Nuclear reactions
Production rate

- The production rate (R) depends on the ennergy of the projectile and the type of projectile, and must be specified with respecc to that.
- The production rate for a particular reactions is proportional to:(target smaller than the projectile current:
- 1) The cross section (σ)
- 2) Number of target nuclides(N_o)
- 3) Projectile flux (ϕ)
  - The projectile flux gives the number of projectiles (e.g.neutrons) passing per unit time and surface ($cm^{-2}s^{-1}$)
- **$R = \sigma\phi N_o$**
  - Dimension (cm^2 x $cm^{-2}s^{-1}$xatoms)
  - =atoms s^{-1}

Nuclear reactions
in a reactor

By irradiation in a reactor, the disintegration rate becomes:

$D = \sigma\phi N_o (1-e^{-\lambda\tau})e^{-\lambda t}$

In a reactor it is normally (but not always) irradiated with so-called **thermal** neutrons, i.e. neutrons with same velocity and distribution as given by the corresponding temeprature (Maxwell-Boltzmann). It is the cross sections for (n,γ)-reactions with this type of neutrons which are given on the chart of nuclides.
In a fes cases by light nuclei, other reactions may occur with thermal neutrons, e.g. (n,p) or (n,α). If so, this is indicated.

Nuclear reactions
in a reactor

Some examples from neutron irradiations:

^{75}As(n,γ)^{76}As (4.3 barn)
^{107}Ag(n,γ)^{108}Ag (36 barn)
^{197}Au(n,γ)^{108}Au (98.7 barn)
^{193}Ir(n,γ)^{194m}Ir (6 barn)
^{193}Ir(n,γ)^{194}Ir (105 barn)
(if several isomers may be formmed, several cross sections are indicated. If so, the are listed in the same order as they appear in the next square, i.e. the ground state at the end.

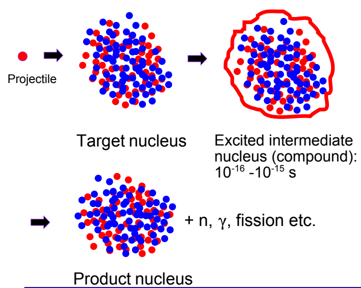
Cross sections are given in the unit "barn" .
1 barn = 10^{-24} cm^2.

Nuclear reactions
Prodution rate

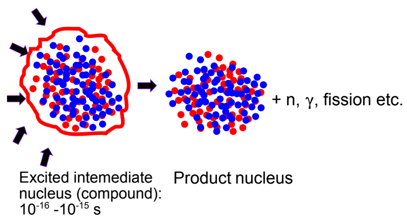
- The production rate R depends upon the energy of the projectile and must be specified in relation to that.
- Production rate for a particular nuclear reaction is proportional to:(target larger than the projectile current)
- Cross section (σ)
- 2) Number of target nuclide per unit surface.N_o/A)
- 3) Prosjectiel-current(I)
  - The projectile furrent is the number of projectiles (i.e.protons) hitting the target pr. unit time (s^{-1})
- **$R = \sigma I(N_o/A)$**
  - Dimension (cm^2 x s^{-1}xatomer cm^{-2})
  - =atoms s^{-1}

Nuclear reactions
Types of reaction
Compound reactions

Scenario:
The target nucleus reacts with the projectile and form an excited intermediate system (compound nucleus) which in turn decays to products:



Nuclear reactions
Types of reaction
Compound reactions



For en compound nucleus reaction, it is indifferent how the compound system was formed. That can happen in many different ways. The kind of products from such a reaction only depends upon the composition and excitation energy of the compound nucleus.

Nuclear reactions
Types of reaction
Compound reactions

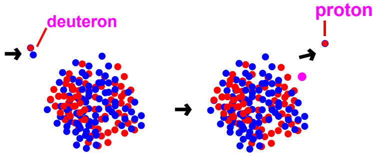
Example:

$^{139}La + ^{16}O$
$^{140}Ce + ^{15}N$ } $\rightarrow$ $^{155}Tb^* \rightarrow ^{149}Tb + 6n$
$^{144}Nd + ^{11}B$

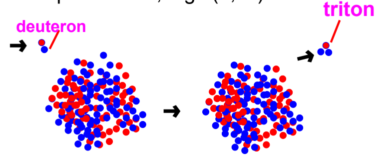
If the projectile energies is chosen to give the same excitation energy of the compound nucleus, the neutron spectra and all other conditions are identical after the reaction.

Nuclear reactions
Direct reactions
Transfer-reactions

Stripping-reactions, e.g. (d,p)



Pick-up reactions, e.g. $(d,^3H)$



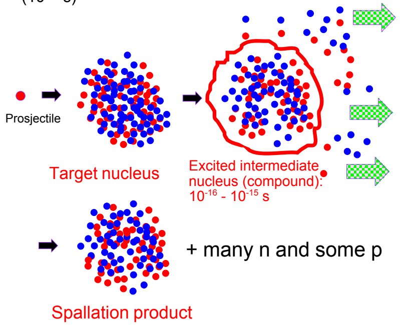
Transfer reactions

Examples:
$^{82}Se(d,p)^{83}Se$
$^{106}Cd(d,t)^{105}Cd$

Transfer-reactions are primarilly superficial events which do not lead to excited compound nuclei. Time scale:about 10^{-20}s, i.e. roughly the time it takesfor a projectile to pass the nucleus

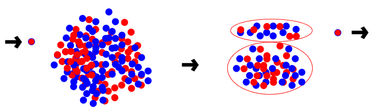
Spallation

Scenario:
Step 1: A highly energetic projectile hits and ejects single nucleons from the target nucleus by direct or indirect collisions (10^{-20} s)
Step 2: The nucleus is left in a highly excited state and "boils off" nucleons, mostly neutrons. (10^{-16} s)



Fragmentation

The nucleus is "cut" into a light and a heavy fragment:



This type of reaction requires high projectile energies (several hundred MeV)