Transcript
Fission-Fusion

A few introductory words of explanation about this transcript.

This transcript includes the words sent to the narrator for inclusion in the latest version of the associated video. Occasionally, the narrator changes a few words on the fly in order to improve the flow. It is written in a manner that suggests to the narrator where emphasis and pauses might go, so it is not intended to be grammatically correct.

The Scene numbers are left in this transcript although they are not necessarily observable by watching the video.

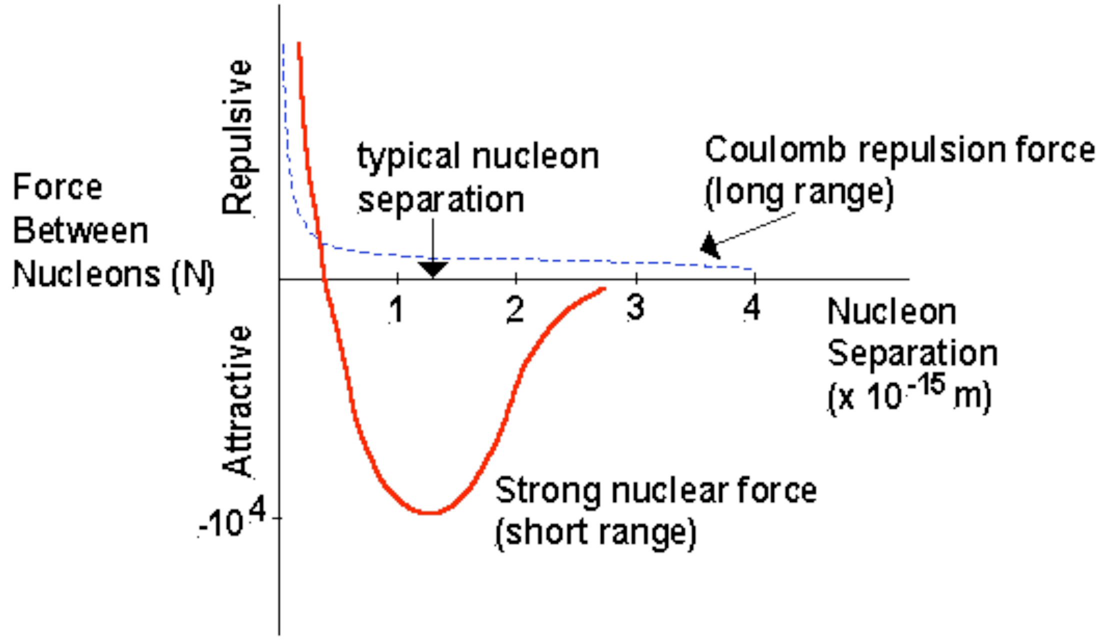
There will also be occasional passages in blue that are NOT in the video but that might be useful corollary information.

There may be occasional figures that suggest what might be on the screen at that time.

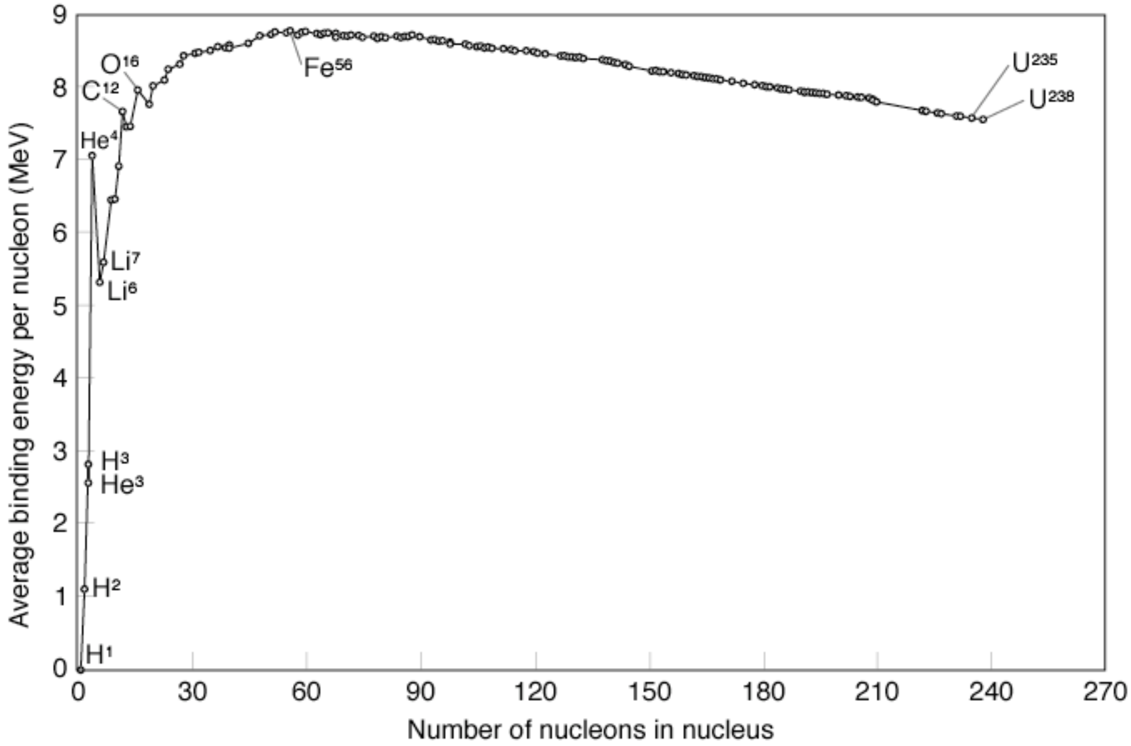
Consider the earth and a rocket ship which are bound together by gravity. If it takes work or energy to pull them apart, then the binding energy is the amount of energy it takes to completely separate them.

Similarly the binding energy in a nucleus is the amount of energy it takes to completely separate the protons and neutrons, (collectively called nucleons.)

There are two forces acting inside the nucleus of atoms. The nuclear force -- a residuum of the strong force that holds quarks together -- is pulling the neutrons and protons together -- and the electric charge on the protons is pushing them apart. The strong force is a lot stronger than the electric force at short ranges up to two and a half times the proton diameter, but at larger distances the electric force dominates.



So as we add nucleons and work our way up the chart of the periodic table, initially, each nucleus is generally little more tightly bound than the one before. This chart gives the actual numbers.



This increase in binding energy continues until we get to iron and nickel where the nucleus has about 60 nucleons in it. At this point, the nucleus has a radius more than two and a half nucleons wide, which you remember is the range at which the repulsive ElectroMagnetic Force begins to dominate.. . So as we add nucleons past this point the electric force trying to tear the nucleus apart starts winning and each added nucleon is a little less-tightly bound.

When we get to lead and bismuth and the nucleus contains 207 nucleons, the electric force wins and atomic nuclei larger than this are unstable and come apart by themselves although it may take a while.

These larger nuclei can return to a more stable arrangement in several ways. They can convert neutrons into protons and give off beta radiation, or kick out whole groups of nucleons four-at-a-time in alpha radiation or they can simply split into two smaller more-stable nuclei. When this happens we call it fission. Fission is different from the other forms of decay because it can be harnessed and controlled via a chain reaction.

Now let's consider what this means from an energy perspective.

According to the binding energy chart, uranium has 7.6 MeV of binding energy for each nucleon for a Total of

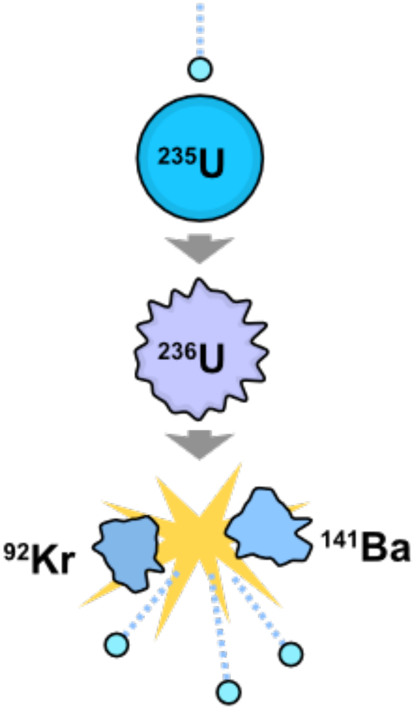
(Green will appear on screen but not spoken aloud)
U(235) has 235 x 7.6 Mev = 1786 MeV

While Barium(144) has 144 x 8.3MeV = 1195 MeV
And Krypton(89) has 89 x 8.8MeV = 783 MeV
And the extra neutrons have no binding energy 0 MeV

1978 MeV

So every time a nucleus of Uranium fissions we get about 192 MeV of energy!

But U-235 left to its own devices might take billions of years to decay, so we will want to help it along.



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We do this by shooting a slow neutron into it. It absorbs the neutron and briefly becomes U-236. Then it splits into Krypton-92 and Barium-141 and 3 free neutrons. Those 3 neutrons go on to split other U-235 atoms into other daughters and MORE neutrons and the process grows and repeats again.

We can put the whole thing in water and the daughter fragments and neutrons will be slowed by the water and cause it to heat up. Finally we can use the steam to make electricity.

This is how a nuclear power plant works.

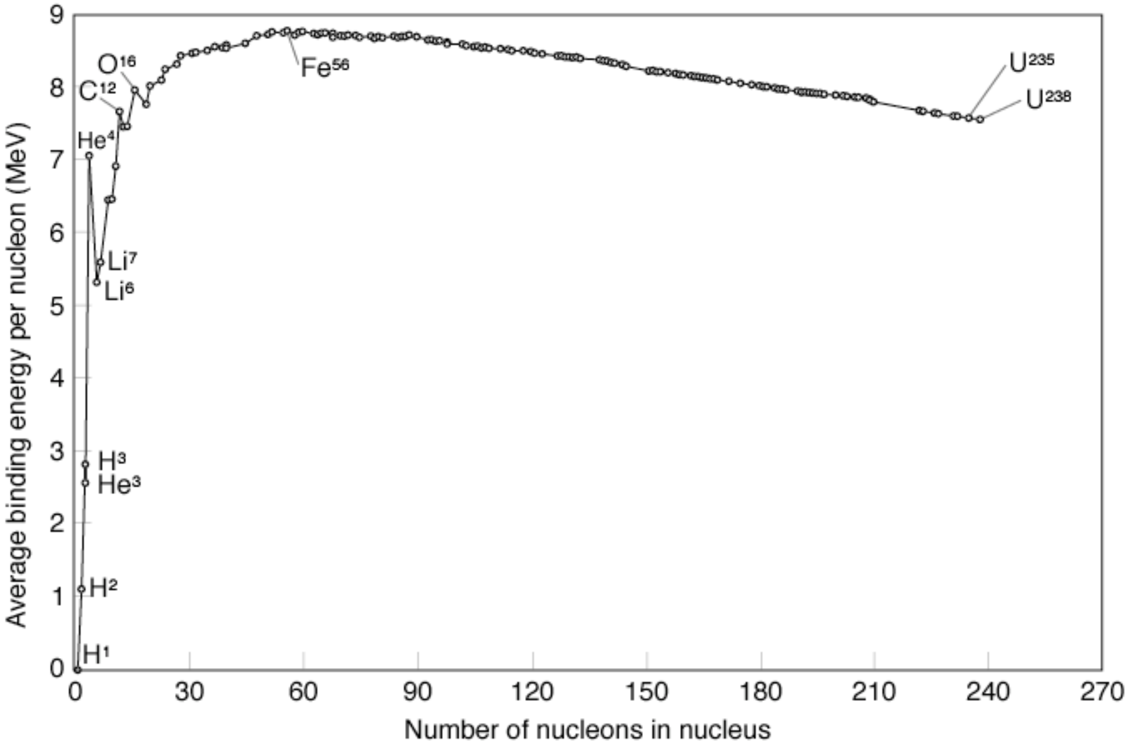
09-106-Fusion

Ever since Einstein demonstrated the equivalence of mass and energy, physicists often give the rest mass of tiny particles like protons, neutrons, and electrons in units of energy. Two convenient energy units are the electron-volt or eV and its cousin – Million-electron-volts or MeV.

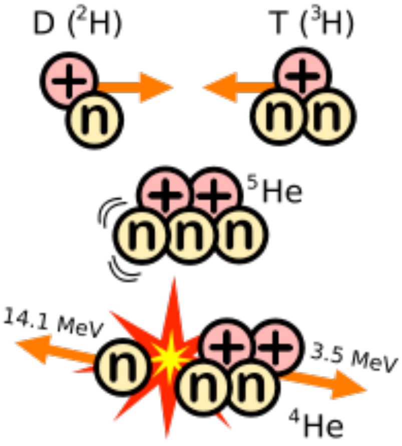
Using these units, here are facts that will come in handy…

Rest mass of proton	938.272	MeV
neutron	939.566	MeV
electron	.511	MeV

Let’s take another look at the chart of binding energy of atomic nuclei and now let’s talk about Fusion.



If we can take a nuclei of deuterium which has one proton and one neutron in its nucleus and get it fuse with a tritium nucleus which has one proton and two neutrons… We would end up with helium, one extra neutron, and some energy, and we would have the basis for an energy making machine.



Let’s run the numbers and see how it works.

The binding energy for deuterium is about 2 MeV.
And the Binding energy for tritium is about 8 MeV.
So the total for the input items is 10 MeV.

The binding energy for Helium is 28 MeV and the free neutron has zero binding energy.

Subtracting the 10 MeV from the 28 MeV reveals that every time this fusion happens, we liberate 18MeV of energy.

And that's pretty good…But there is a problem. Getting the protons in the deuterium and tritium close enough together so the nuclear force fuses them together is hard to do on earth.

This is the energy that powers the sun and stars, but the sun's gravity holds the fuel in place while the high temperature gives the nucleii enough speed to overcome the electric repulsion.

If we could make a miniature star in the lab – a microsun – then we would be well on our way to having a great solution to our energy problems. And although this has proven difficult -- significant progress continues to be made.

Similar to Tritium is an isotope of Helium called helium-3. It could be substituted in the above reaction and would produce a similar amount of energy. What's the difference? Well there are an estimated 1,000,000 tons of easily mined He-3 on the moon's surface.

It would take only 25 tons to satisfy ALL the energy needs of the United States for an entire year.

And 25 tons also happens to be the maximum payload of the space shuttle.

And now you know why we are going back to the moon.