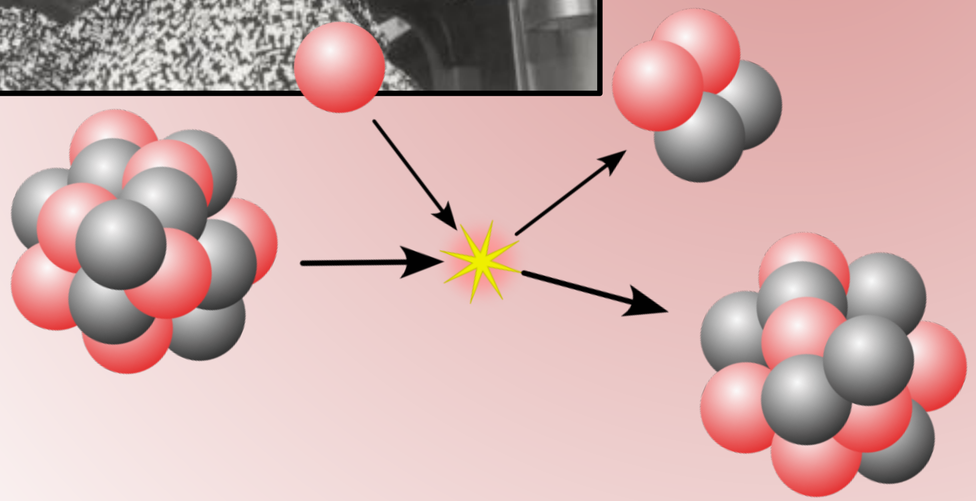
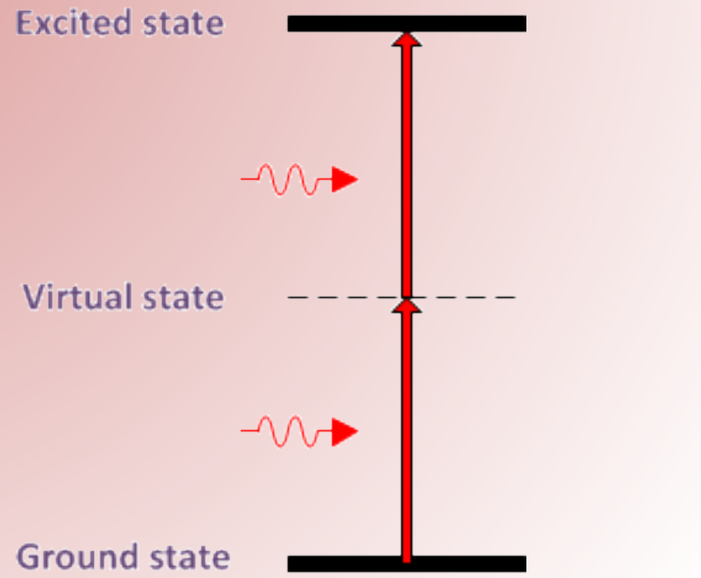


Maria Goeppert Mayer was a theoretical physicist and Nobel Laureate who developed the mathematical model for the **structure of nuclear shells**, and first theorized **two-photon absorption** by atoms, as well as **double beta decay**.





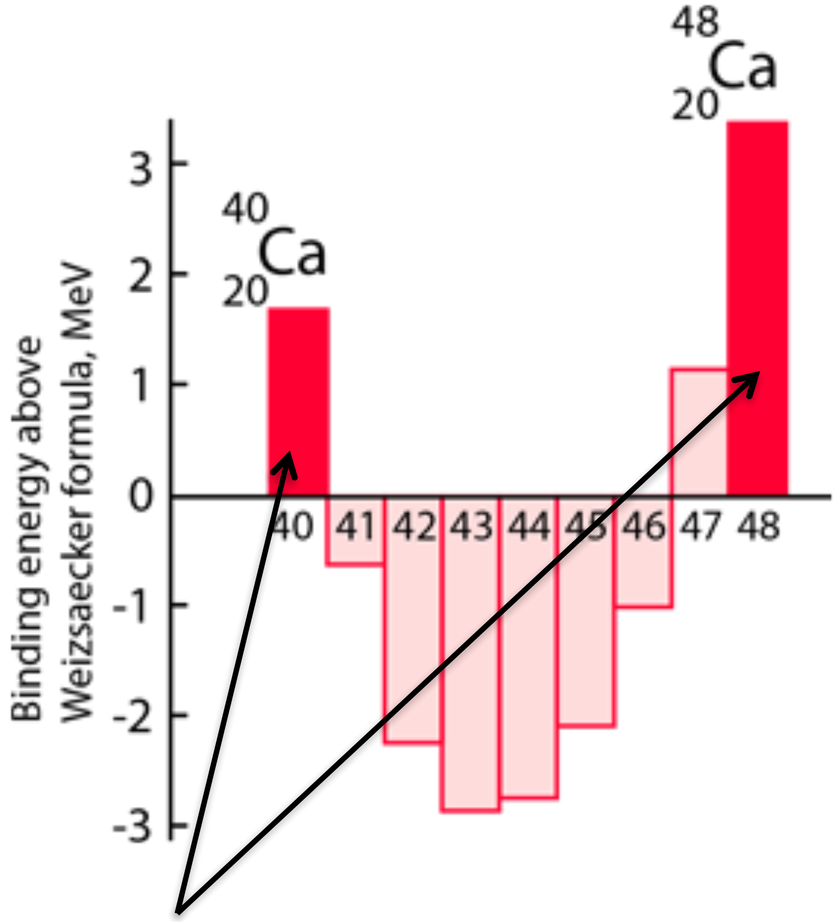


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While working on lists of isotope abundances, Goeppert Mayer noticed that **certain nuclei were especially stable,** namely those with **2, 8, 20, 28 or 50 protons or neutrons.**

These numbers were later termed **"magic numbers**" by Eugene Wigner.

To explain this, she suggested the **shell structure for nuclei, analogous to the electron shell structure in atoms.**



"Doubly magic" isotopes are particularly stable



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In the shell structure for nuclei, each nucleon moves in a central potential well created by other nucleons, and the orbits form a series of shells of increasing energy. Nuclei with completely filled outer shells are most stable. By also factoring in spin-orbit coupling, Goeppert was able to predict the 'magic numbers'.

"Woods-Saxon" *potential (strong interaction between nucleon and nucleus)*

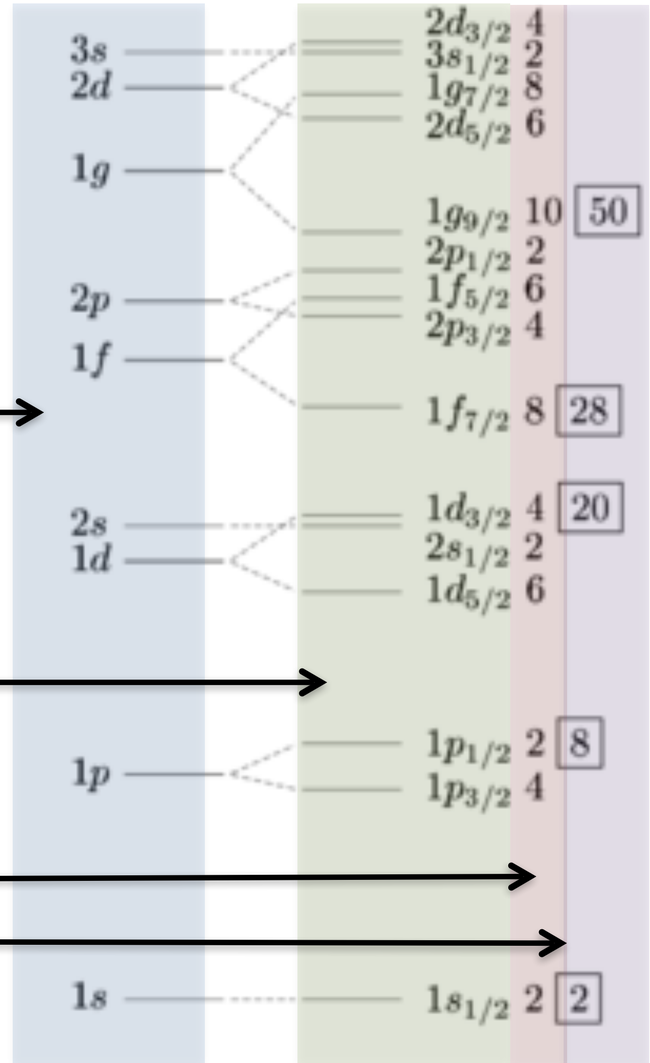
$$V(r) = -\frac{V_0}{1+\exp\left(((r-R)/\delta)\right)}$$

Spin-orbit coupling *included (interaction between orbital angular momentum and spin angular momentum)*

$$V(r) \rightarrow V(r) + W(r)\mathbf{L}\cdot\mathbf{S}.$$

Multiplicity of states

"Magic numbers" = closed shells





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In her 1931 PhD thesis, **Goeppert Mayer predicted two-photon absorption.**
It took 30 years, with the invention of the laser, for this ever be observed!

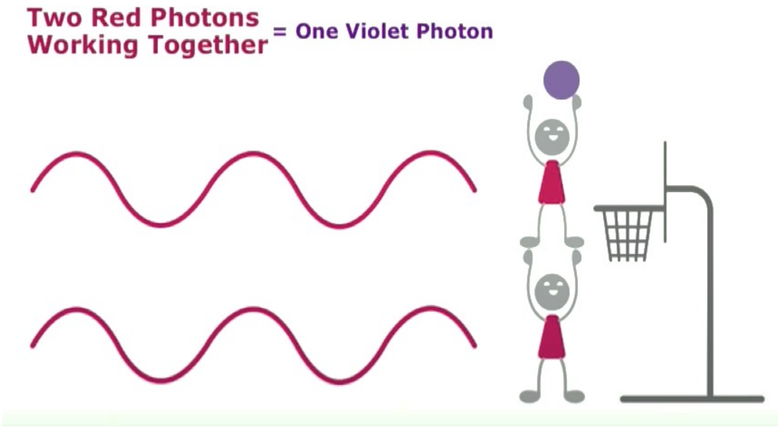
Lasers are tightly packed enough that multiple light particles (**photons**) can interact with a single atom.

Photon energy → Height of player

Height of basketball net → Energy required to free an electron



If multiple photons work together, you can free electrons that are held more tightly!



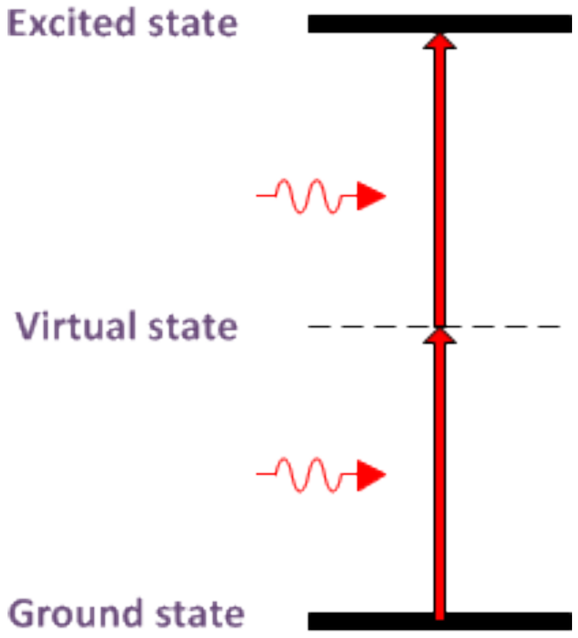
Source: D. Strickland Nobel Prize lecture



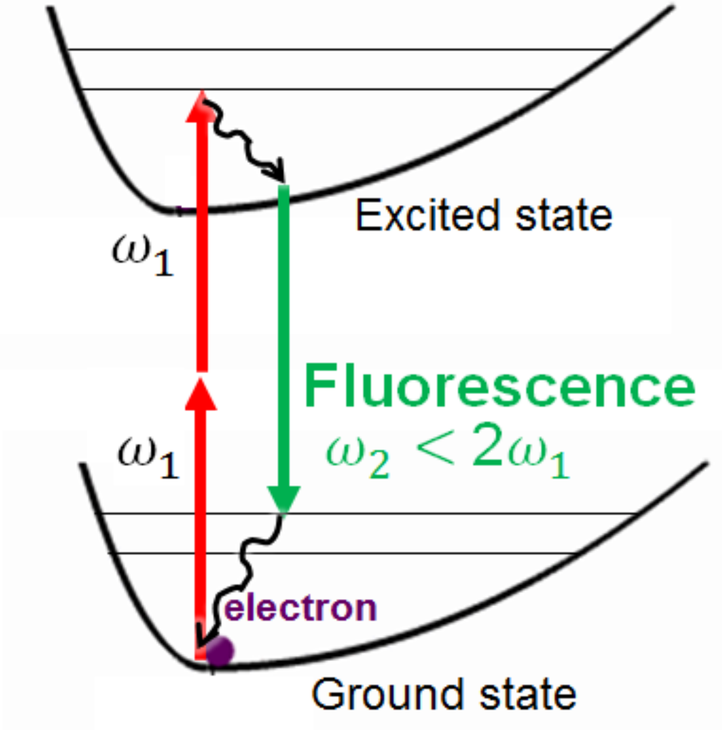
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Two-photon absorption (TPA) = simultaneous absorption of two photons of identical of differing frequencies to excite a molecule from one energy state (ground) to a higher energy state.



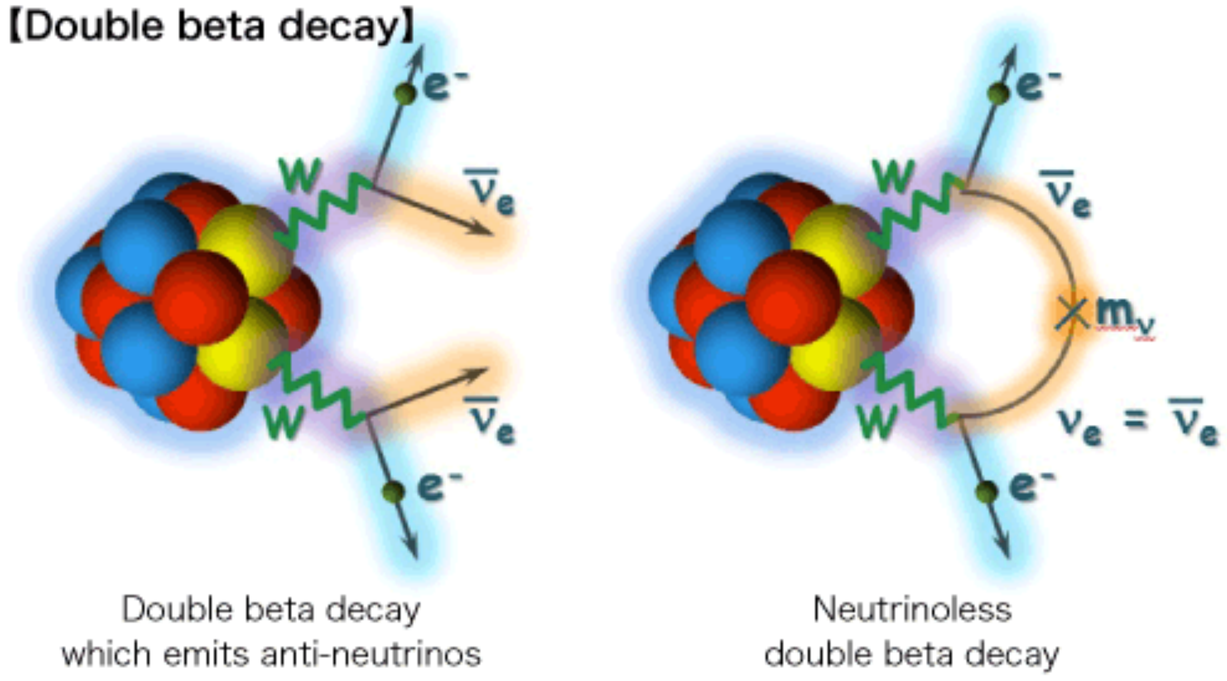
TPA of a fluorescent molecule leads to **two-photon excited fluorescence**, where the excited state decays by spontaneous emission of a photon





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In 1935, **Goeppert Mayer predicted double beta decay.**
More than 50 years later, the first laboratory observation of double beta decay was made by Micheal Moe in 1987.



Double beta decay which emits anti-neutrinos

Neutrinoless double beta decay

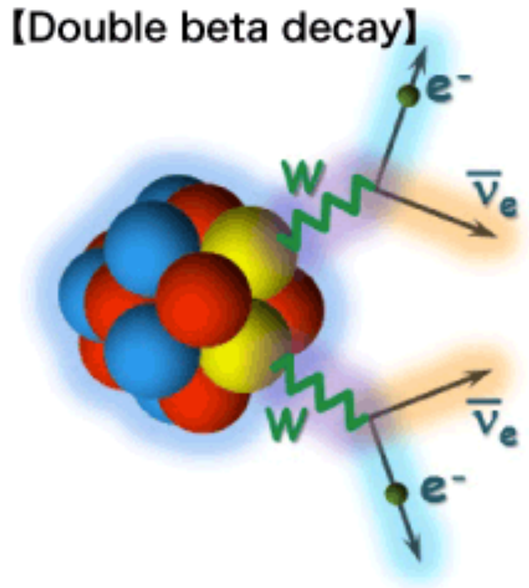
Double beta decay (2νββ) is a type of radioactive decay, where two neutrons transform into two protons inside an atomic nucleus and two beta particles (electrons or positrons) are produced.

Neutrinoless double beta decay (0νββ) is yet to be observed, but is theorized if the neutrino is it's own antiparticle (Majorana particle)



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Double beta decay
which emits anti-neutrinos

Double beta decay ($2\nu\beta\beta$) is a type of radioactive decay, where two neutrons transform into two protons inside an atomic nucleus and two beta particles (electrons or positrons) are produced.

The process can be thought of as two β^- decays :

$$ {}^{1}_{0}n \rightarrow {}^{1}_{1}p \rightarrow {}^{0}_{-1}\beta + \bar{\nu} $$

The final nucleus must have a larger binding energy than the original nucleus, and lepton number is conserved.



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Double Beta-Disintegration

M. GOEPPERT-MAYER, *The Johns Hopkins University*

(Received May 20, 1935)

From the Fermi theory of β-disintegration the probability of simultaneous emission of two electrons (and two neutrinos) has been calculated. The result is that this process occurs sufficiently rarely to allow a half-life of over 10^{17} years for a nucleus, even if its isobar of atomic number different by 2 were more stable by 20 times the electron mass.

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