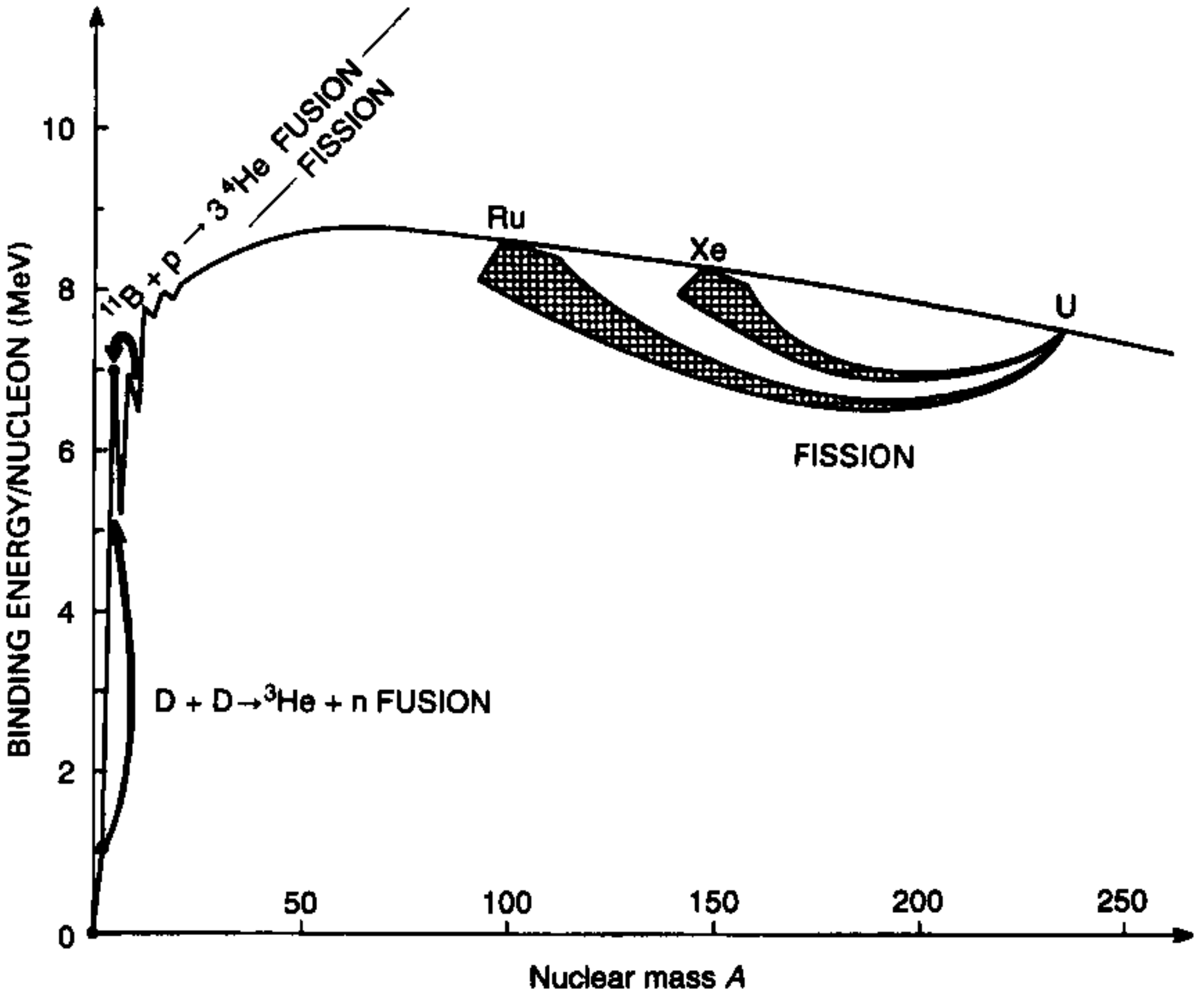
Fission

Fission



BINDING ENERGY/NUCLEON (MeV)
10
8
6
4
2
0
50
100
150
200
250
Nuclear mass A
$^{11}B + p \rightarrow 3\,^4He$ FUSION
FISSION
Ru
Xe
U
FISSION
$D + D \rightarrow {}^3He + n$ FUSION

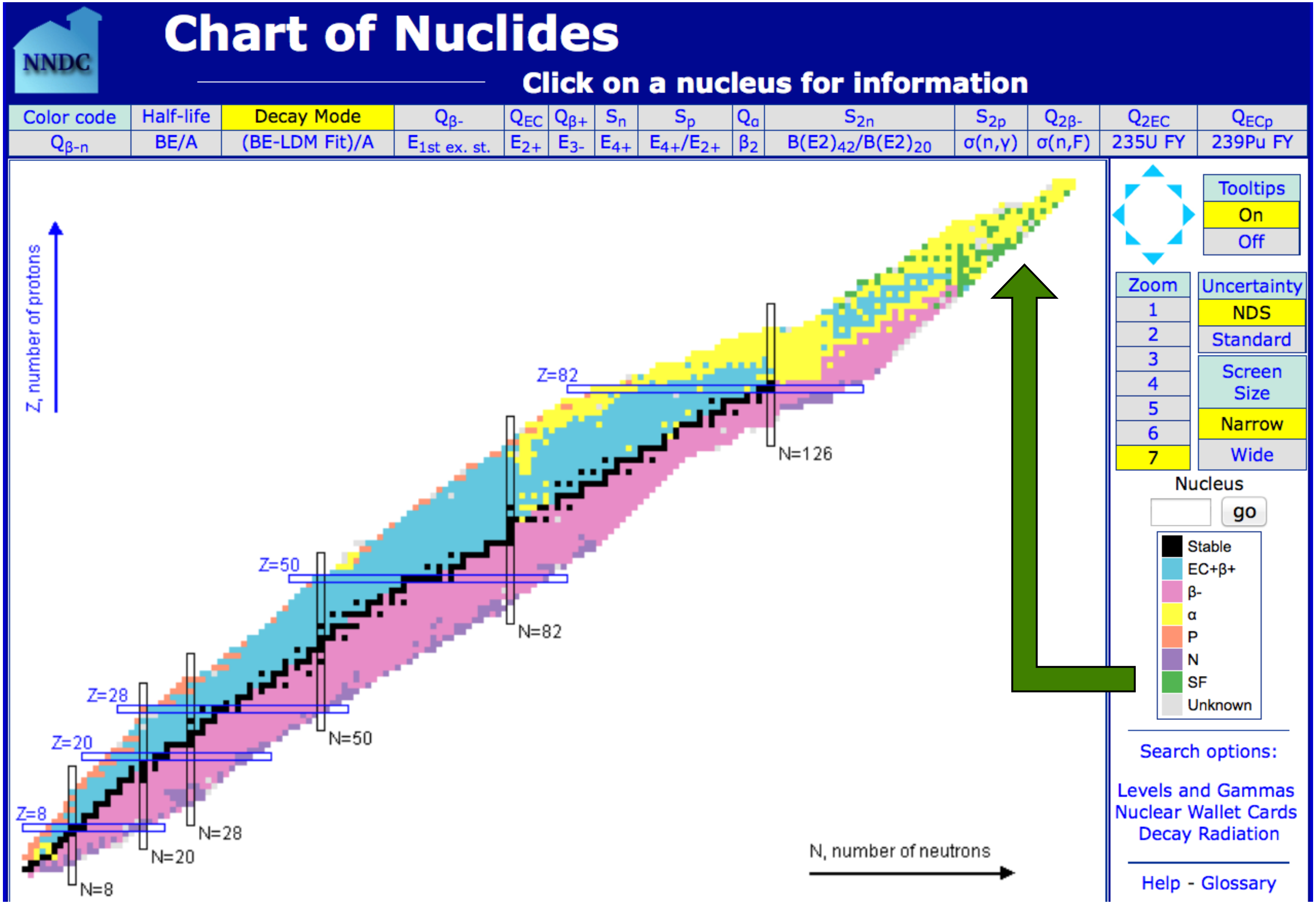
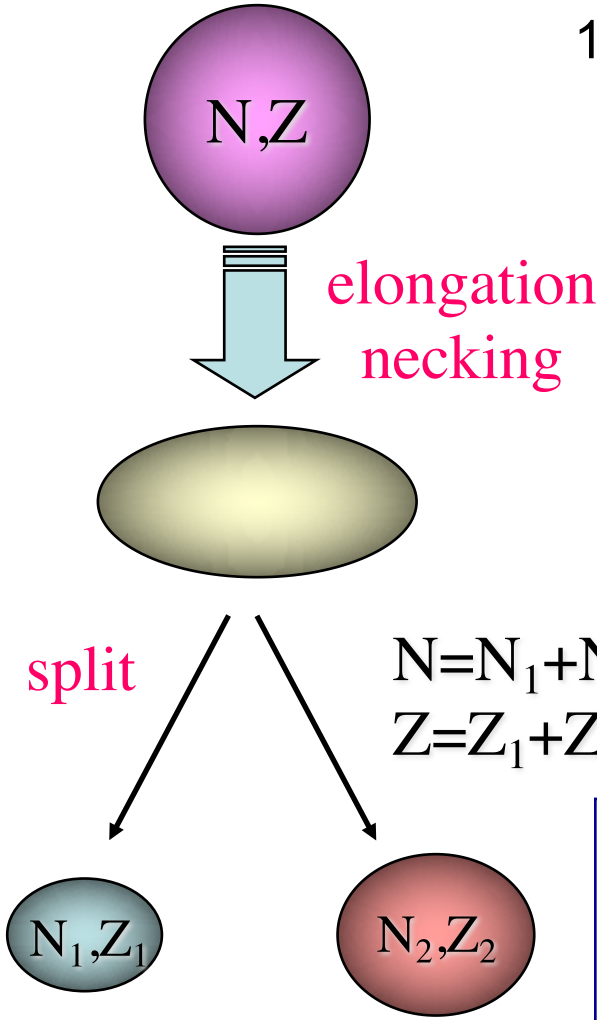


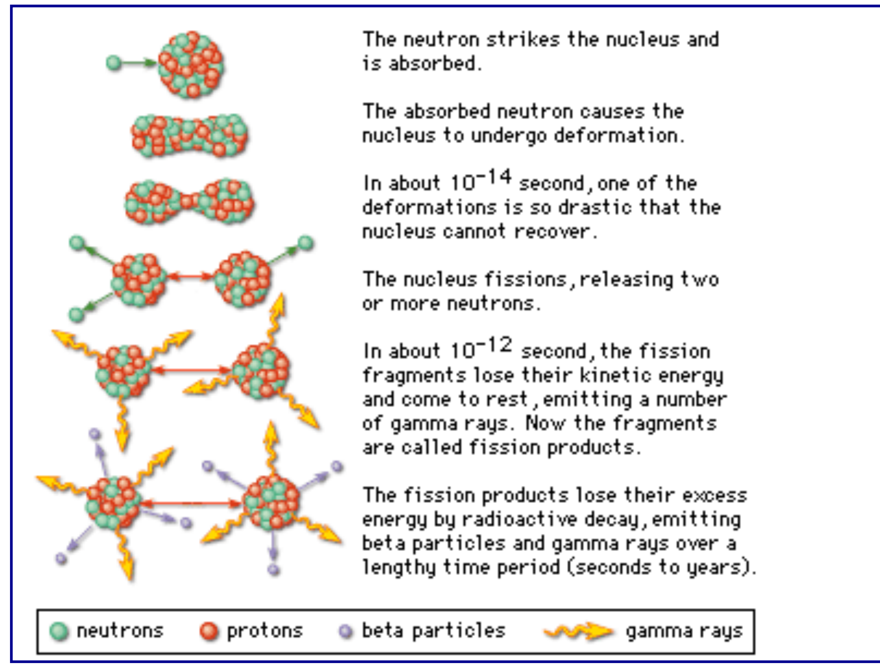
Chart of Nuclides
NNDC
Click on a nucleus for information
Color code
Half-life
Decay Mode
Qβ-
QEC
Qβ+
Sn
Sp
Qα
S2n
S2p
Q2β-
Q2EC
QECp
Qβ-n
BE/A
(BE-LDM Fit)/A
E1st ex. st.
E2+
E3-
E4+
E4+/E2+
β2
B(E2)42/B(E2)20
σ(n,γ)
σ(n,F)
235U FY
239Pu FY
Tooltips
On
Off
Zoom
1
2
3
4
5
6
7
Uncertainty
NDS
Standard
Screen Size
Narrow
Wide
Nucleus
go
Stable
EC+β+
β-
α
P
N
SF
Unknown
Search options:
Levels and Gammas
Nuclear Wallet Cards
Decay Radiation
Help - Glossary
Z, number of protons
N, number of neutrons
Z=82
Z=50
Z=28
Z=20
Z=8
N=126
N=82
N=50
N=28
N=20
N=8

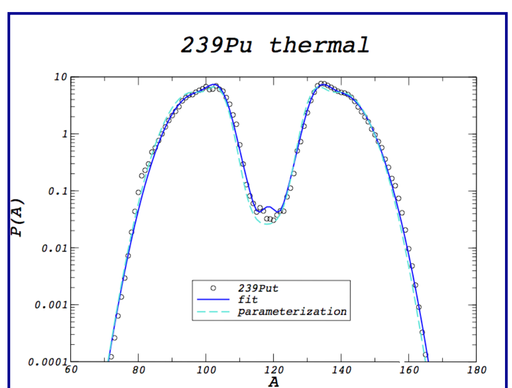
1938 Hahn & Strassmann
1939 Meitner & Frisch
1939 Bohr & Wheeler
1940 Petrzhak & Flerov

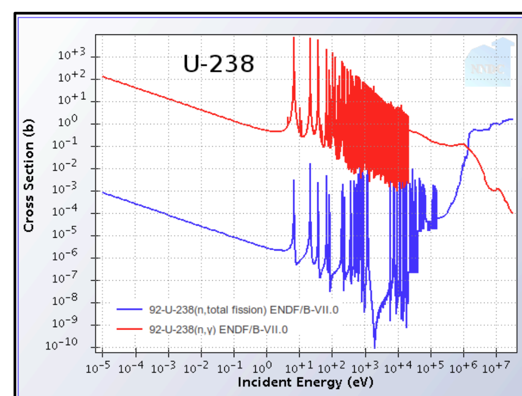


$$N = N_1 + N_2$$
$$Z = Z_1 + Z_2$$

Fission yields (fragments)





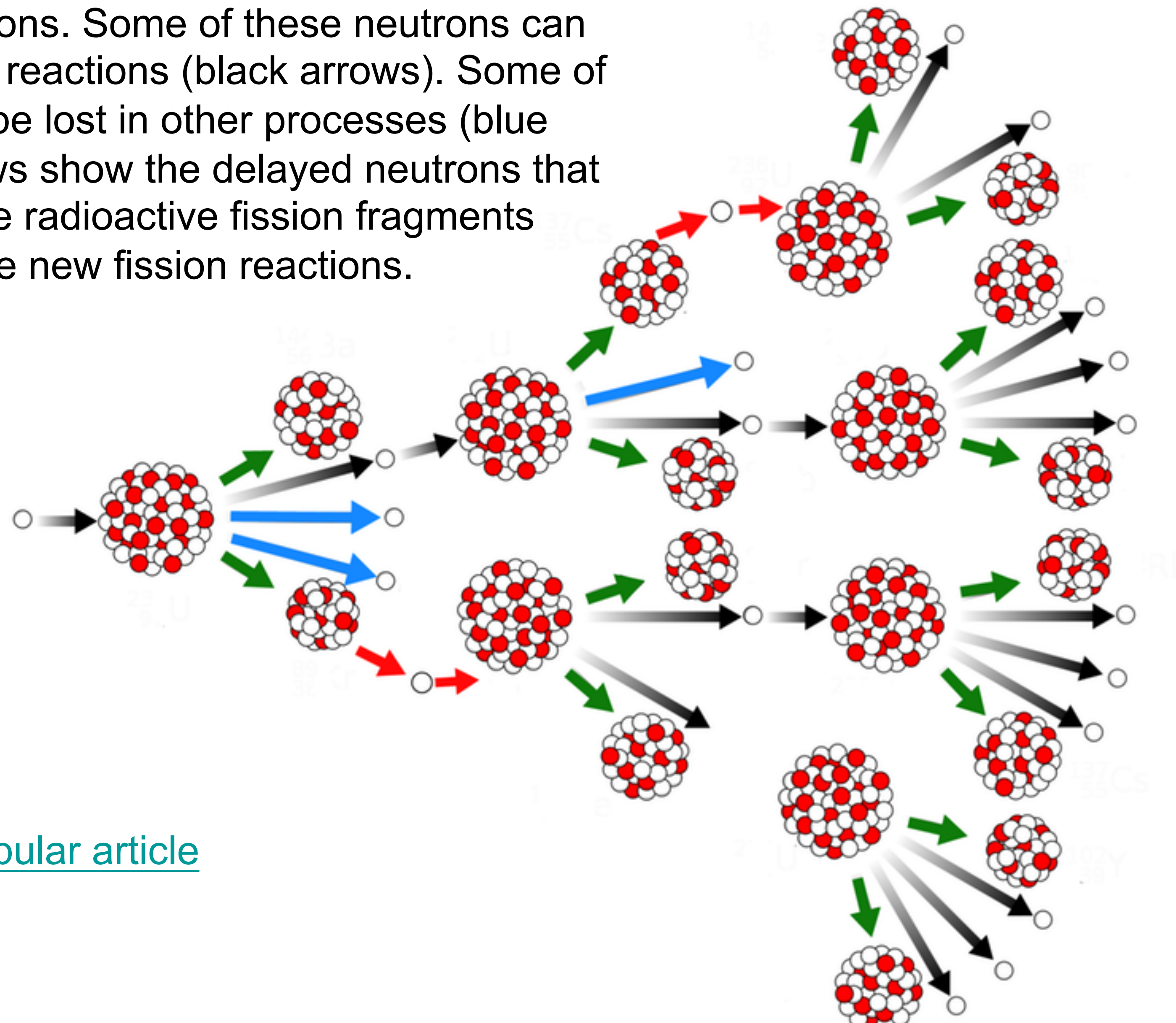


Understanding the fission process is crucial for many areas of science and technology:

- Fission governs the production and existence of many transuranium elements, including the predicted long-lived super-heavy species.
- Fission influences the formation of heavy elements in a neutron rich environment.
- Fission produces reactor antineutrinos
- Improved understanding of the fission process will enable scientists to enhance the safety and reliability of nuclear reactors.
- Fission is important for stockpile stewardship

The new phase in fission theory is expected to rely heavily on advanced modeling and simulation capabilities utilizing massively parallel leadership-class computers

A nuclear chain reaction. Green arrows show the split of a uranium nucleus in two fission fragments, emitting new neutrons. Some of these neutrons can induce new fission reactions (black arrows). Some of the neutrons may be lost in other processes (blue arrows). Red arrows show the delayed neutrons that come later from the radioactive fission fragments and that can induce new fission reactions.



See [popular article]

1939: Bohr's paper on fission

These circumstances find their straightforward explanation in the fact, stressed by Meitner and Frisch, that the mutual repulsion between the electric charges in a nucleus will for highly charged nuclei counteract to a large extent the effect of the short-range forces between the nuclear particles in opposing a deformation of the nucleus. The nuclear problem concerned reminds us indeed in several ways of the question of the stability of a charged liquid drop, and in particular, any deformation of a nucleus, sufficiently large for its fission, may be treated approximately as a classical mechanical problem,

The continuation of the experiments on the new type of nuclear disintegrations, and above all the closer examination of the conditions for their occurrence, should certainly yield most valuable information as regards the mechanism of nuclear excitation.

N. BOHR.

At the Institute for Advanced Study,
Princeton, N.J. Jan. 20.

Letters to the Editor

The Editor does not hold himself responsible for opinions expressed by his correspondents. He cannot undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of NATURE. No notice is taken of anonymous communications.

NOTES ON POINTS IN SOME OF THIS WEEK'S LETTERS APPEAR ON P. 337.

CORRESPONDENTS ARE INVITED TO ATTACH SIMILAR SUMMARIES TO THEIR COMMUNICATIONS.

Disintegration of Heavy Nuclei

THROUGH the kindness of the authors I have been informed of the content of the letters[1] recently sent to the Editor of NATURE by Prof. Meitner and Dr. Frisch. In the first letter, these authors propose an interpretation of the remarkable findings of Hahn and Strassmann as indication for a new type of disintegration of heavy nuclei, consisting in a fission of the nucleus into two parts of approximately equal masses and charges with release of enormous energy. In the second letter, Dr. Frisch describes experi- …h these parts are directly detected by … ionization they produce. Due to the …rtance of this discovery, I should be …few comments on the mechanism of the … from the point of view of the general …ed in recent years, to account for the … of the nuclear reactions hitherto

…to these ideas, any nuclear reaction …collisions or radiation involves as an …stage the formation of a compound …hich the excitation energy is distri- … the various degrees of freedom in …ling the thermal agitation of a solid …y. The relative probabilities of the …ble courses of the reaction will there- …n the facility with which this energy …sed as radiation or converted into a …o produce the disintegration of the …leus. In the case of ordinary reactions, …disintegration consists in the escape of …e, this conversion means the concentra- … part of the energy on some particle … of the nucleus, and resembles therefore …on of a molecule from a liquid drop. … of disintegrations comparable to the …ich a drop into two droplets, it is evidently necessary, however, that the quasi-thermal distribution of energy be largely converted into … mode of vibration of the compound …ving a considerable deformation of the …ce.

…es, the course of the disintegration may … to result from a fluctuation in the …stribution of the energy between the …es of freedom of the system, the prob- …currence of which is essentially deter- … amount of energy to be concentrated …ular type of motion considered and by …ture' corresponding to the nuclear …ince the effective cross-sections for the …nena for neutrons of different velocities … about the same order of magnitude as …ions for ordinary nuclear reactions, we … conclude that for the heaviest nuclei …on energy sufficient for the fission is of the same order of magnitude as the energy necessary for the escape of a single nuclear particle. For somewhat lighter nuclei, however, where only evaporation-like disintegrations have so far been observed, the former energy should be considerably larger than the binding energy of a particle.

These circumstances find their straightforward explanation in the fact, stressed by Meitner and Frisch, that the mutual repulsion between the electric charges in a nucleus will for highly charged nuclei counteract to a large extent the effect of the short-range forces between the nuclear particles in opposing a deformation of the nucleus. The nuclear problem concerned reminds us indeed in several ways of the question of the stability of a charged liquid drop, and in particular, any deformation of a nucleus, sufficiently large for its fission, may be treated approximately as a classical mechanical problem, since the corresponding amplitude must evidently be large compared with the quantum mechanical zero-point oscillations. Just this condition would in fact seem to provide an understanding of the remarkable stability of heavy nuclei in their normal state or in the states of low excitation, in spite of the large amount of energy which would be liberated by an imaginable division of such nuclei.

The continuation of the experiments on the new type of nuclear disintegrations, and above all the closer examination of the conditions for their occurrence, should certainly yield most valuable information as regards the mechanism of nuclear excitation.

N. BOHR.

At the Institute for Advanced Study,
Princeton, N.J. Jan. 20.

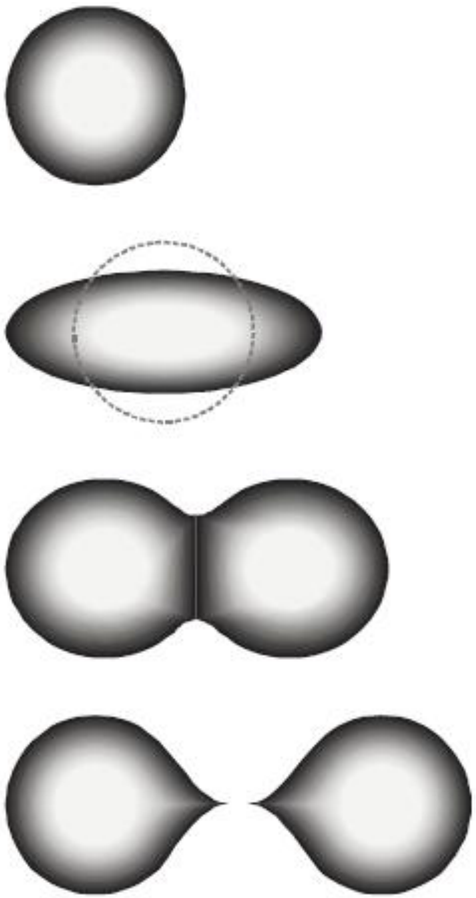
[1] [NATURE, 143, 239 and 275 (1939)].

Photoactivation of Solids and its Effect on Adsorption

CONSIDERABLE attention has been given recently to chemical processes involving an activating influence of a crystal excited by irradiation[1]. The mechanism of such photosensitized reactions, although unknown in detail, is generally believed to be a more or less complete transfer of the energy absorbed by the crystal to the reacting components, physically or chemically. Accordingly, the essential difference between photosensitized processes and real photo-chemical ones is the distance between the place of absorption and the place of reaction. But there must also be another, more general, effect of irradiation on the activity of crystals. Due to the change in the electronic state of the particles in the lattice by the absorption of light (change in charge and degree of polarization, formation of space charges, etc.), the forces between the particles are changed and, consequently, there is also a change in potential of the

Deformed liquid drop (Bohr & Wheeler, 1939)

fission of nuclear droplet



$$E_{LDM}(def) = E_S(0)\left[B_S(def) - 1 + 2x\left(B_C(def) - 1\right)\right]$$

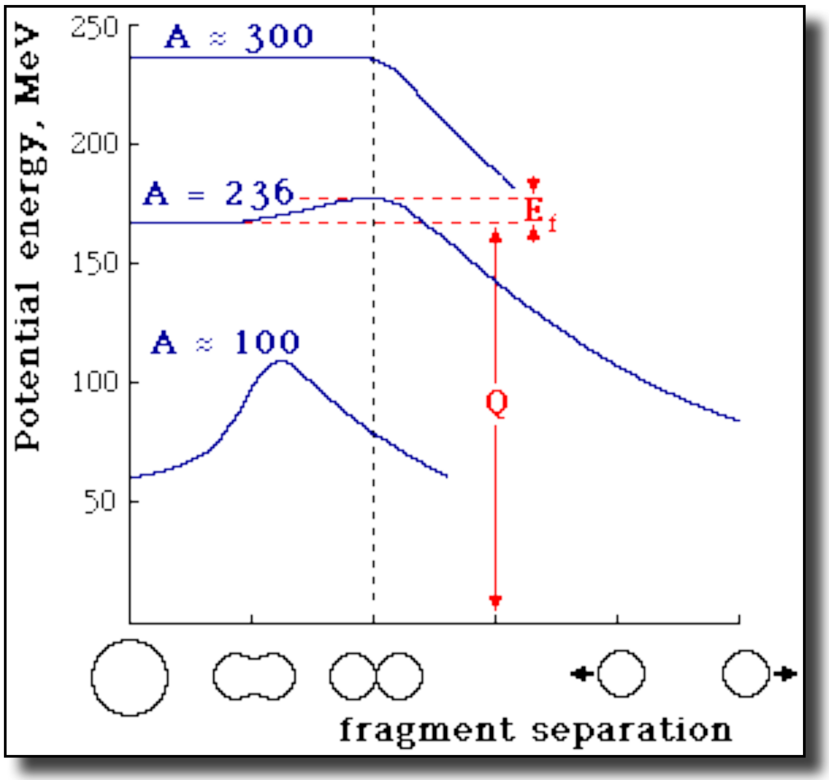
$$B_S(def) = \frac{E_S(def)}{E_S(0)}, \quad B_C(def) = \frac{E_C(def)}{E_C(0)}$$

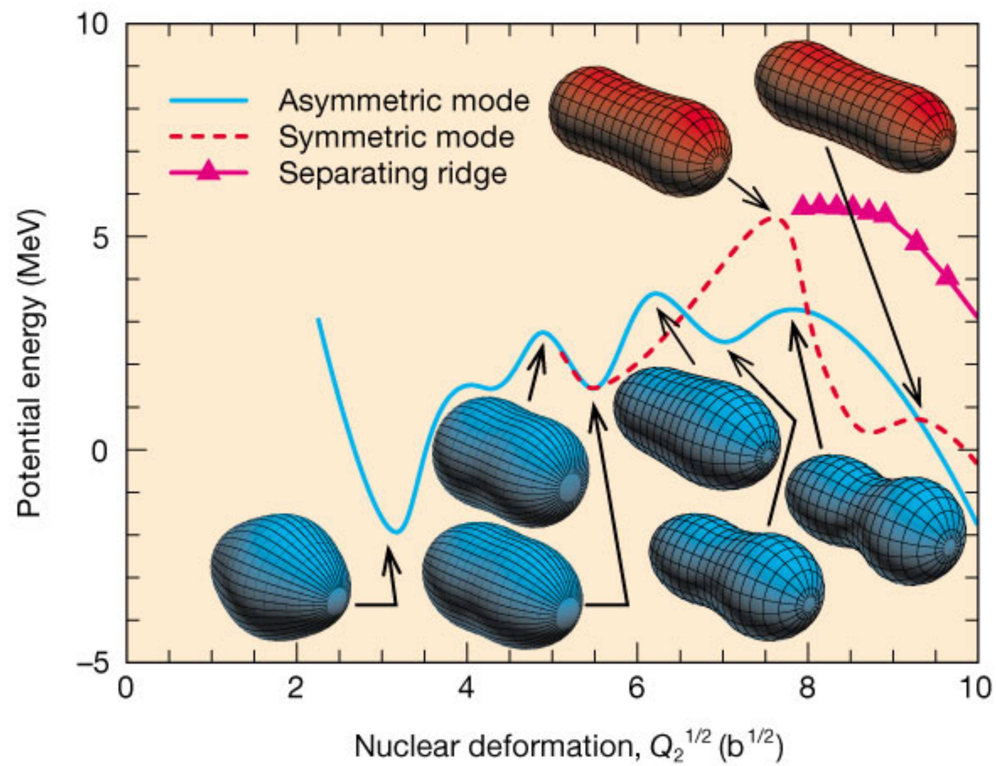
$$x = \frac{E_C(0)}{2E_S(0)} = \frac{Z^2/A}{\left(Z^2/A\right)_{crit}} \approx \frac{Z^2}{50\,A}$$

x: fissility parameter

The nuclear droplet stays stable and spherical for x<1. For x>1, it fissions immediately. For ^{238}U, x=0.8

Realistic calculations
Nature 409, 785 (2001)





- All elements heavier than A=110-120 are fission unstable!
- But… the fission process is fairly unimportant for nuclei with A<230. Why?