CAIE Physics A-level

23 - Nuclear Physics

Flashcards

What equation is used to describe the equivalence between mass and energy?

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$$E = mc^2$$

What is the mass defect?

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The difference between the total mass of all the nucleons separately, compared to the mass of the nucleus.

Why is there a mass defect?

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Energy is released as the nucleons bind together into a nucleus. The mass-energy equivalence means this produces a mass defect.

What is binding energy?

What is binding energy?

The energy required to separate a nucleus into its constituent parts.

(This will be the same numerical value as the energy released when the nucleus binds, and is equivalent to the mass defect).

True or false? A low binding energy per nucleon will mean that an element is more stable.

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False: A low binding energy per nucleon means not much energy would be required to separate the nucleus (ie. it's more likely to decay and thus less stable).

What is nuclear fission?

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Nuclear fission is the process by which an unstable nucleus splits into smaller nuclei. It often occurs in atoms with the large nuclei.

The binding energy per nucleon increases when fission occurs so energy is also released.

What is nuclear fusion?

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Nuclear fusion is the process by which two small nuclei fuse together to form a larger one. The new nucleus has a larger binding energy per nucleon than the old one, so energy is also released.

Which process (fission or fusion) releases the most energy?

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Fusion releases a lot more energy for the amount reacting material involved (i.e. per mole of the reacting substances).

This is because the change in binding energy per nucleon is much more drastic.

Sketch a graph of nucleon number against binding energy per nucleon?

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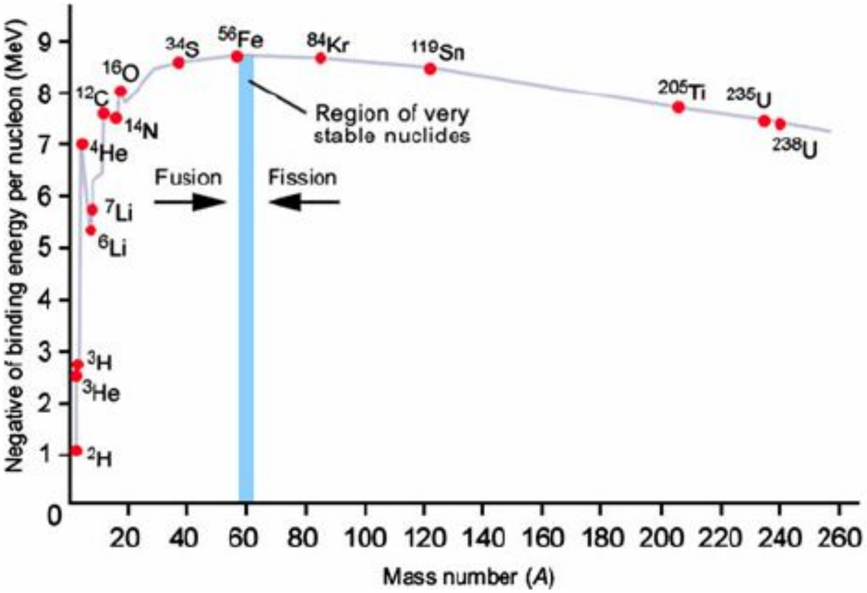
Note that, on the fusion side of the graph, the gradient rises much more steeply with nucleon number than it falls on the fission side of the graph. This large increase in binding energy per nucleon, for low nucleon fusion reactions, explains the huge energy output.



Why is it difficult to make fusion occur on Earth?

Why is it difficult to make fusion occur on Earth?

There is a large repulsion between the two positively charged nuclei, therefore a lot of energy is required to overcome the repulsion and fuse them together.

It is hard to get a material that can withstand the heat and be cost effective.

Complete the following equation:

$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + \boxed{}\ {}^{1}_{0}n\ .$$

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Complete the following equation:

$$_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{56}^{141}Ba + {}_{36}^{92}Kr + 3\ {}_{0}^{1}n\ .$$

What equation would you use to calculate the energy output of a nuclear reaction?

What equation would you use to calculate the energy output of a nuclear reaction?

$$E = c^2 \Delta m$$

Where ‘Δm’ is the change in mass of the reacted vs the originally reacting material.

What is radioactive decay?

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Radioactive decay is a spontaneous process in which unstable atomic nuclei break down, releasing energy in the form of radiation.

Is there any way of determining when an individual nucleus will decay?

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No.

Decay of individual nuclei is random.

Is there any way of determining the number of nuclei, of a given species, that will decay over a period of time?

Is there any way of determining the number of nuclei, of a given species, that will decay over a period of time?

Yes.

Although the decay of individual nuclei is random, the number of decays of a species, within a closed system, can be known. The rate of decay of all species decreases exponentially over time.

What is meant by the term ‘activity’? Can you give an equation to describe it?

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Activity is the number of decay events per unit time (usually seconds).

$$A = \lambda N$$

Where ‘A’ is activity, ‘λ’ is the decay constant (specific to each individual atomic species) and ‘N’ is the number of atoms, of the decaying species, remaining.

Define the term ‘half-life’.

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A radioactive half-life is the time taken for the number of decaying atomic species to decrease by half. This is the same time that it takes for the activity of the species to decrease by half. Different atomic species have different half-lives.

Does the half-life of a species remain constant throughout the decay process? Use a graph to help explain.

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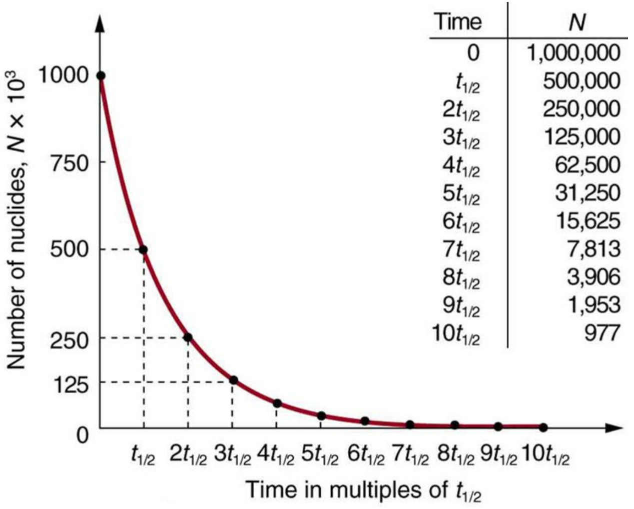
Yes it does. As it can be seen on the graph, in exponential decay, as the number of undecayed atoms decreases, the activity decreases proportionally.



Time	N
0	1,000,000
$t_{1/2}$	500,000
$2t_{1/2}$	250,000
$3t_{1/2}$	125,000
$4t_{1/2}$	62,500
$5t_{1/2}$	31,250
$6t_{1/2}$	15,625
$7t_{1/2}$	7,813
$8t_{1/2}$	3,906
$9t_{1/2}$	1,953
$10t_{1/2}$	977

Use equations to explain how the number decayed nuclei and the decay activity changes through time.

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Number: $N = N_0e^{-\lambda t}$

Activity: $A = A_0e^{-\lambda t}$

Where 'N_0' and 'A_0' are the number of undecayed atoms and the activity at t=0 respectively.

Use the equation $x = x_0e^{-\lambda t}$ to figure out the relationship between the decay constant (λ) and the half life ($t_{1/2}$).

Use the equation $X = X_0e^{-\lambda t}$ to figure out the relationship between the decay constant (λ) and the half life ($t_{1/2}$).

At $t = t_{1/2}$, $X = X_0/2$, so $X_0/2 = X_0e^{-\lambda t}$

$e^{-\lambda t} = ½$

$-\lambda t = \ln(½)$

$\lambda = \ln(2)/t = 0.693/t = 0.693/t_{1/2}$