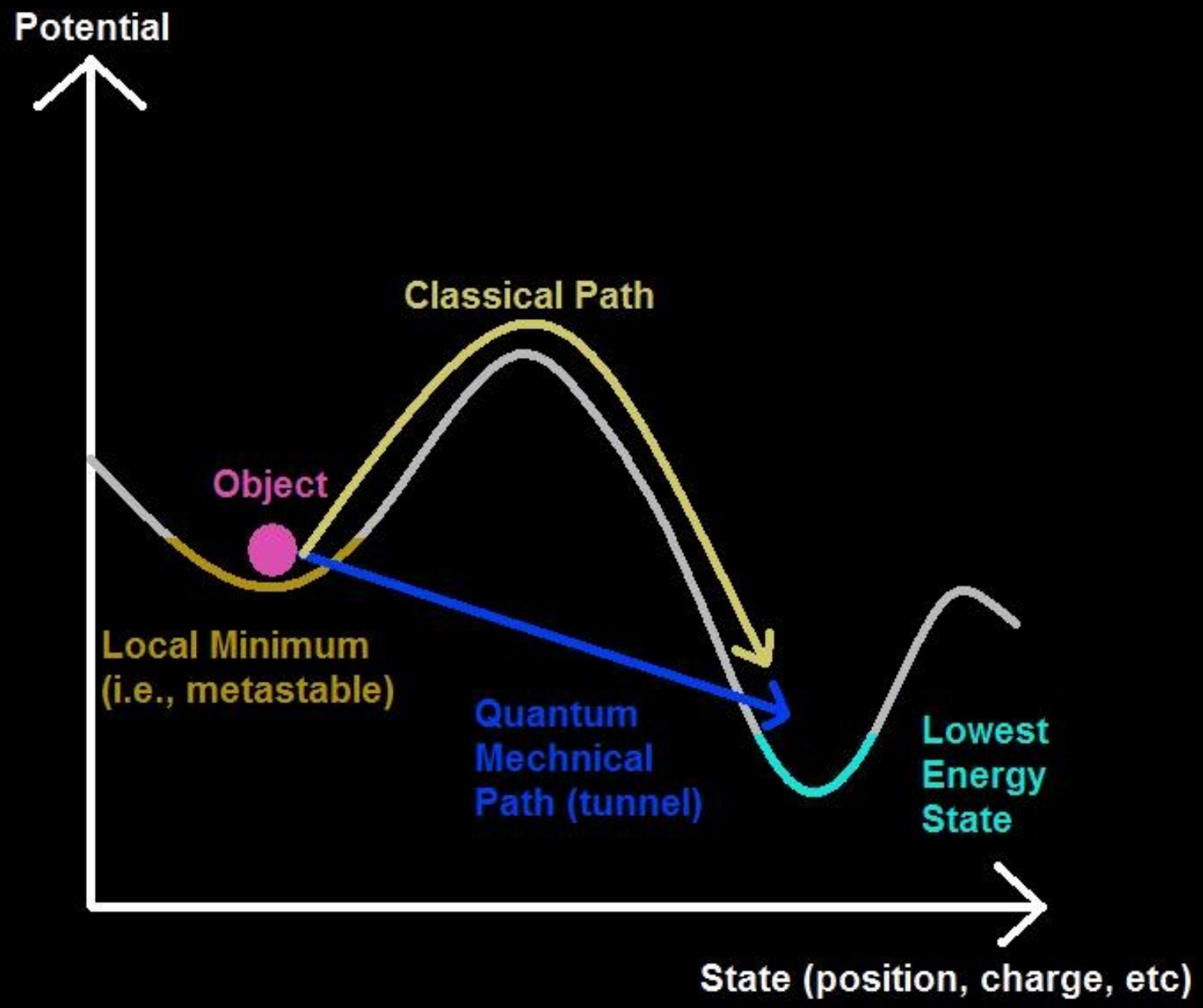

Deuterium
Helium
Energy
Tritium
Neutron

	Q (MeV)
$p+p \rightarrow \alpha + e+ + \nu^*_e$	0,42
$D + D \rightarrow$ He-3 + n	3.27
$D + D \rightarrow$ He-3 + H	4.02
$T + D \rightarrow$ He-4 + γ	23,8
$D + T \rightarrow$ He-4 + n	17,6
$D + T \rightarrow$ He-4 + H	18,4


$Q = T_b + T_Y$
$(A + X \rightarrow Y + b)$
Efecto túnel
Características Fusión
Modelo de Gamow
Barrera Culombiana
Estructura Gota Líquida


Potential
Classical Path
Object
Local Minimum
(i.e., metastable)
Quantum
Mechnical
Path (tunnel)
Lowest
Energy
State
State (position, charge, etc)

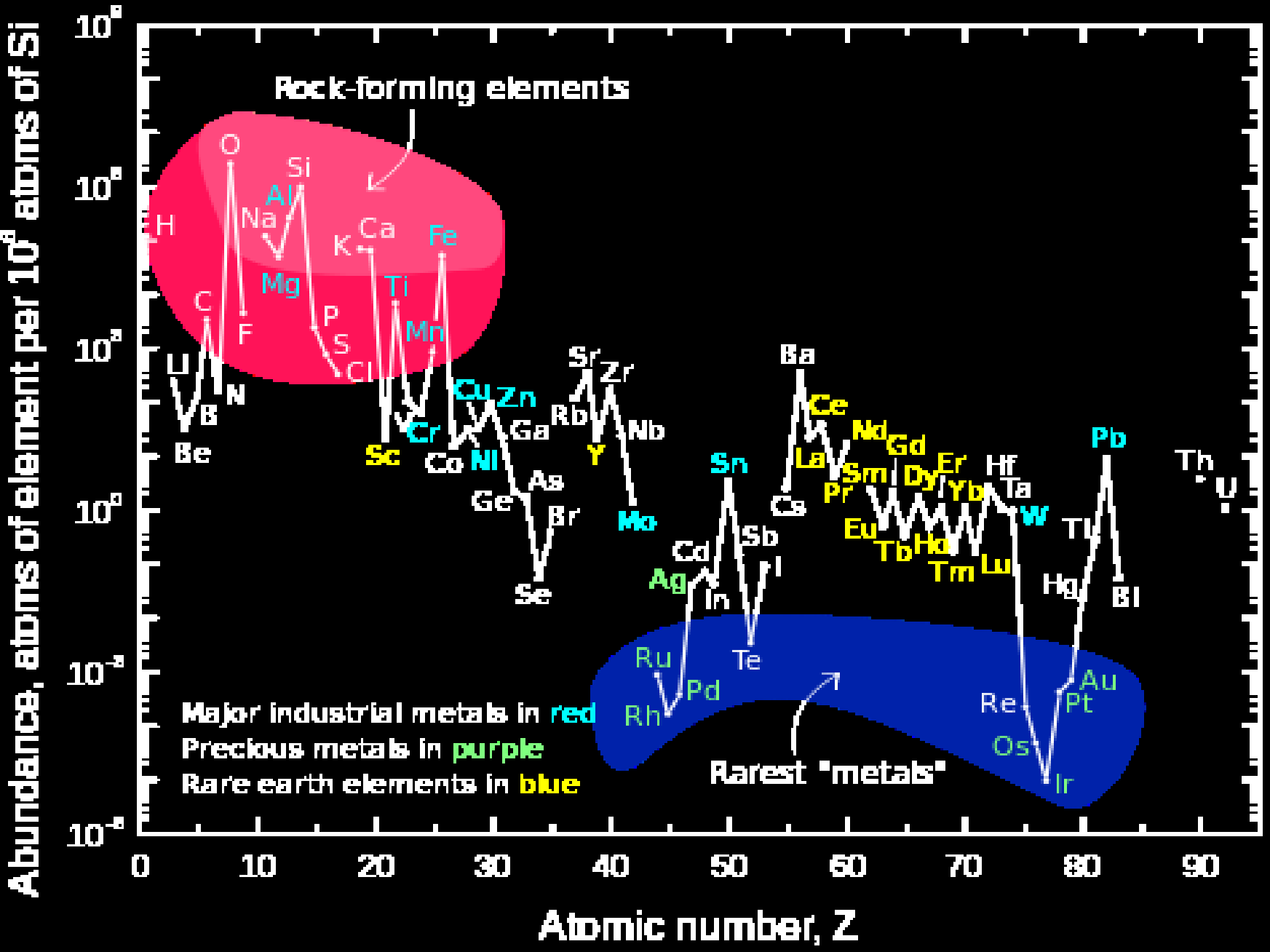
Pico de Gamow

$$E_G = E_B^{1/3} \left(\frac{kT}{2} \right)^{2/3}$$

$$E_B = 2(\pi Z_a Z_b \alpha)^2 \mu c^2$$

Reacción D-T

- Mayor ritmo que otras Rx
- Buena Sección eficaz
- Barrera de Potencial pequeña
- Alta probabilidad de efecto tunel


Abundance, atoms of element per 10^8 atoms of Si
10^6
10^4
10^2
10^0
10^{-2}
10^{-4}
0
10
20
30
40
50
60
70
80
90
Atomic number, Z
Rock-forming elements
H
O
Si
Al
Na
Ca
K
Fe
Mg
Ti
C
F
P
S
Cl
Mn
Li
B
Be
N
Sc
Cr
Co
Ni
Cu
Zn
Ga
Ge
As
Se
Br
Rb
Sr
Zr
Y
Nb
Mo
Ag
Cd
In
Sn
Sb
I
Te
Cs
Ba
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
Hf
Ta
W
Re
Os
Ir
Pt
Au
Hg
Tl
Pb
Bi
Th
U
Ru
Rh
Pd
Major industrial metals in red
Precious metals in purple
Rare earth elements in blue
Rarest "metals"

REACTOR
FISIÓN

Conf. Magnético

Conf. Inercial

Fusión en frio

D + T → He-4 + n

- Temperatura sobre 10^8 (~10 keV)

- Alta densidad del sistema

- Tiempo suficiente de confinamiento

$$E_f = \frac{1}{4} n^2 \langle \sigma v \rangle Q \tau$$

$$E_T = 3nkT$$

$$E_f > E_T$$

$$\frac{1}{4} n^2 \langle \sigma v \rangle Q \tau > 3nkT$$

$$n\tau > 12 \frac{kT}{\langle \sigma v \rangle Q}$$

$$n\tau > 10^{20} \ s/m^3$$

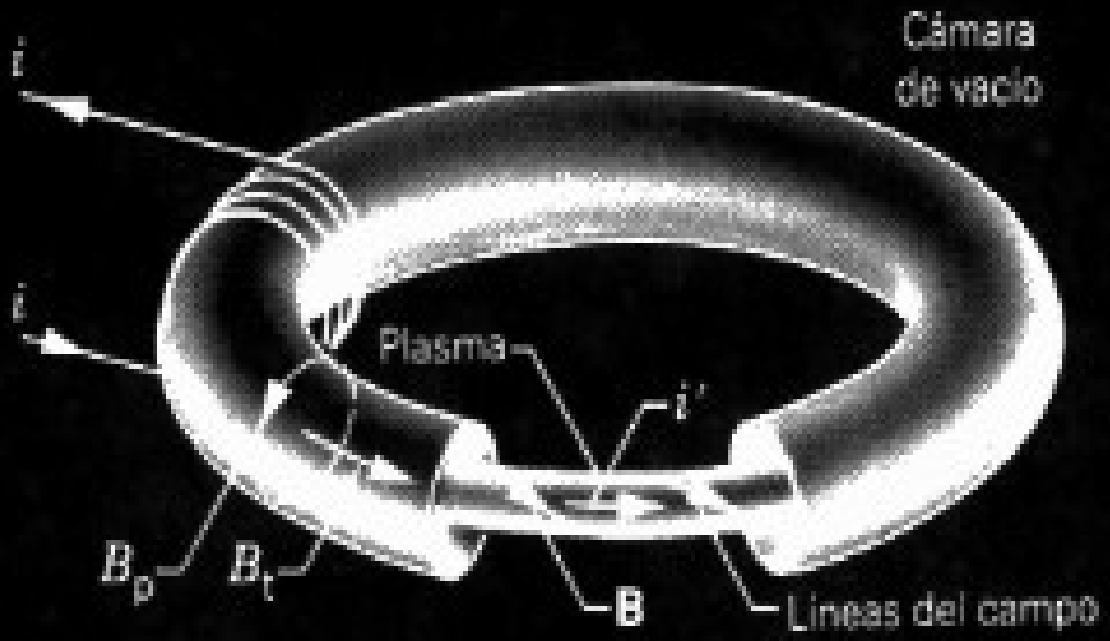
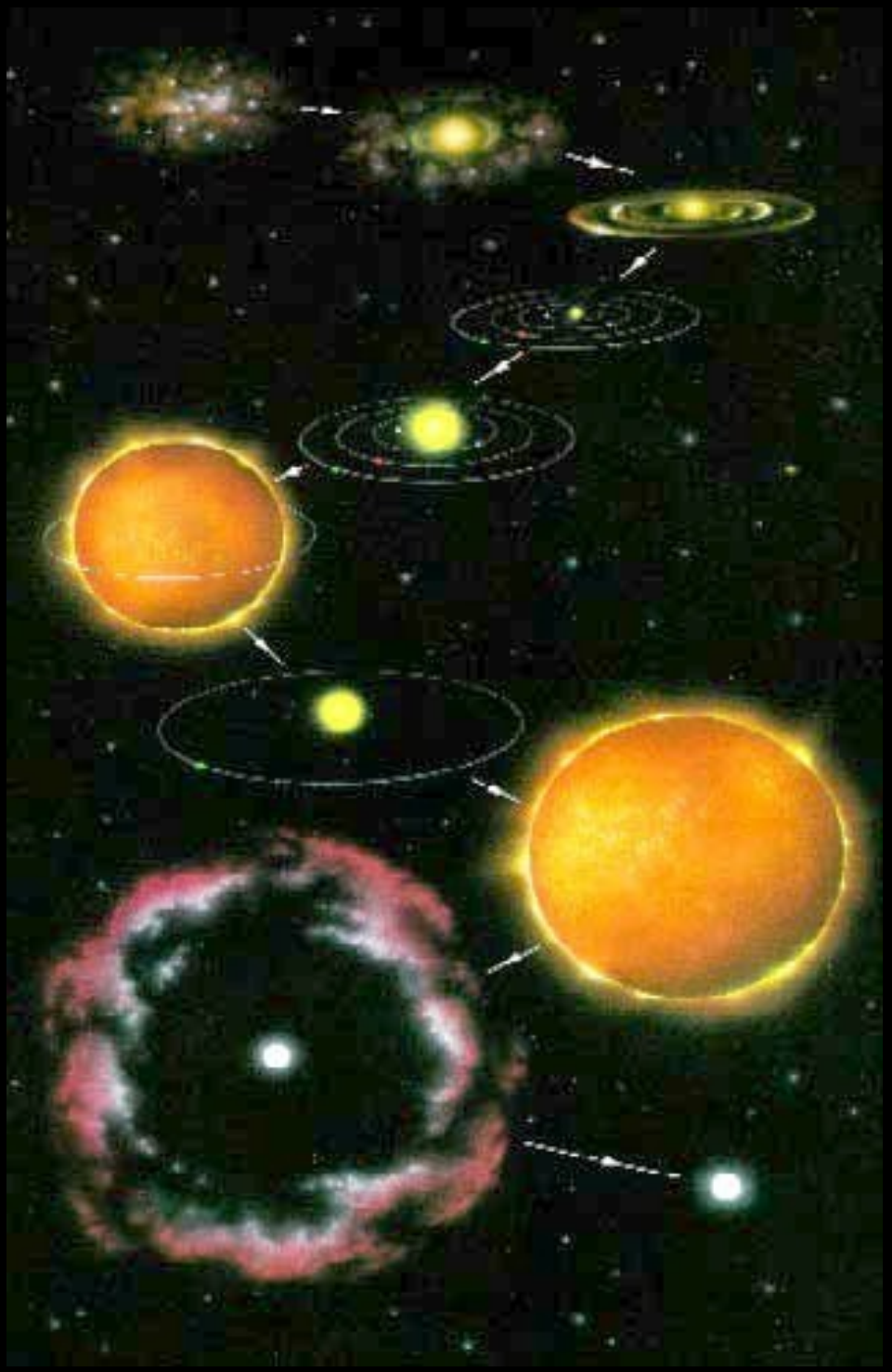


Figura 11 La cámara toroidal que constituye la base del tokamak. Nótese el plasma, el campo magnético helicoidal **B** que lo confina, y la corriente inducida *i'* que lo calienta.


MISCONSTRUE - IMAGE 1



Cadenas PP

$$^1H + {}^1H \rightarrow {}^2H + e^+ + \upsilon_e$$

$$^2H + {}^1H \rightarrow {}^3He + \gamma$$

PPI

$$^3He + {}^3He \rightarrow {}^4He + 2H$$

$$^3He + {}^4He \rightarrow {}^7Be + \gamma$$

PPII

$$^7Be + e^- \rightarrow {}^7Li + \upsilon_e$$

$$^7Li + H \rightarrow {}^4He + {}^4He$$

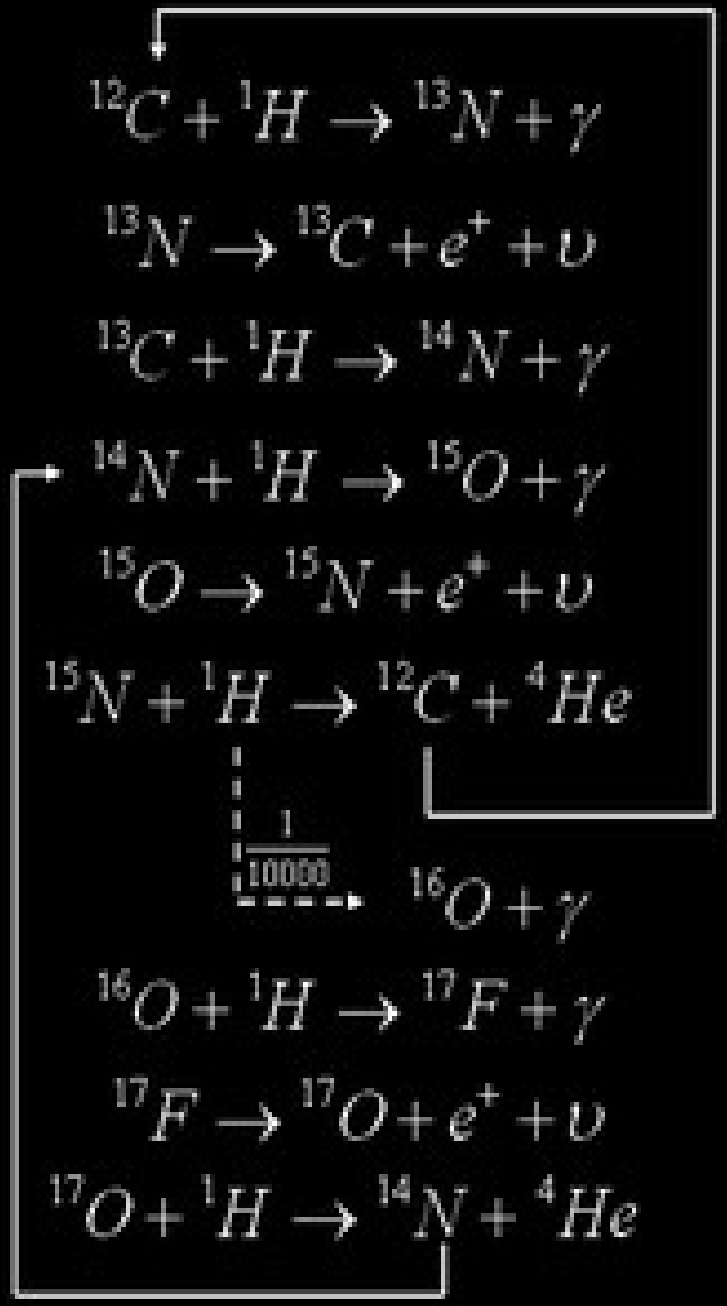
PPIII

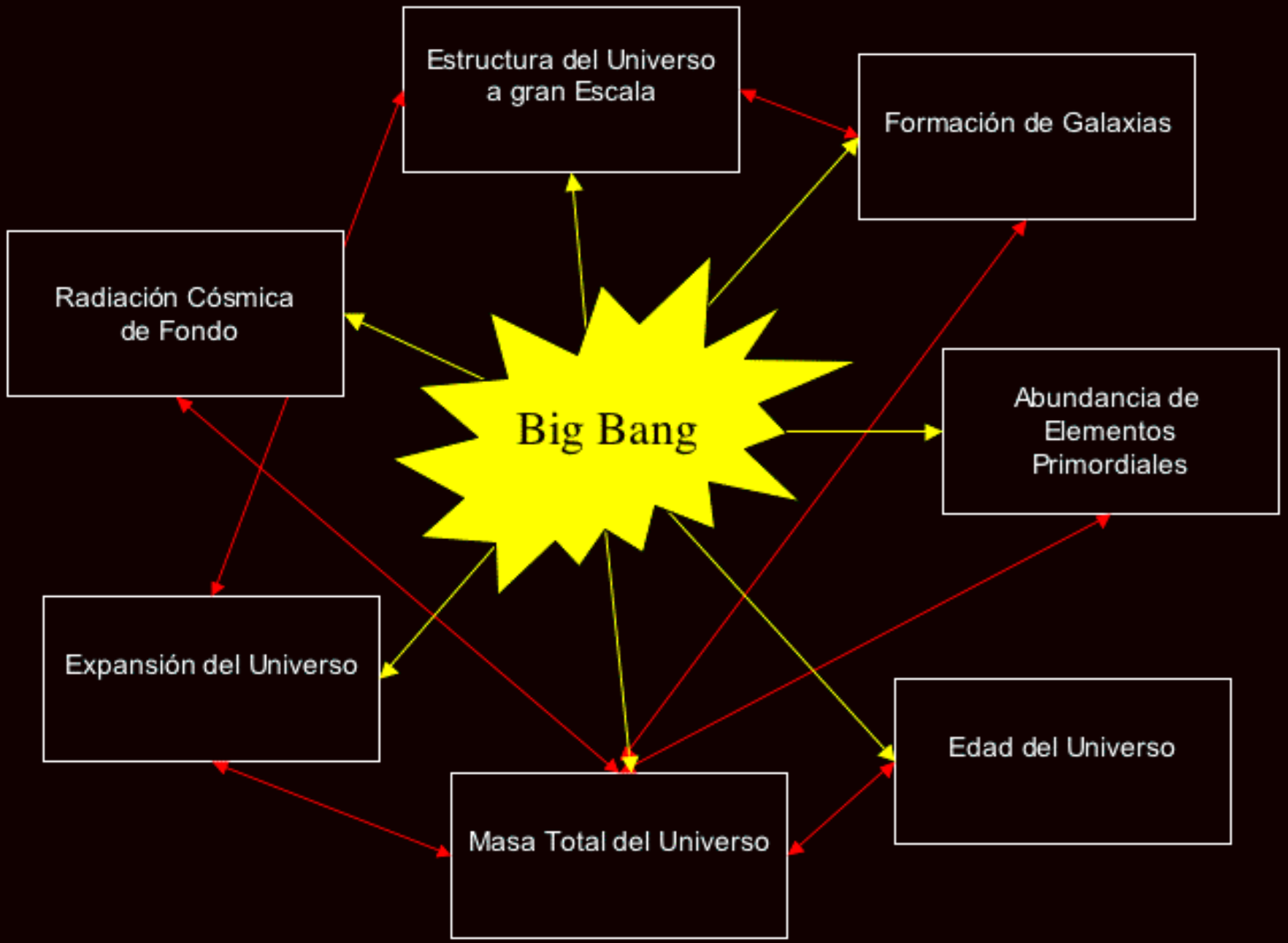
$$^7Be + H \rightarrow {}^8B + \gamma$$

$$^8B \rightarrow {}^8Be + e^- + \overline{\upsilon}_e$$

$$^8Be \rightarrow {}^4He + {}^4He$$

Ciclo CNO


$^{12}C + {}^{1}H \rightarrow {}^{13}N + \gamma$
$^{13}N \rightarrow {}^{13}C + e^{+} + \upsilon$
$^{13}C + {}^{1}H \rightarrow {}^{14}N + \gamma$
$^{14}N + {}^{1}H \rightarrow {}^{15}O + \gamma$
$^{15}O \rightarrow {}^{15}N + e^{+} + \upsilon$
$^{15}N + {}^{1}H \rightarrow {}^{12}C + {}^{4}He$
1
10000
$^{16}O + \gamma$
$^{16}O + {}^{1}H \rightarrow {}^{17}F + \gamma$
$^{17}F \rightarrow {}^{17}O + e^{+} + \upsilon$
$^{17}O + {}^{1}H \rightarrow {}^{14}N + {}^{4}He$


Estructura del Universo a gran Escala
Formación de Galaxias
Radiación Cósmica de Fondo
Big Bang
Abundancia de Elementos Primordiales
Expansión del Universo
Edad del Universo
Masa Total del Universo

Quarks
Neutron
Hydrogen nucleus
Hydrogen atom
Protogalaxy
Electron
Proton
Helium nucleus
Helium atom
Galaxy
THE BIG BANG THEORY
TIME BEGINS
ONE SECOND
PRESENT DAY
Time
Temperature
10⁻⁴³ sec.
10⁻³² sec.
10⁻⁶ sec.
3 min.
300,000 yrs.
10,000°C
1 billion yrs.
-200°C
15 billion yrs.
-270°C
1 The cosmos goes through a superfast "inflation," expanding from the size of an atom to that of a grapefruit in a tiny fraction of a second
2 Post-inflation, the universe is a seething, hot soup of electrons, quarks and other particles
3 A rapidly cooling cosmos permits quarks to clump into protons and neutrons
4 Still too hot to form into atoms, charged electrons and protons prevent light from shining; the universe is a superhot fog
5 Electrons combine with protons and neutrons to form atoms, mostly hydrogen and helium. Light can finally shine
6 Gravity makes hydrogen and helium gas coalesce to form the giant clouds that will become galaxies; smaller clumps of gas collapse to form the first stars
7 As galaxies cluster together under gravity, the first stars die and spew heavy elements into space; these will eventually form into new stars and planets

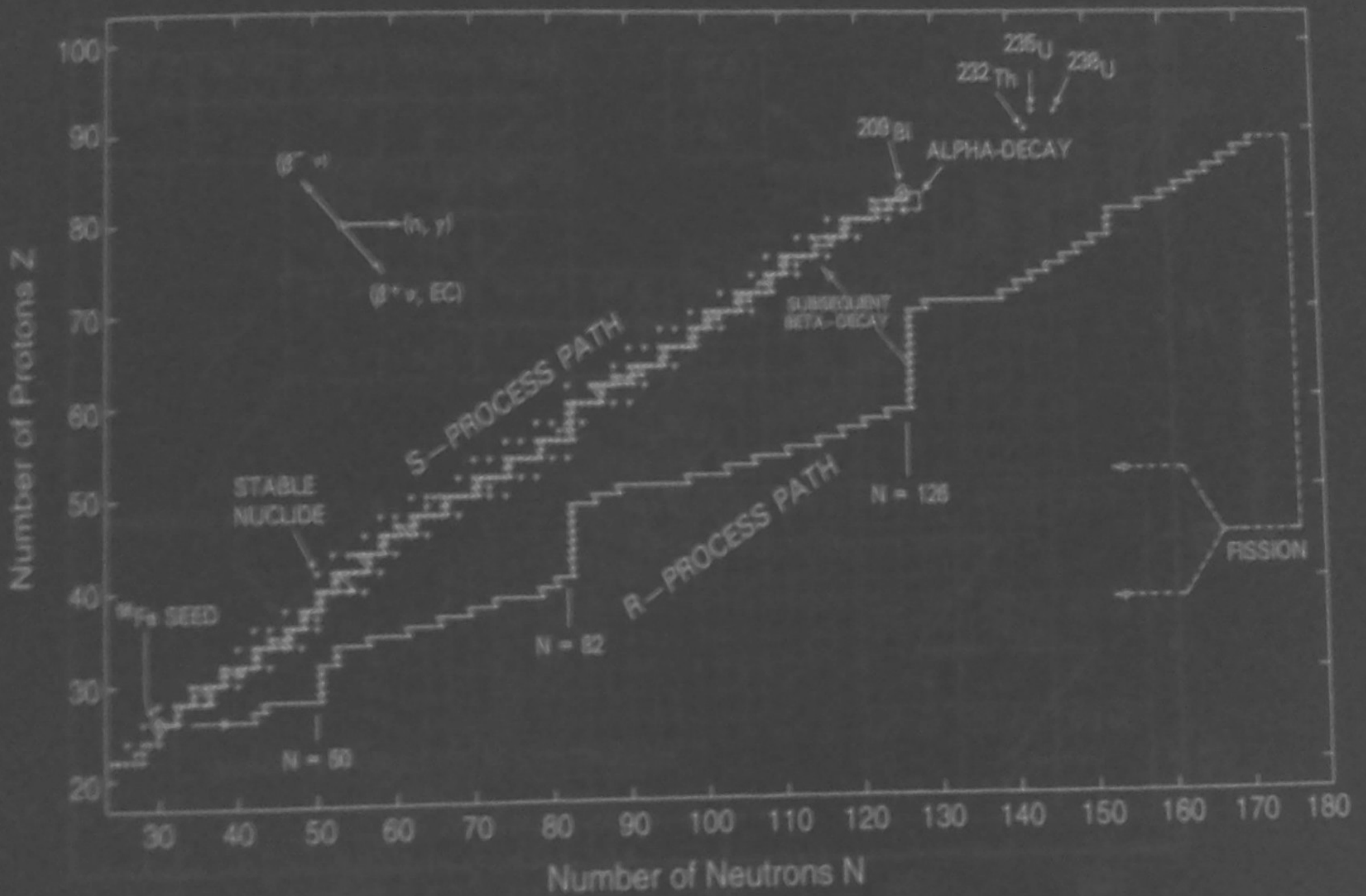
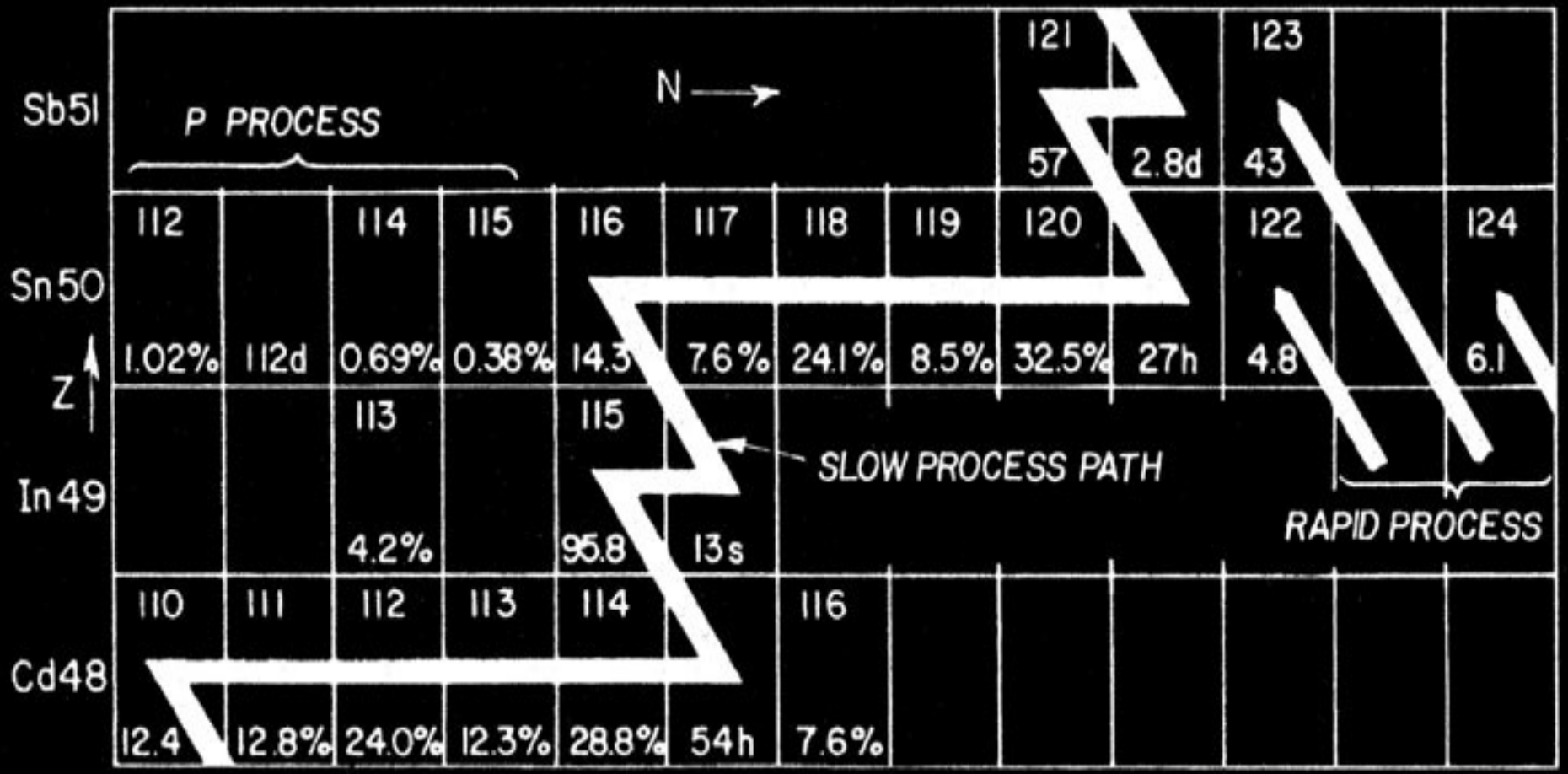


Figure 12.15 Neutron capture paths are shown for the s and r processes. (From C. E. Rolfs and W. S. Rodney, *Cauldrons in the Cosmos*, Chicago University Press, Chicago, 1988.)


Sb51
Sn50
In49
Cd48
Z
N
P PROCESS
SLOW PROCESS PATH
RAPID PROCESS
121
57
2.8d
123
43
112
1.02%
112d
114
0.69%
115
0.38%
116
14.3
117
7.6%
118
24.1%
119
8.5%
120
32.5%
27h
122
4.8
124
6.1
113
4.2%
115
95.8
13s
110
12.4
111
12.8%
112
24.0%
113
12.3%
114
28.8%
54h
116
7.6%