

**ANSELME  
LANTURLU** 

# **Yours Energetically**

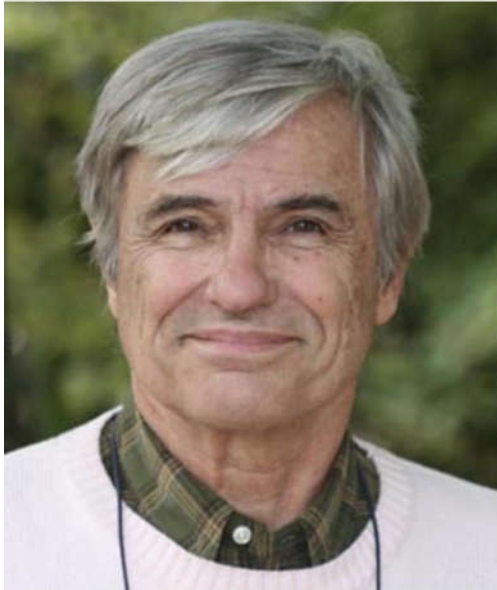
by Jean-Pierre Petit

Translated by John Murphy



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Jean-Pierre Petit



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# PROLOGUE

Once upon a time there was a world in which humans did not know fire. They cooked their food by exposing it to the heat of the sun.



It'd be nice if we could find something else...

When night fell they took big rocks into their cave to benefit from the heat they had stored during the day.



...tiring...

Are you asleep?

No, the stones are already cold.

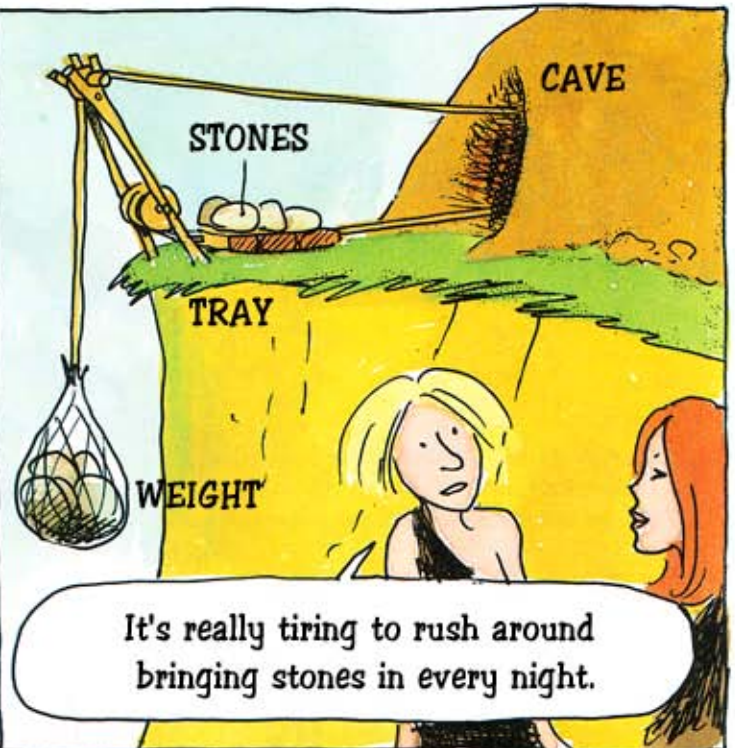


We're freezing...

When winter comes it'll be worse. Half the tribe has already got a cold.

What are you doing?

I'm looking for a way of **STORING ENERGY**.



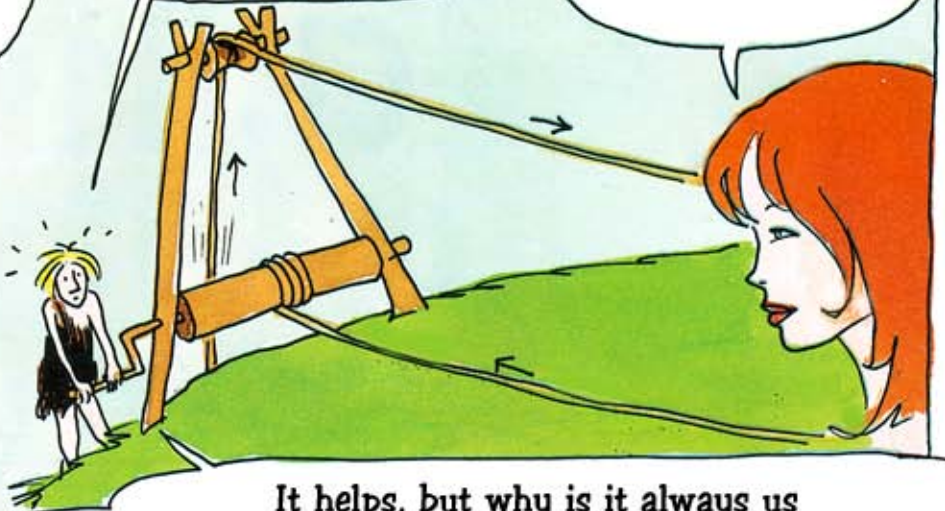
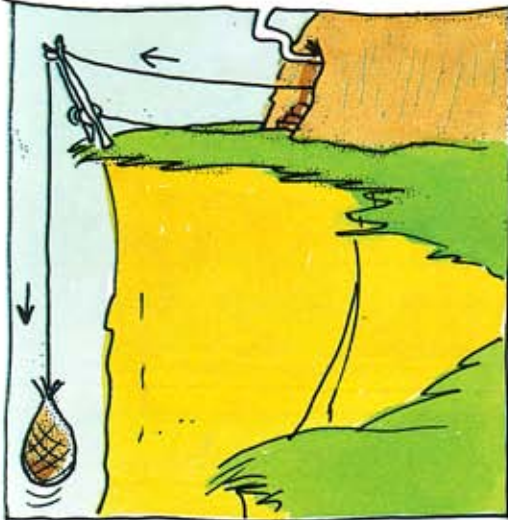
It's really tiring to rush around bringing stones in every night.



So I've invented a system which pulls the tray full of hot stones up into the cave each night.

And in the daytime I winch the counterweight back up.

You're stocking **POTENTIAL ENERGY**.



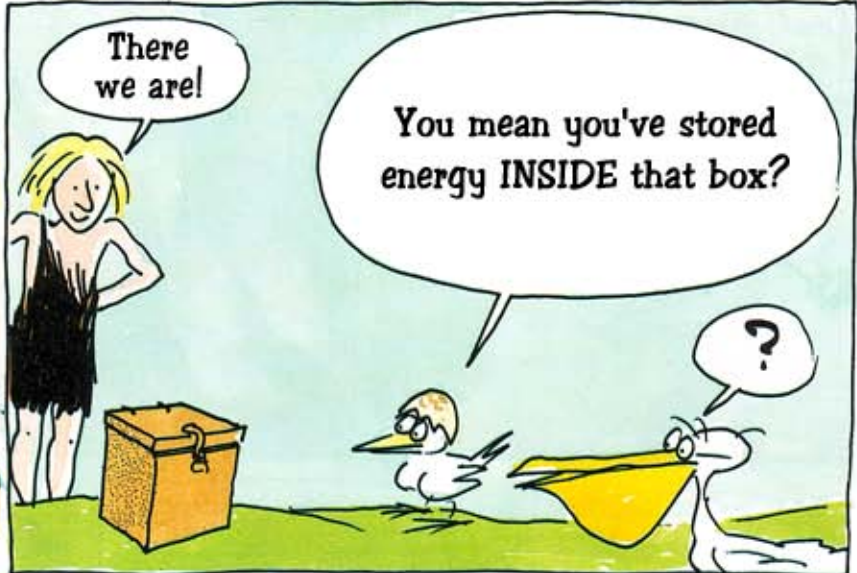
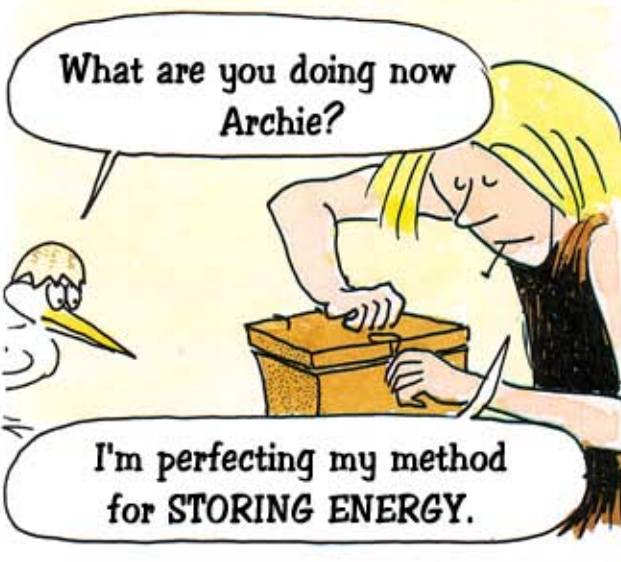
It helps, but why is it always us that have to do the **WORK**?

What are you doing now Archie?

There we are!

You mean you've stored energy **INSIDE** that box?

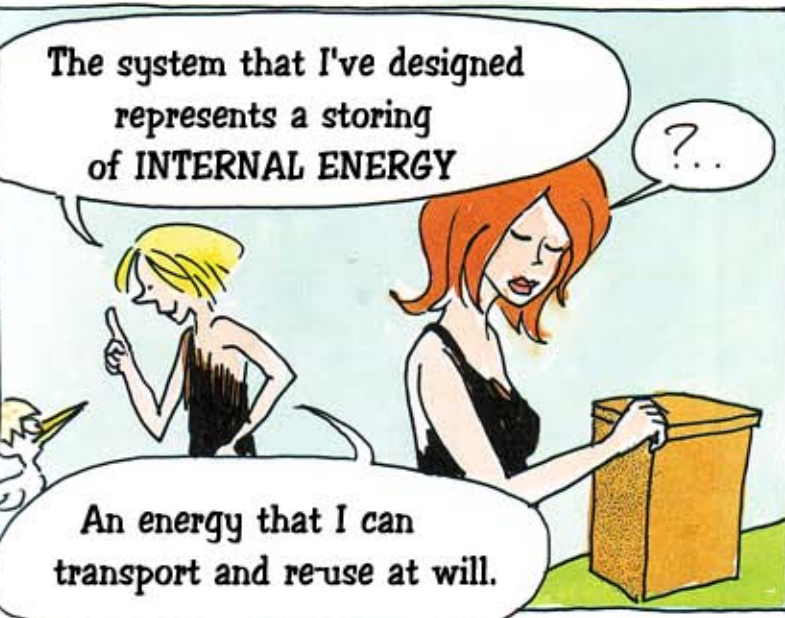
I'm perfecting my method for **STORING ENERGY**.



The system that I've designed represents a storing of **INTERNAL ENERGY**

??

An energy that I can transport and re-use at will.



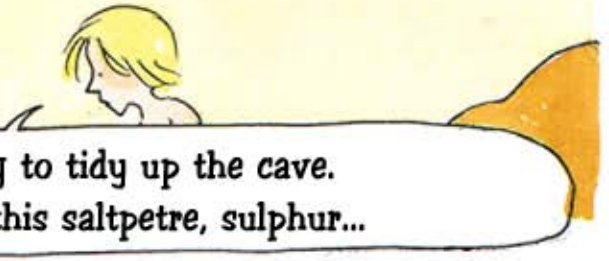


# CHEMICAL ENERGY

Sophie!  
It was just the STORAGE  
OF INTERNAL ENERGY!



I'm going to tidy up the cave.  
Look at this saltpetre, sulphur...



And this charcoal left over  
from the forest fire that  
God Thunder made.



If I don't clean up  
Sophie will kill me.



...just this  
big stone left





Sophie! I've found something.  
There's **ENERGY** in this **BLACK POWDER**  
I've just invented.



We'll be able to use it  
to cook things and keep warm!

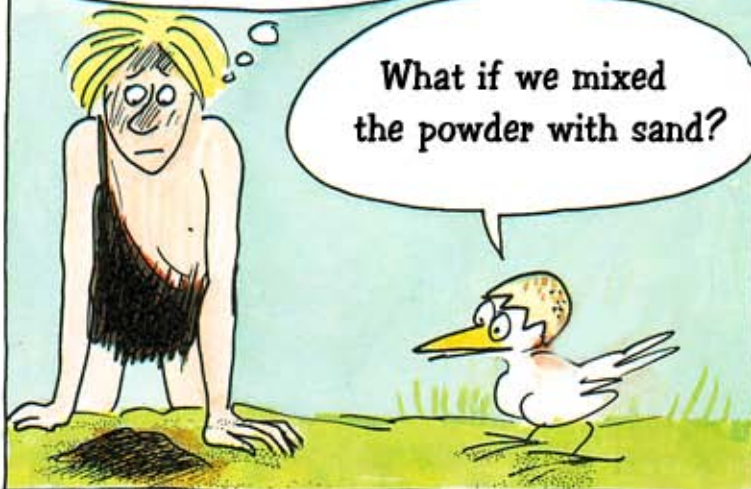


You'll see...

Ok, but if you want my opinion,  
it isn't very easy to use.

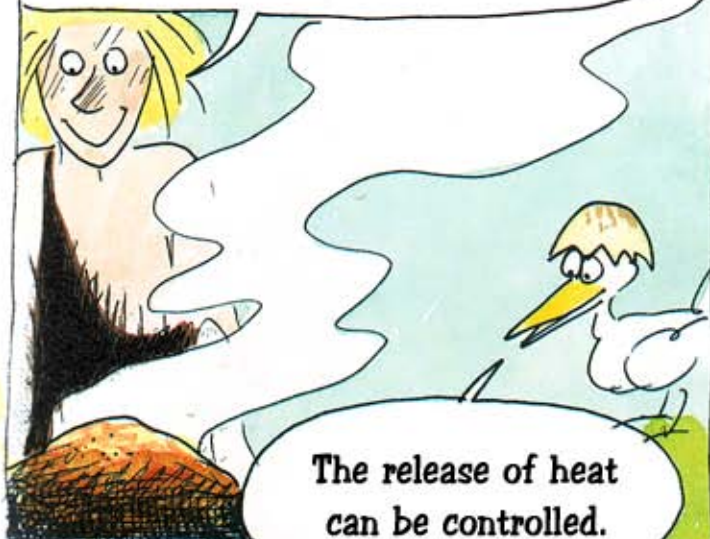


Should I forget it?



What if we mixed  
the powder with sand?

That works!!!  
The sand calms the mixture so that  
it frees energy more slowly!



The release of heat  
can be controlled.

We won't be freezing cold this winter.





Well it gives off a lot of heat but we can hardly breathe.



I think you mean we're suffocating.

Right sending the smoke into this bag helps, it's better already.



It condenses into soot so I can get rid of it easily.

Although I must say it's not really that practical.

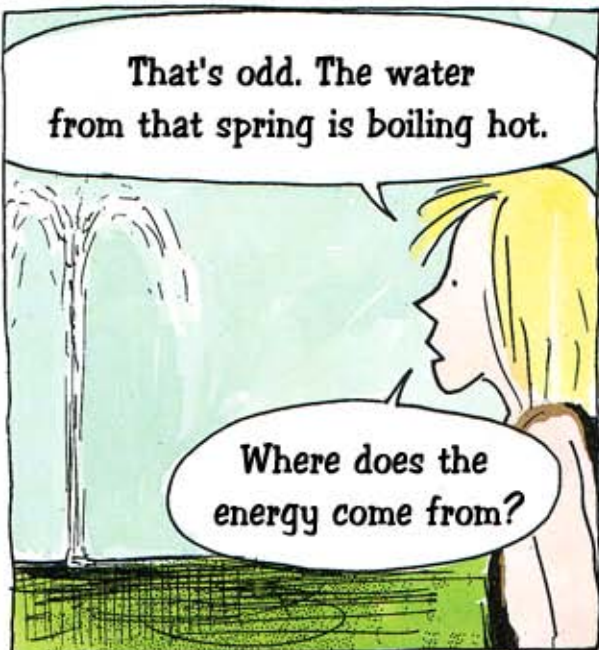


I can't just throw all that anywhere, I'll poison the water in the lake.



# NUCLEAR ENERGY

That's odd. The water from that spring is boiling hot.



Where does the energy come from?

Perhaps there are devils under the Earth's surface.



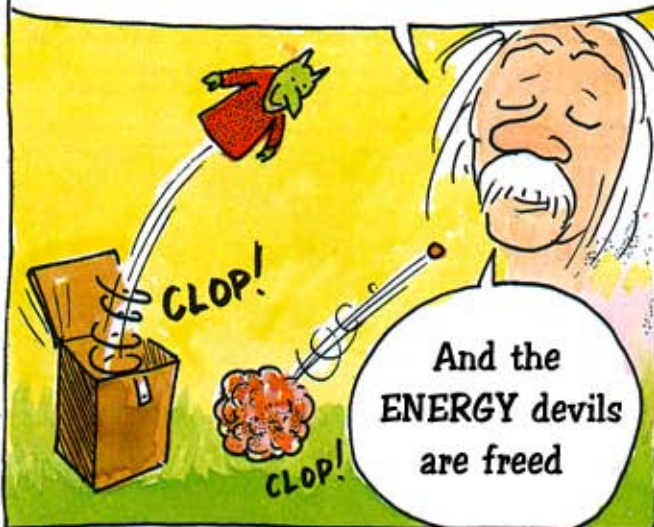


...boxes with devils inside!?



An old legend said that once, **ENERGY** was shut inside the **NUCLEII** of certain **ATOMS** like **URANIUM**. These atoms were made in the suns, in their infernal furnaces, then ejected and imprisoned in the mass of Earth when it was formed.

But these atoms aren't solid boxes and sometimes a top pops off.



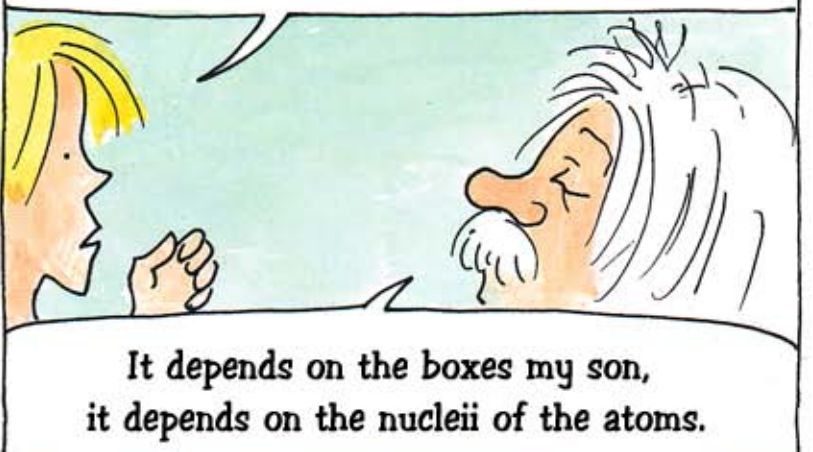
The legend says that at the **END OF TIME** all the devils will be out of their boxes and there won't be any energy like this left in the universe.



But it will take a long time, a very long time...



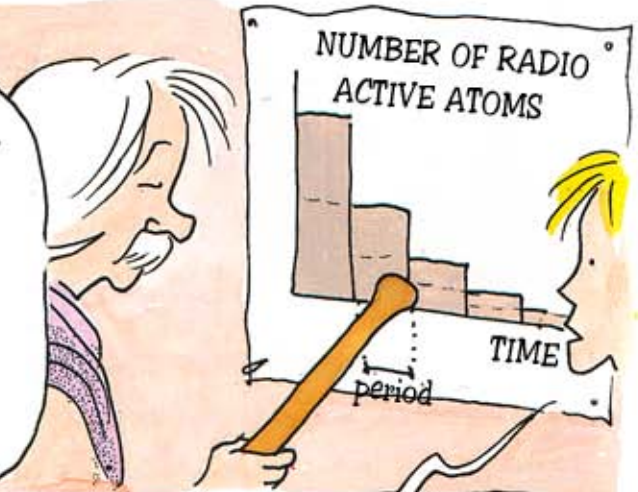
So how long will the devils remain in their boxes? How long will the **NUCLEII** keep the **ENERGY** they have?





# RADIOACTIVE PERIOD OF AN ELEMENT

If we take an ensemble of boxes with devils in them, after a time  $T$ , called **HALF-LIFE**, or **PERIOD**, half of the devils will have been freed. In an identical lapse of time, half the remaining boxes will open in their turn, and so on. This half-life can vary greatly, from hundreds of thousands of years to a fraction of a second.



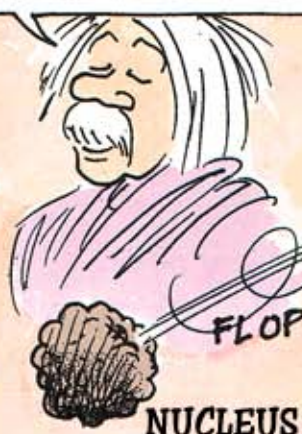
And if there weren't all these boxes with their devils, all these nuclei filled with energy inside the Earth then we'd be much colder in winter.

It would be nice if I could find all these atoms charged with energy.



If I could put enough of them into a bottle I could keep warm all winter.

Careful Archibald, the **NUCLEAR ENERGY** springs are much more powerful than **CHEMICAL ENERGY**, **HUNDREDS OF THOUSANDS TIMES MORE POWERFUL**.



FLOP!

NUCLEUS



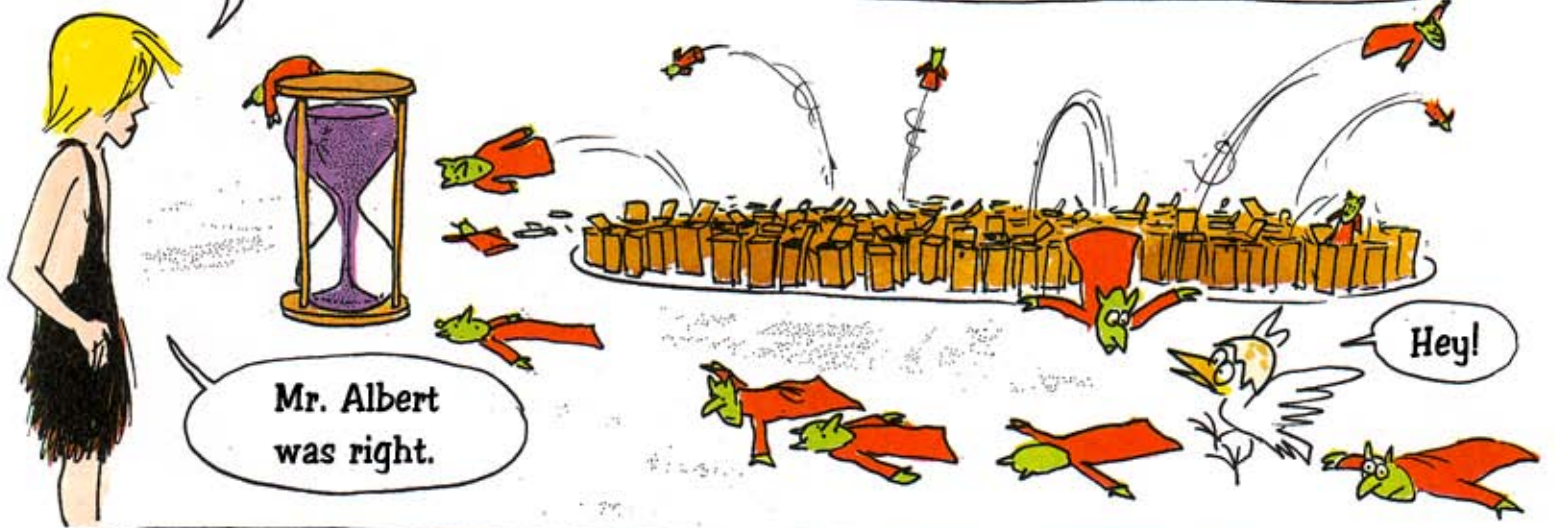
So the devils emitted by the radioactive nuclei shoot out with great violence.



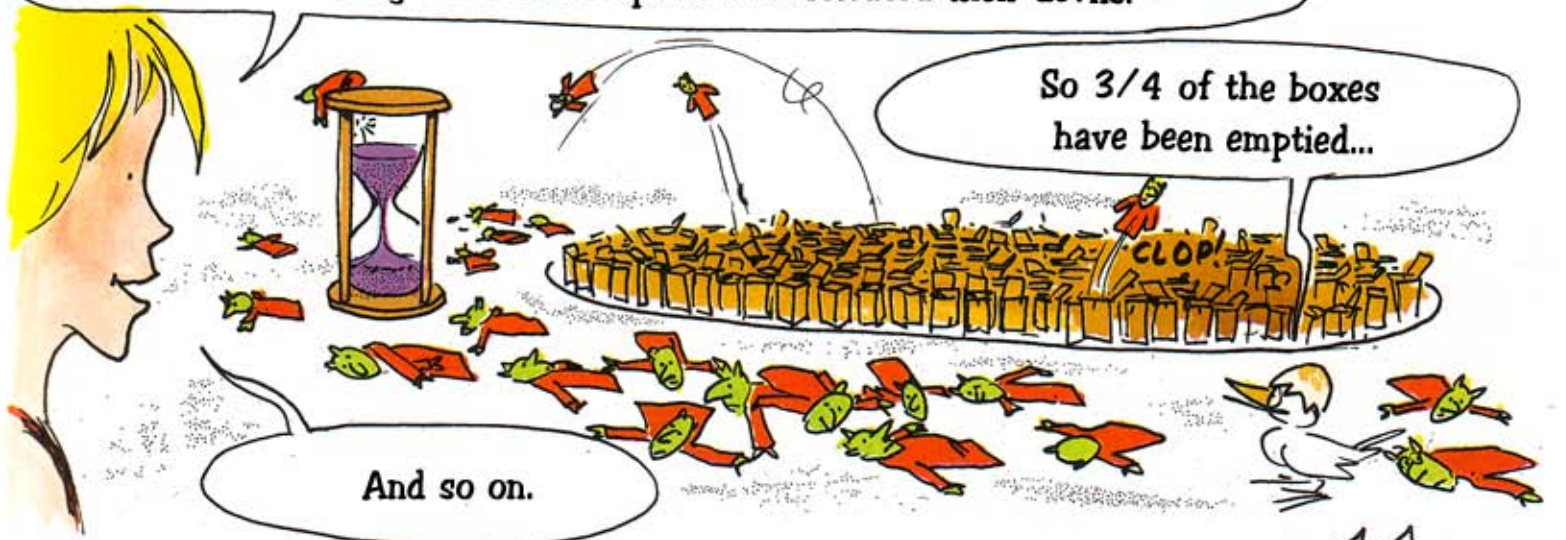
Let's see if what Mr. Albert says is true.  
The boxes' fasteners slide progressively and so they open one by one.



Good, after a time period equal to their half-life, half the boxes are empty.



After an equivalent lapse of time half  
the remaining boxes have opened and released their devils.



So  $\frac{3}{4}$  of the boxes  
have been emptied...



So that means that it slows with time, the rhythm of boxes opening tends to diminish.

The Earth must have been a lot more radioactive in the beginning.

And then it calmed down.

# CONVERSION OF ENERGY

But where's the **HEAT** in all that?

What if we put it in a cooking pot?

Let's try...

It works. The **ENERGY** emitted by the **RADIOACTIVE ATOMS** is absorbed by the water and **CONVERTED INTO HEAT**.

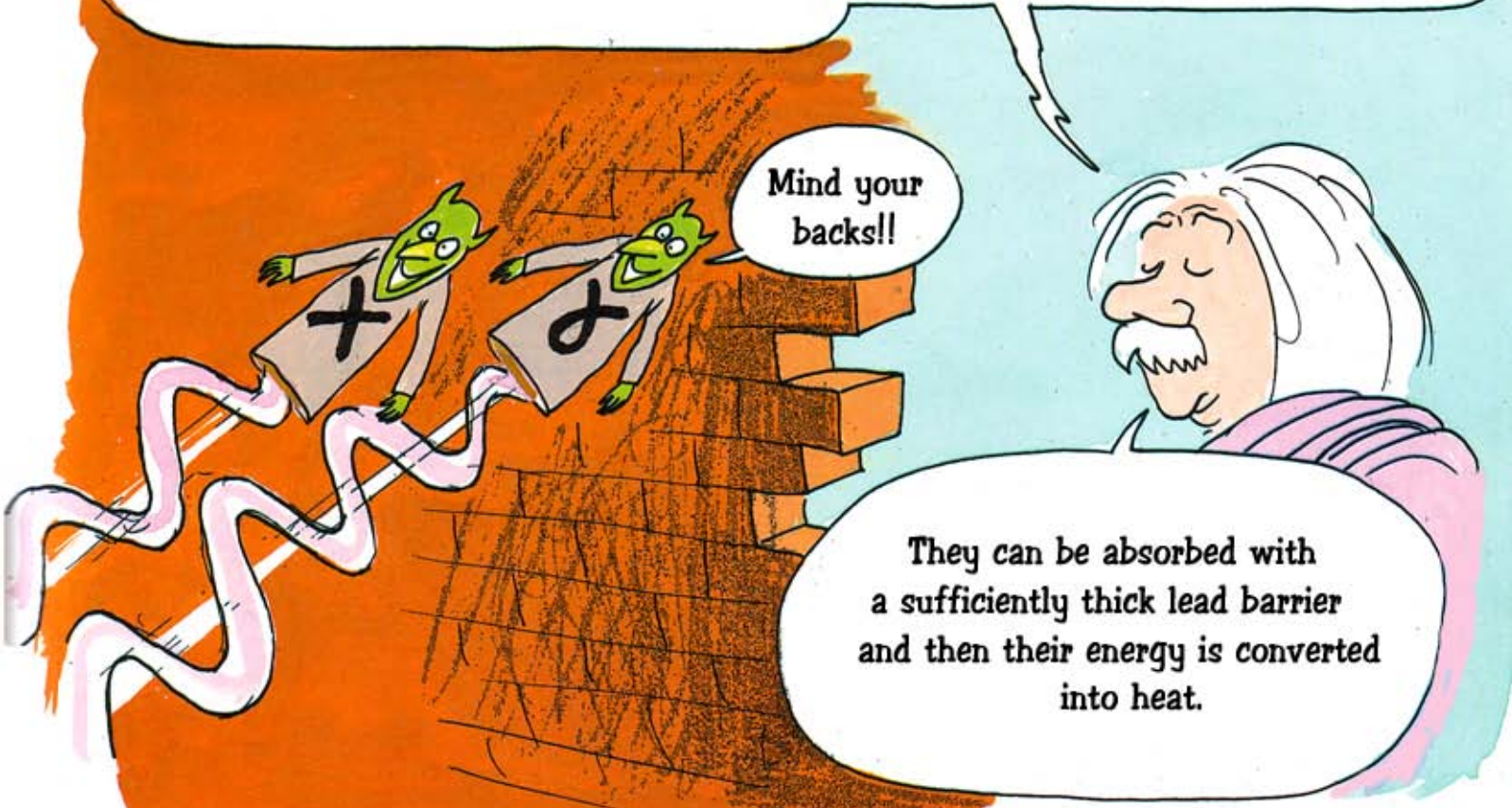
Yes but this **NATURAL RADIOACTIVITY** doesn't release much **ENERGY**.

So we'd need a lot of radioactive material to be able to keep ourselves warm.



# THE DIFFERENT SPECIES OF DEVILS

Basically there is only one devil species. The first things that nuclei can emit are X or  $\gamma$  RADIATION. A sort of invisible light.



Mind your backs!!

They can be absorbed with a sufficiently thick lead barrier and then their energy is converted into heat.

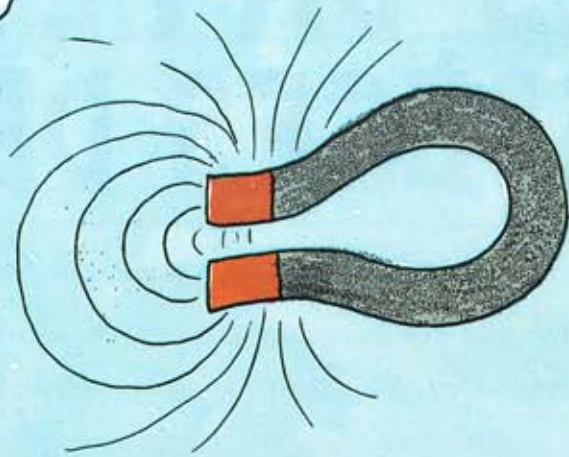
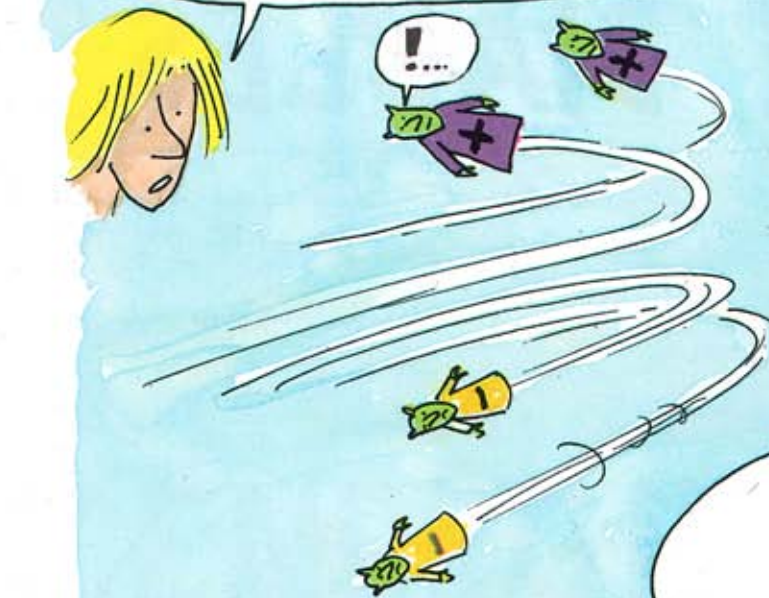
There are other types of devils that have an **ELECTRIC CHARGE**

Do they go fast?

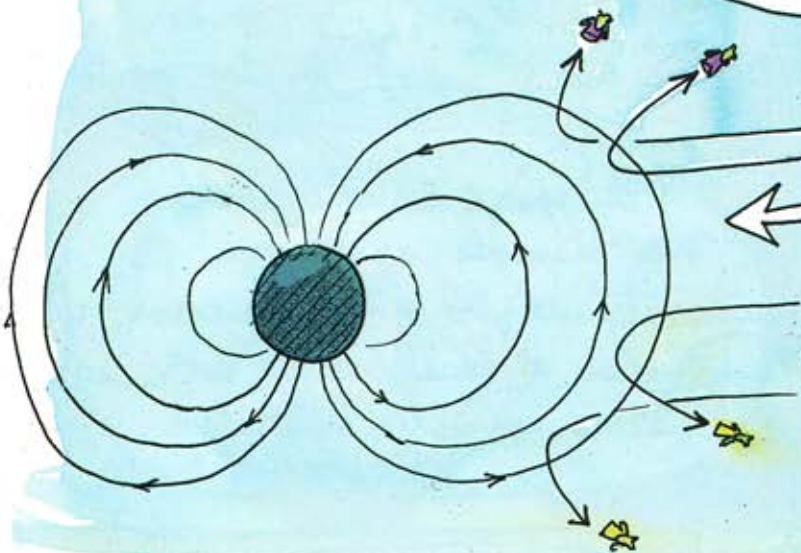
It depends on their **ENERGY** but they can reach speeds of several thousand kilometres a second.



At that speed they should be able to go straight through anything...



No, for they bounce off a **MAGNETIC FIELD**



In the same way, charged solar particles emitted by the Sun (solar wind) are reflected by the earth's magnetic field (\*)



So the earth is **PROTECTED** by its magnetic field.



Yes. If Earth didn't have this natural protective magnetic shield, the charged particles from the Sun would seriously damage living tissue.

(\*) For Earth, the geographic and magnetic poles are in inverted positions.



The third type of devils' space is the worst:  
**NEUTRONS**. They too are careering about  
at speeds up to 20,000 km/s. As they don't have  
an **ELECTRIC CHARGE**, they can't be stopped  
by a magnetic barrier.



All these devils can do  
irreversible damage to living tissue.  
We have to protect ourselves from them.

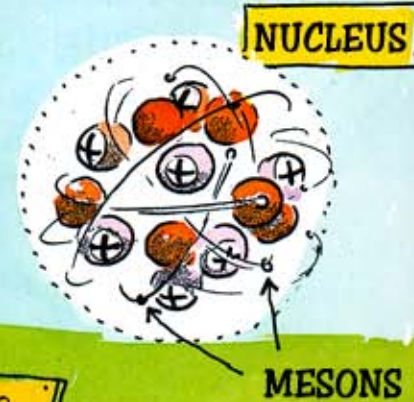
The neutrons and the electrically  
charged particles have mass and carry kinetic energy  
 $\frac{1}{2}mv^2$  which can be absorbed by a solid, a liquid or  
a gas and converted into heat. But I'd like  
to know more about these nuclei.





# NUCLEUS STABILITY

To make NUCLEII you need NEUTRONS, PROTONS and particles called MESONS.

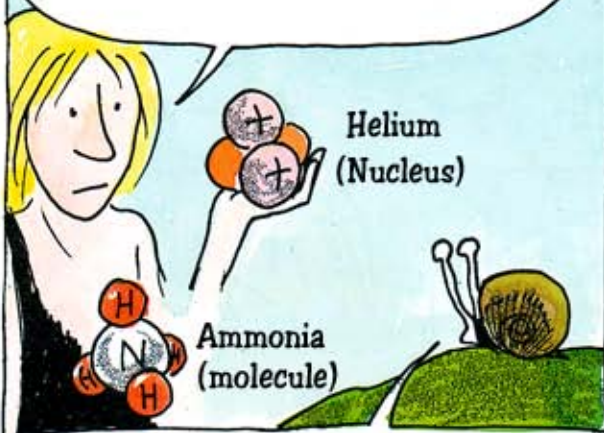


Uranium 235  
92 PROTONS  
+ 143 NEUTRONS  
= 235 NUCLEONS

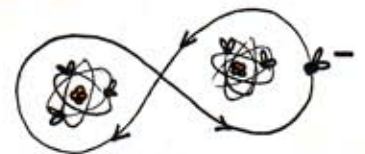
Plutonium 239  
94 PROTONS  
+ 145 NEUTRONS  
= 239 NUCLEONS

MESONS in the NUCLEII act a bit like ELECTRONS in MOLECULES: they ensure COHESION.

So NUCLEII are MOLECULES?

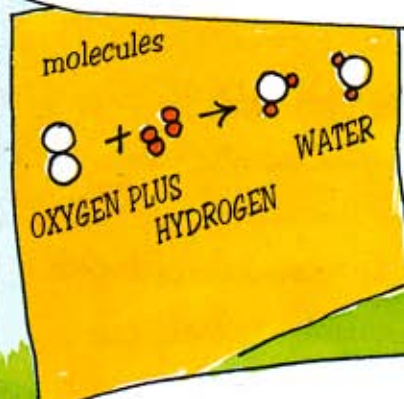


NUCLEII are an assembly of NUCLEONS. MOLECULES are an assembly of NUCLEII. And, in fact, we are assemblies of molecules.



Electron ensuring A MOLECULAR LIAISON.

CHEMISTRY interprets the rearrangement of MOLECULES.



NUCLEAR PHYSICS studies the REARRANGEMENT of NUCLEII



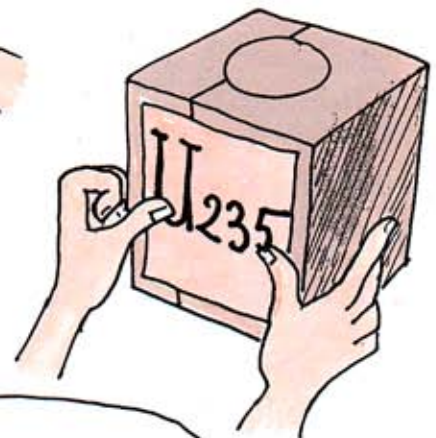
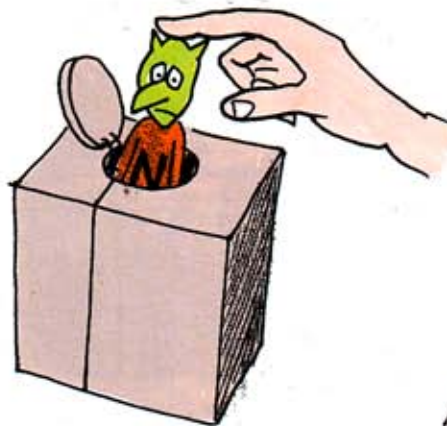
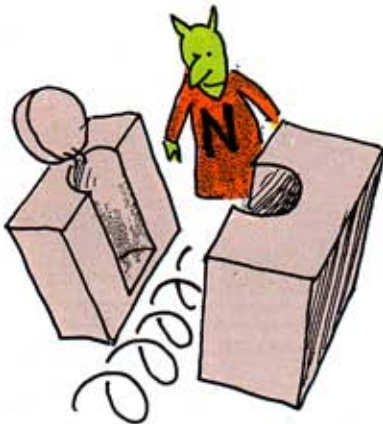
A nucleus that is considered to be **UNSTABLE** is a nucleus with a short life

But neutrons, when acting on certain nuclei (themselves relatively stable having very long lives) can destabilise them completely and cause them to split, **FISSION**.

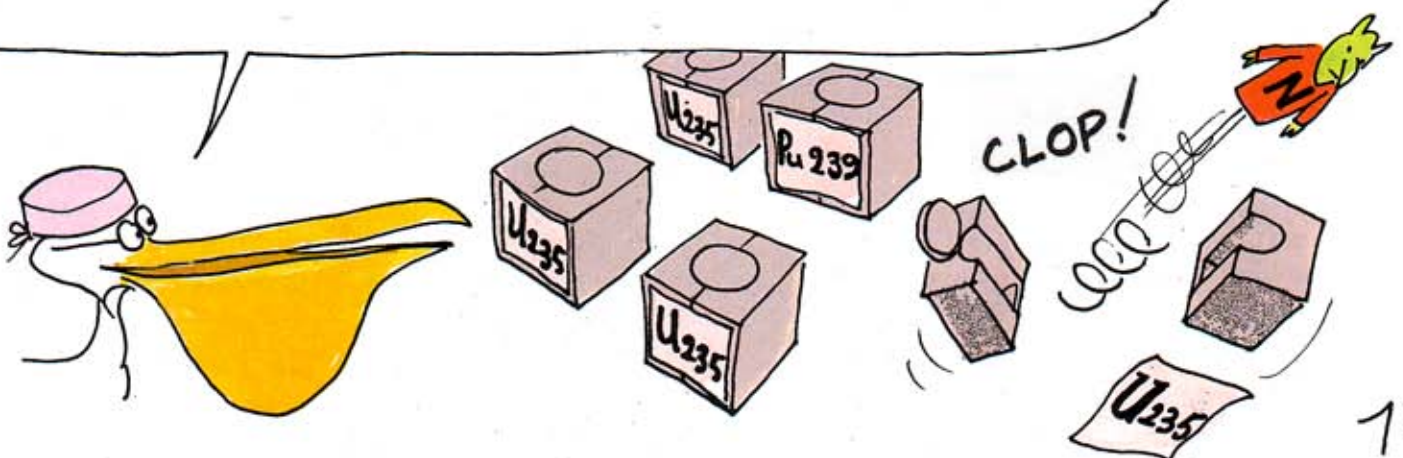
That's the case for **URANIUM 235** and **PLUTONIUM 239**

# FISSION

These nuclei can be represented as an assembly of two blocks of different masses and with one neutron.



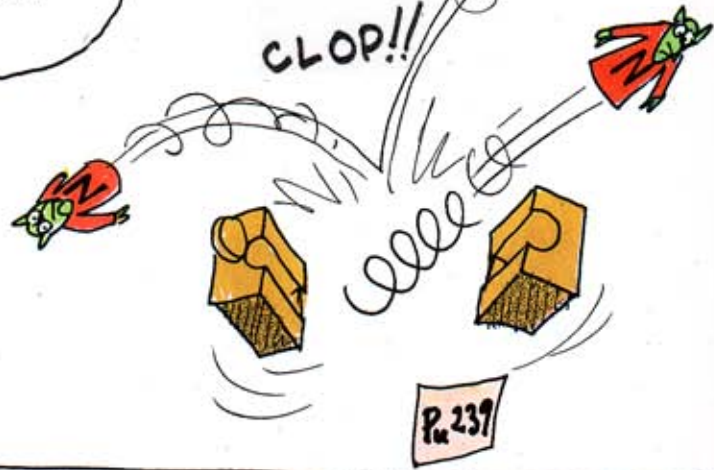
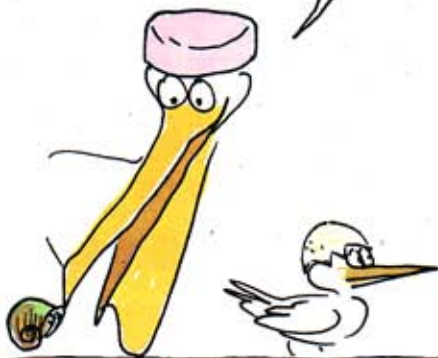
Uranium 235 and Plutonium 239 nuclei have a certain type of natural radioactivity, associated with a very long period.





Here's a FISSION reaction.

The encounter with a neutron has destabilised the Plutonium nucleus. The result of this reaction is the re-emission of 2 neutrons (\*)



I'm going to study that closely.

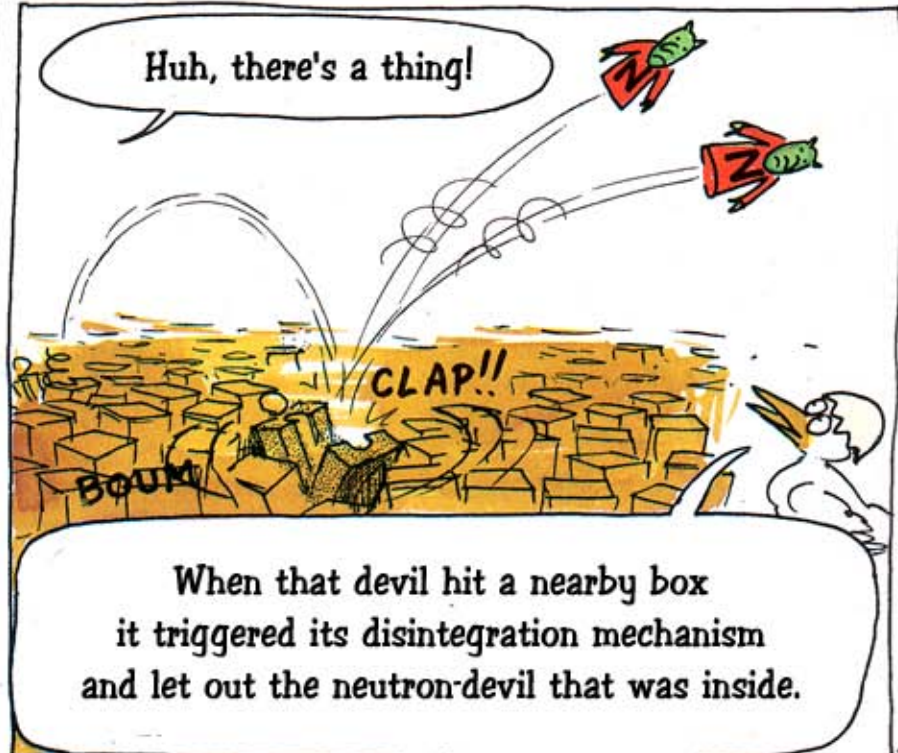
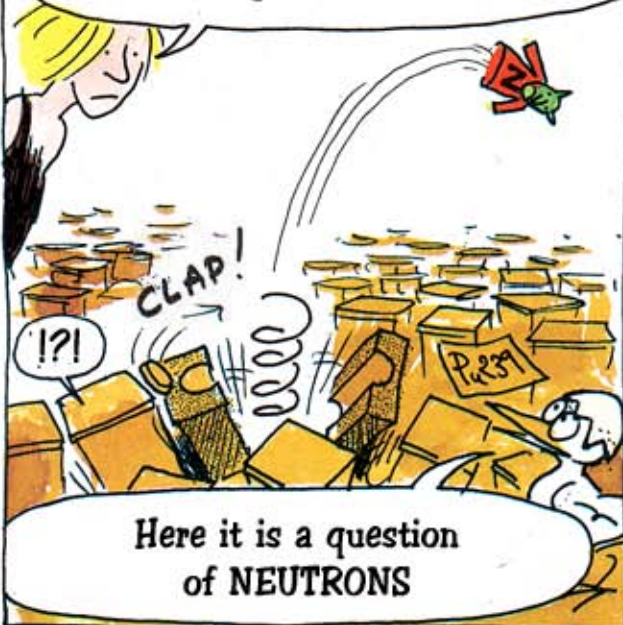
Archie has assembled lots of devil boxes inside a circle of radius R.

Uranium 235 or Plutonium 239



Now the ENERGY devils are coming out of their boxes

Huh, there's a thing!



Here it is a question of NEUTRONS

When that devil hit a nearby box it triggered its disintegration mechanism and let out the neutron-devil that was inside.

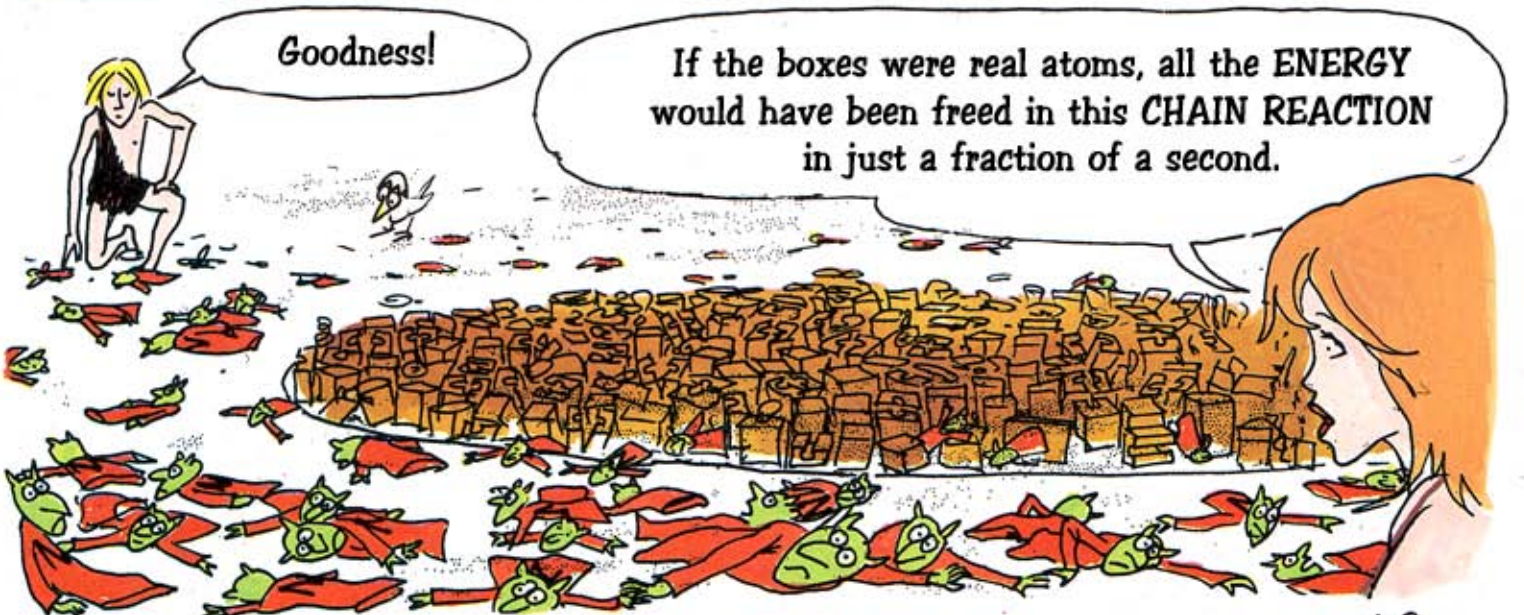
(\*) This is a schematic image. In fact the incident neutron is first absorbed by the fuse nucleus ( $U235$  becomes  $U236$  and  $P239$  becomes  $P240$ ). These are new objects, very unstable, which break down almost immediately.



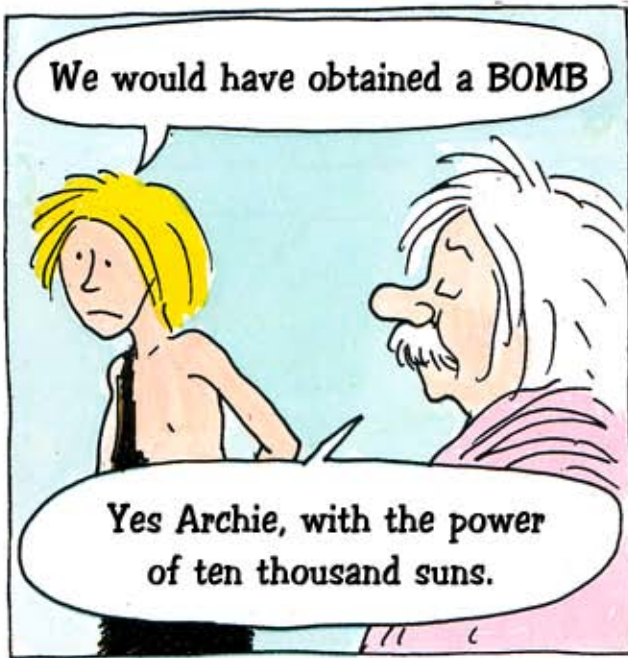
# CHAIN REACTIONS



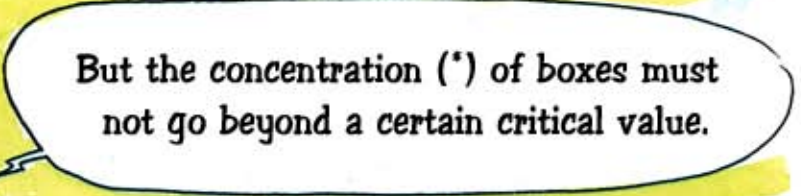
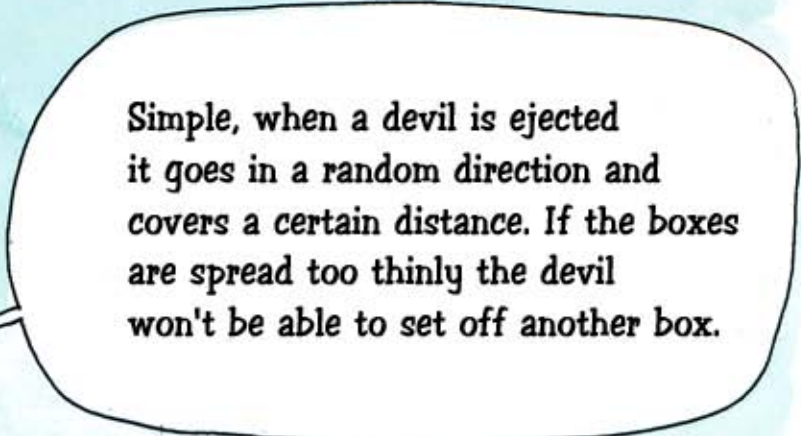
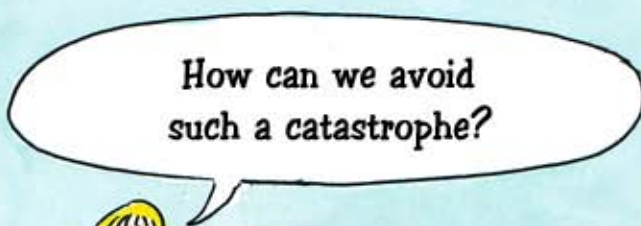
The two devils then make two more boxes open!







# CRITICAL CONDITIONS



(\*) Normally referred to as the CRITICAL MASS.



In fact, between the weak **NATURAL RADIOACTIVITY** emission level and the **CHAIN REACTION**, we can find an average term. By adjusting this **CONCENTRATION**, which is quite difficult and delicate, we can set the number of devils that will be ejected each second, that is to say the energy flow.



# THE NUCLEAR REACTOR

Isn't there a better way to control the process?

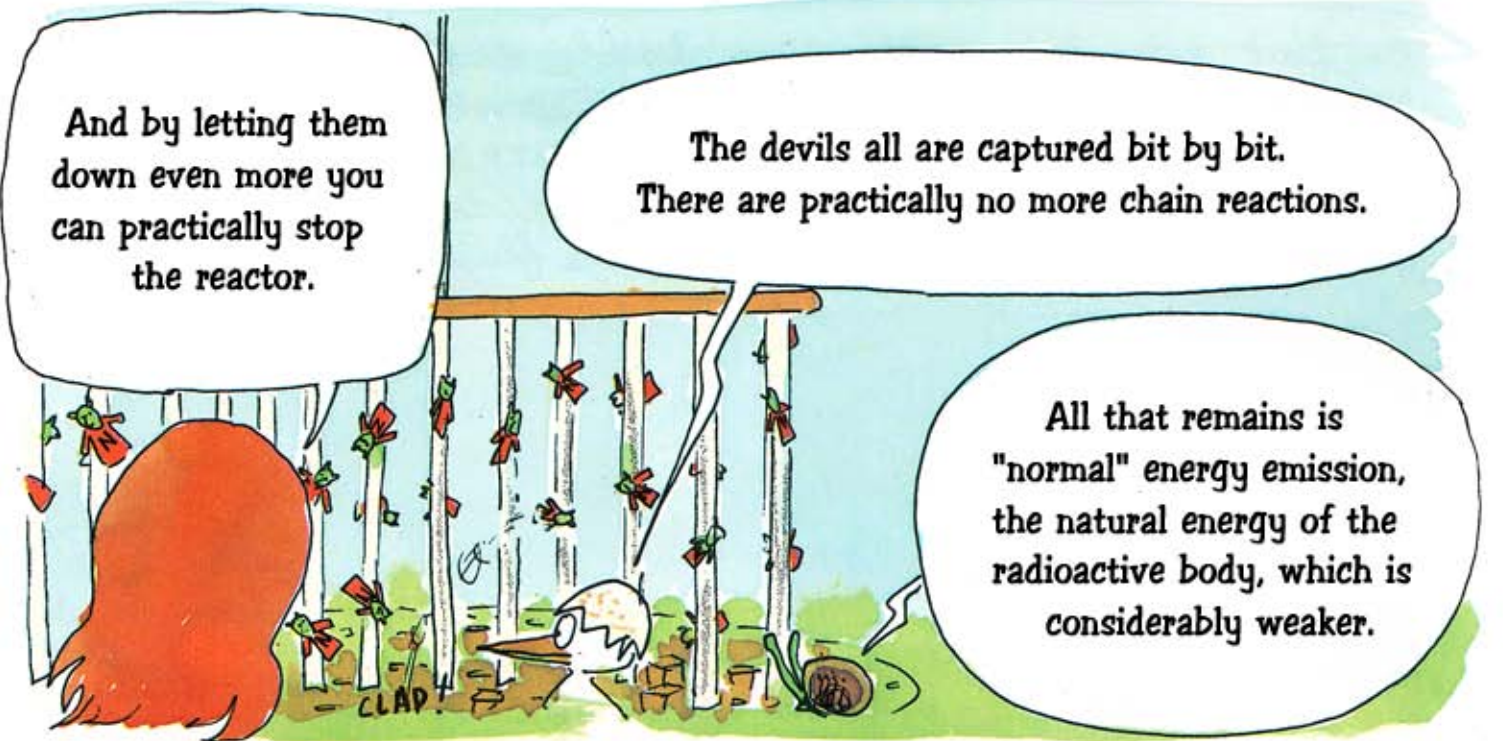
We could introduce something that absorbs the devils, the energy.

It looks like flypaper.

Let's see...

By letting down the sticky paper strips I absorb some of the devils and that allows me to limit the reactor's activity as I want






And by letting them down even more you can practically stop the reactor.

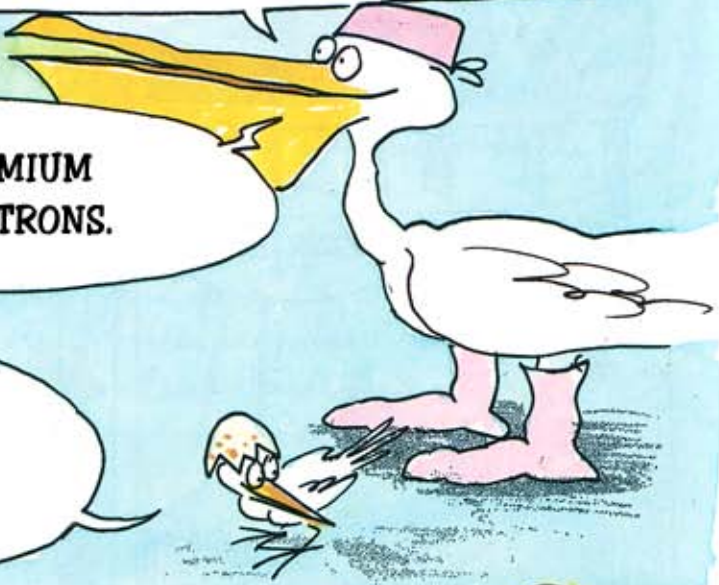
The devils all are captured bit by bit. There are practically no more chain reactions.

All that remains is "normal" energy emission, the natural energy of the radioactive body, which is considerably weaker.

So. To make a **NUCLEAR REACTOR** you just need to collect together enough heavy nuclei, **URANIUM 235** or **PLUTONIUM 239**. And we can control the reactor's activity with a body that absorbs the devils, here they are **FISSION** neutrons.



In short, Uranium minerals contain 0.7% Uranium 235 (**FISSILE**). The rest is Uranium 238, which isn't.



And we'll use **CADMIUM** to absorb the **NEUTRONS**.

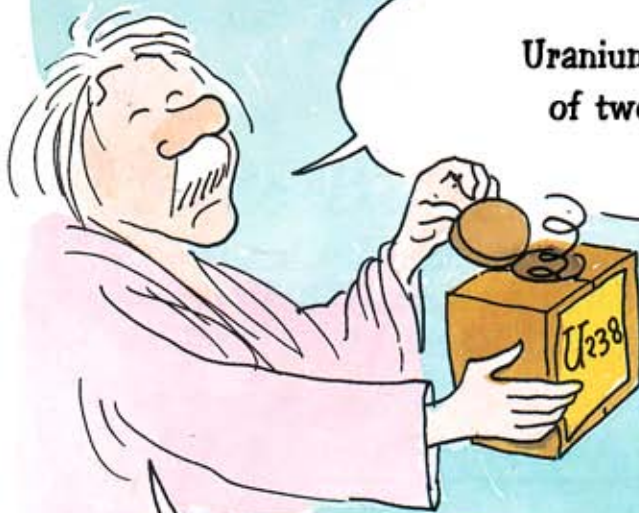
Apparently Plutonium 239 doesn't exist in nature so how can we think about using it in a reactor?

Er yes...you're right.



# FERTILE MATERIAL

Uranium 238 could be considered to be an assembly of two elements. There's room left for a neutron.



If a neutron lodges itself in a nucleus of Uranium 238

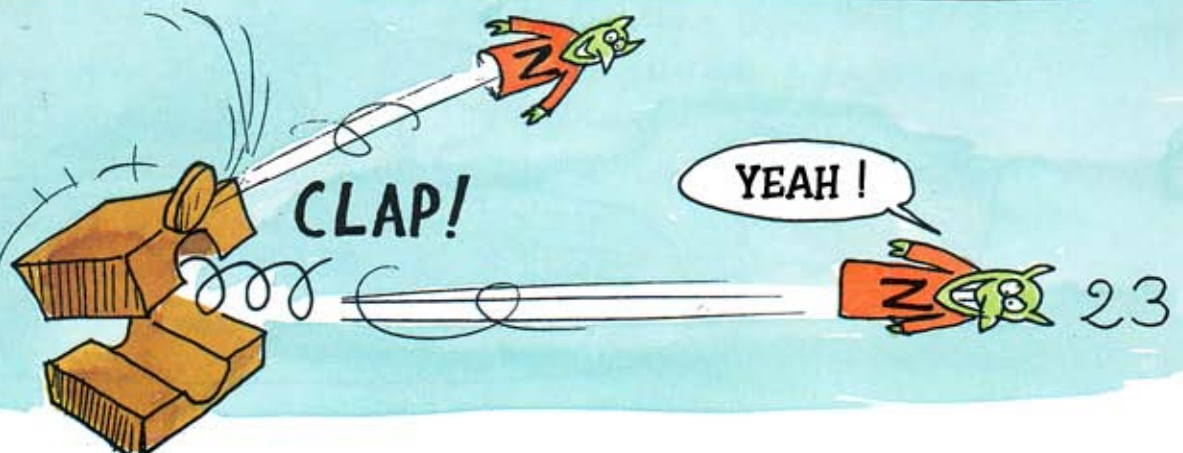
it will change into Plutonium 239 and that is FISSILE

In other words, when a Uranium reactor is operating it contains a mix of FISSILE material and FERTILE material. It converts a certain amount of the FERTILE material into FISSILE material



A certain amount?  
How much is that?

It depends how we operate the reactor. At first FISSION NEUTRONS are emitted in all directions, at 20,000 kilometers a second.

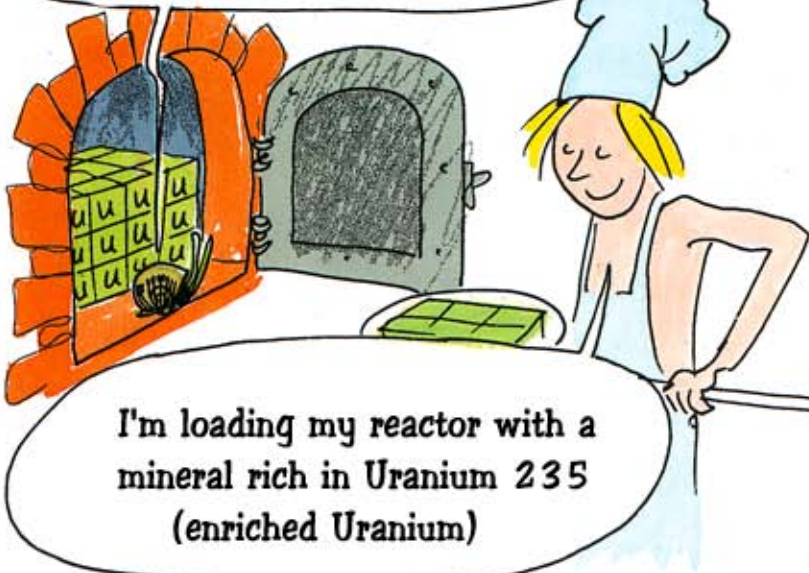




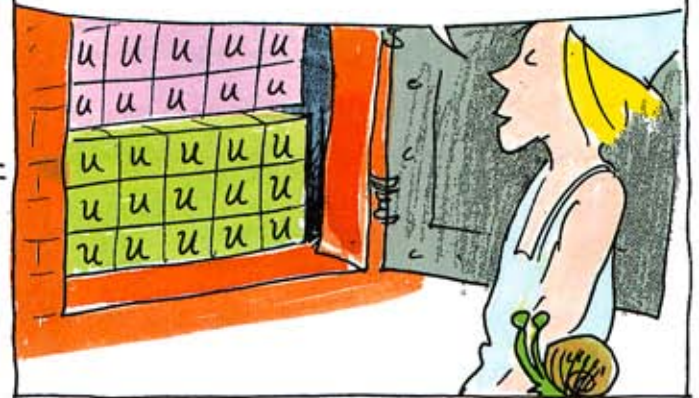
# RAPID NEUTRON REACTORS

These **RAPID NEUTRONS** interact easily with fertile **U238** thus creating **Pu239** at a good rate.

What are you doing?



Then I put on a **FERTILE COVER** of **U238**



The **FAST NEUTRONS** move at **20,000 km/s** in the **HEART** of the **REACTOR**. If we thought of them as gas molecules they would be at a temperature of **16 thousand million degrees**.

**THREE YEARS LATER**

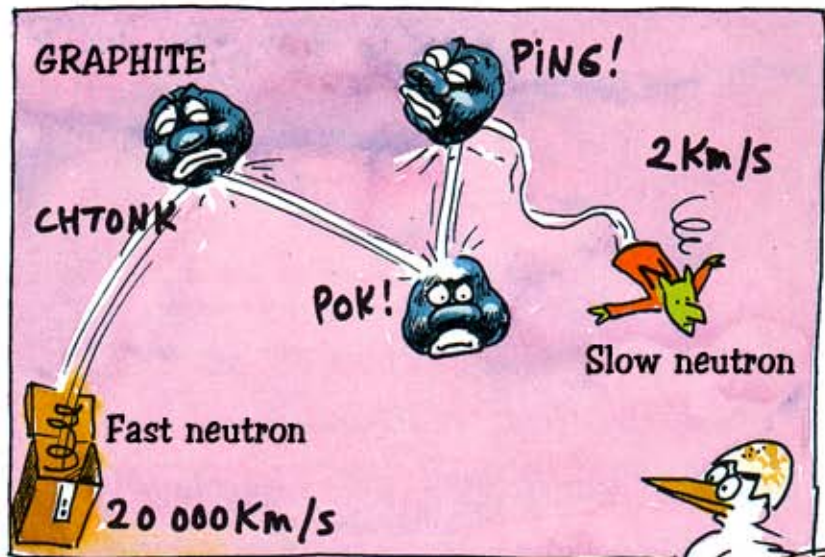
Oh! Archie has made **MORE Pu239** than he has used **U235**, It's a **SUPERGENERATOR**

That's normal because each act of fission brings into play **TWO** rapid neutrons which allow the transformation of **2 U238** into **Pu239**



# SLOW NEUTRON REACTORS

With **CADMIUM** I can absorb neutrons and so easily control the reactor's activity (or even stop it). But with **GRAPHITE** and **HEAVY WATER** I can **SLOW** the neutrons without absorbing them. These are called **MODERATORS**



In this way we can lower the **THERMAL AGITATION SPEED** of the neutrons to 2 Km/s. This neutron gas, cold, is at the general temperature of the reactor.



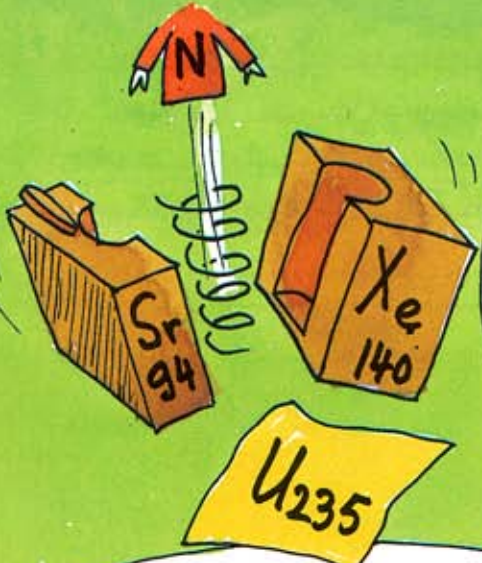
A little **Pu 239** is still made but a lot less than in a rapid neutron reactor

There is no clear frontier between the two types of reactor. There are also 'warm' reactors, half way between the two.






# RADIOACTIVE WASTE INDUCED RADIOACTIVITY



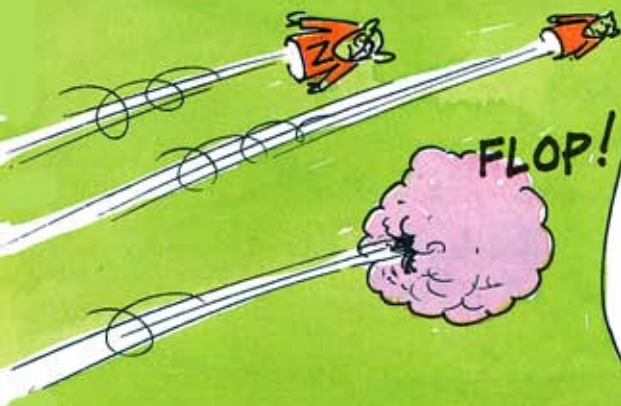
The U235 and Pu239 nuclei break into two pieces in many different ways. Here the example is of Uranium 235 being split into radioactive Strontium 94 and Xenon 140. Note that  $94+140+1=235$

The diagram shows a yellow paper labeled 'U235' with a small grey sphere (neutron) nearby. A red jacket with 'N' on it is being thrown upwards by a spring. Two brown boxes represent fission products: one labeled 'Sr 94' and another labeled 'Xe 140'.



All that is a bit of a nuisance. Many FISSION BY-PRODUCTS have a long life and remain radioactive for a very long time. STRONTIUM can fix itself in bone material and IODINE in the Thyroid. Plutonium is also very dangerous, it can provoke CANCERS and LEUKEMIA

A large field of orange barrels representing radioactive waste. A white stork with a yellow beak and a white cap is standing among the barrels, looking towards the left.



Fission neutrons can also be absorbed by peaceful atoms, such as those forming the structure of the reactor, which can make them dangerous and unstable as well as radioactive, so increasing the amount of radioactive waste.

Two white beams representing neutrons, each with a red jacket labeled 'N' at the end, are shown. One beam is hitting a pink, cloud-like atom, with the word 'FLOP!' written next to it.



# MADE-TO-MEASURE RADIOELEMENTS



So a reactor produces unstable radioactive waste with different periods.


No, they're nuclei that are likely to lose mass by emitting Helium atoms, electrons or anti-electrons (\*)

You mean that they're nuclei that are likely to split in their turn?

Look, there's Archie carting away the waste

CLAP!

We can create 'made-to-measure' radioelements with different periods by placing certain elements in the reactor and submitting them to a bombardment of devils. In that way we get what is called artificial radioactivity.

I'm a poor  lonesome scientist

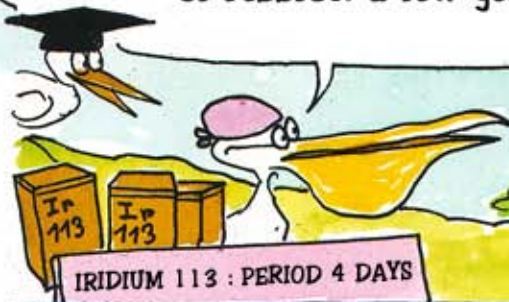
Ga 68 PERIOD : 1 HOUR

(\*) "Alpha" or "Beta" radioactivity.



ARTIFICIAL RADIOELEMENTS were discovered in the 1930s by FREDERIC and IRENE JOLIOT-CURIE which led to the discovery of FISSION a few years later.

Oh look, Archibald has disappeared, but we can LOCATE him because of the devils escaping from his load of waste.



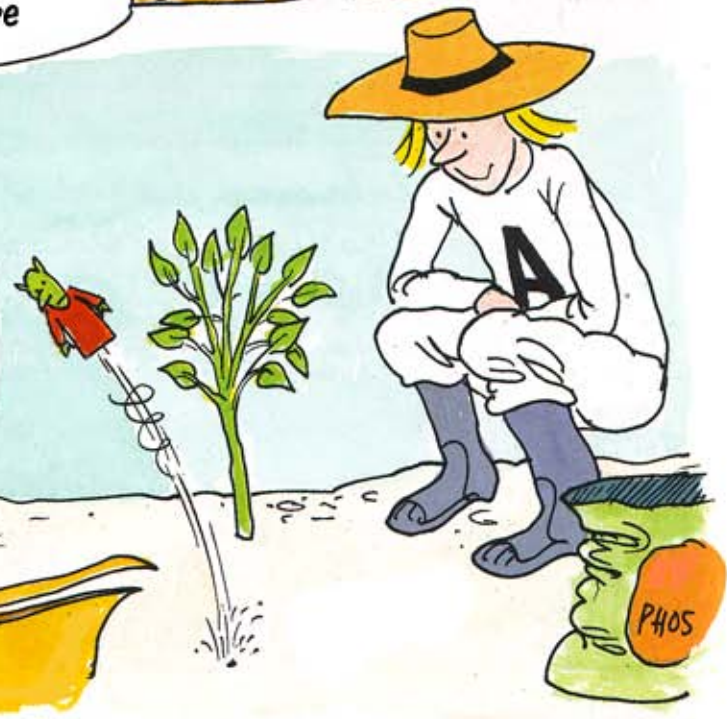
I've got an idea! By detecting the particle emission, using this ARTIFICIAL RADIOACTIVITY, we can follow the TRACK of the nuclei.

We could even put the nuclei, radioactive isotopes, on biological molecules (MARKING) which would allow us to follow their migration in living tissue.




Hey, there's somebody dangerously unstable here

There are all sorts of peaceful uses for artificial radioactivity. For instance we can study the movement of fertiliser in the soil by including a radioactive isotope of phosphorus in the phosphate.







# A-BOMBS




Nuclear physics has allowed considerable progress to be made in fireworks science. In suddenly bringing together two masses of fissile material ( $U235$  and  $Pu239$ ) with the help of an explosive, we create critical conditions and provoke an intense chain reaction, with undeniable aesthetic effects.




Let's see. By bringing together these two masses I obtain a **CRITICAL MASS**



A great number of all sorts of devils are emitted and the radioactive waste rises into the upper atmosphere by ascendance which is caused by the release of intense heat. But that's nice because the neighbours can benefit too



If you want to join the **HAPPY PYROTECHNICIANS** you'll need a pure fissile material (100%  $U235$  or  $Pu239$ ). There are two ways to do it, either refine natural Uranium or apply to your neighbourhood reactor to collect the  $Pu239$  that is produced after each cycle of operation.



It's coming, it's coming !..



# FUSION



Say, the Sun is a planet that must contain a lot of Uranium for it to be so hot.

No Archie, that isn't it.  
In **CHEMICAL REACTIONS** we start off with a mix of substances, such as **HYDROGEN** and **OXYGEN**

But...nothing's happening ?!

It's because the temperature isn't high enough.

Let's warm up the mix.

**PAF!**

And what does that give?

H<sub>2</sub>O, water

So there are lots of reactions that give off a great deal of energy without producing toxic substances.

If one day we use flying planes with a hydrogen-oxygen mix (stored in liquid form) all they'd leave behind as they passed would be clouds!



Maybe we could also "burn" the nuclei mixtures.

Yes, if we brought their temperature up high enough

DEUTERIUM

TRITIUM

HELIUM

We could make DEUTERIUM react with TRITIUM, which are two sorts of HEAVY HYDROGEN (the hydrogen nucleus is light, constituted of a single proton P). The nuclei of these ISOTOPES are only differentiated by the number of neutrons they have. The mix od Deuterium and Tritium tends to give Helium

GRAND DEVIL BALL

Here's an element of the gas HEAVY HYDROGEN, half DEUTERIUM, half TRITIUM. At normal temperature the ELECTRONS turn around the nuclei and ensure molecular liaison (by linking the nuclei two by two)



Deuterium molecule



Tritium molecule



Then the dance rhythm becomes really devilish. Molecules break up (disassociation) and the electron-bees orbit around a single nucleus.

### APPROACHING THREE THOUSAND DEGREES

There's no way we can orbit around these nucelii, they're always moving.

Yep, it's becoming infernal. I give up...

Pfff...

The hot gas then becomes a soup of nucleii and free electrons, a **HOT PLASMA**.

Warm up Marcel, warm up.

**Above 150 MILLION DEGREES (IGNITION TEMPERATURE)** something happens

You know what, we'd be better as a foursome.

They're excited...

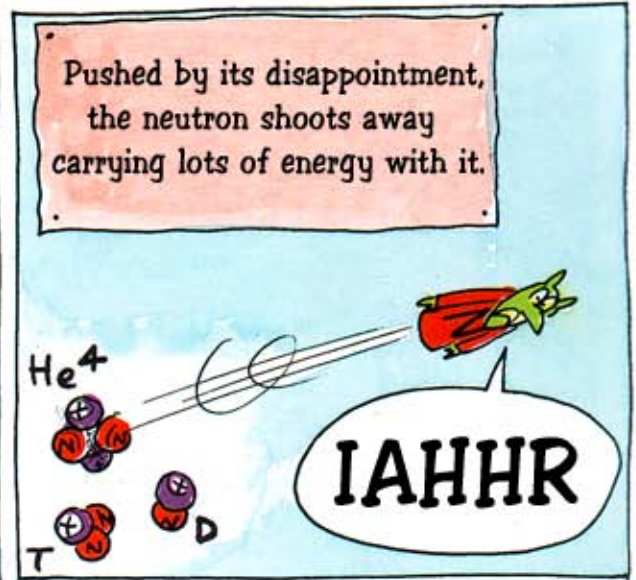
You think so?

I sense a dirty trick

Yes, at this temperature, it would be more stable

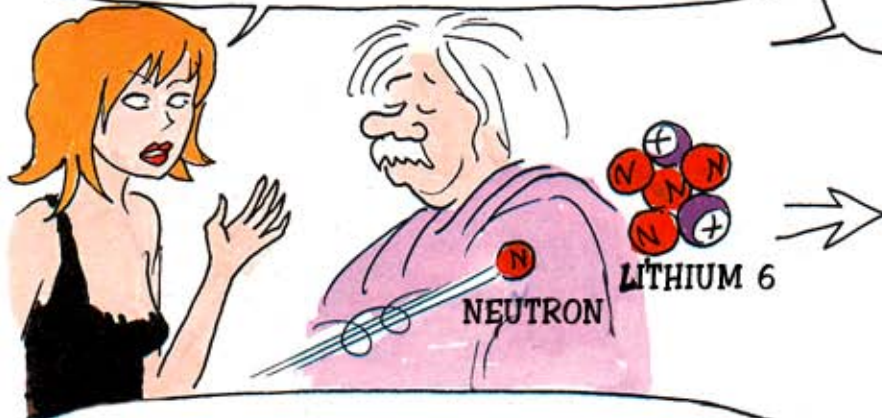
Hey wait!..  $2+3=5$ , but Helium has 4 nucleons doesn't it?





In this case, FUSION is just as polluting as FISSION because these fusion neutrons will transform the nearby atoms, turning them into radioactive atoms.

So we try to absorb these neutrons with Lithium 6, which gives Helium 4 and Tritium 3.



In other words, the envelope of Lithium 6 behaves as a "fertile" material. This reaction is supposed to give "fusion fuel", Tritium 3.

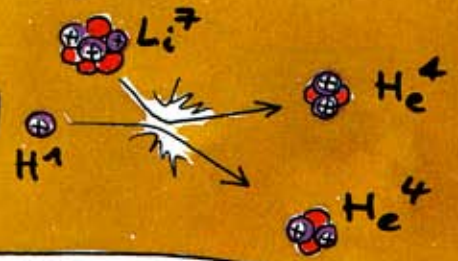
Yes, a fusion reactor is related to a supergenerator. Luckily, because Tritium 3 is unstable (\*) and doesn't exist in a natural state.



(\*) Its half-life is only 12 years.

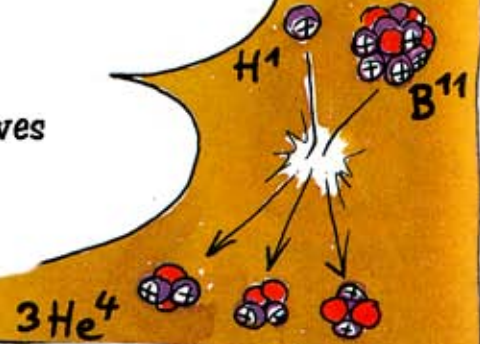


Nevertheless, I see that there are all sorts of fusion reactions and nuclei rearrangements which don't release free neutrons.



Lithium 7 + Hydrogen 1 (light) gives  
2 Helium 4  
(7 + 1 = 2 x 4)

Boron 11 + Hydrogen 1 gives  
3 Helium 4  
(11 + 1 = 3 x 4)



The first has an ignition temperature of 500 million degrees and, for the second, close on a thousand million degrees!..

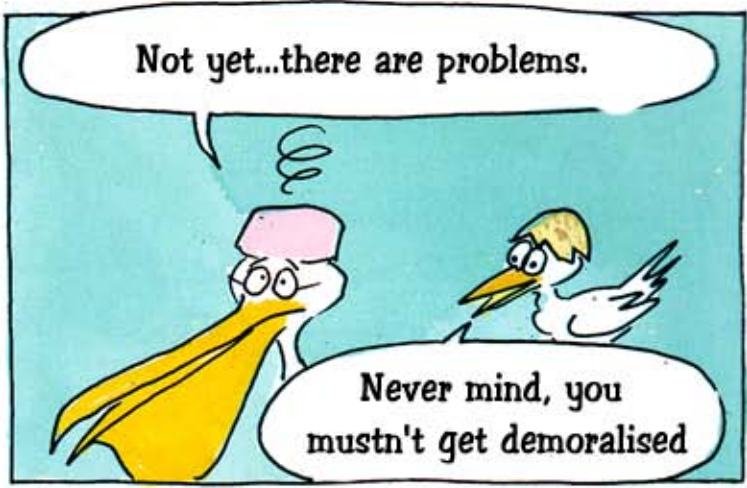
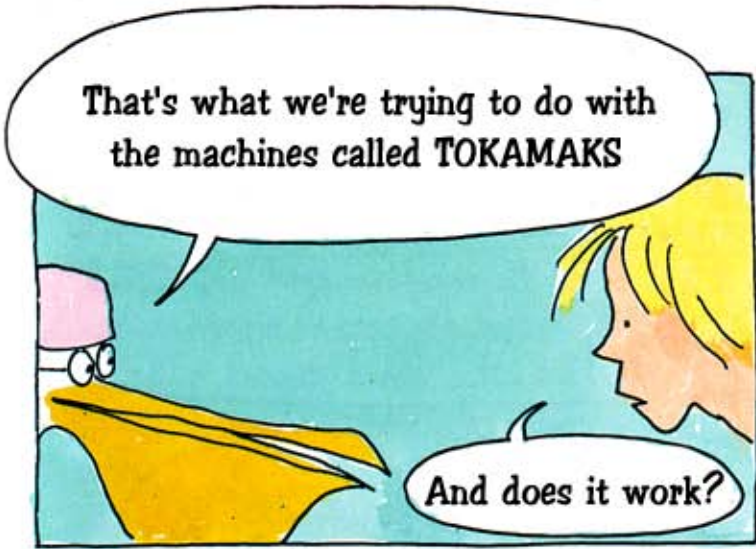
Hmm...obviously...but exactly how do we fuse these nuclei?

In the heart of the sun it happens slowly but at a temperature that is only 15 million degrees.

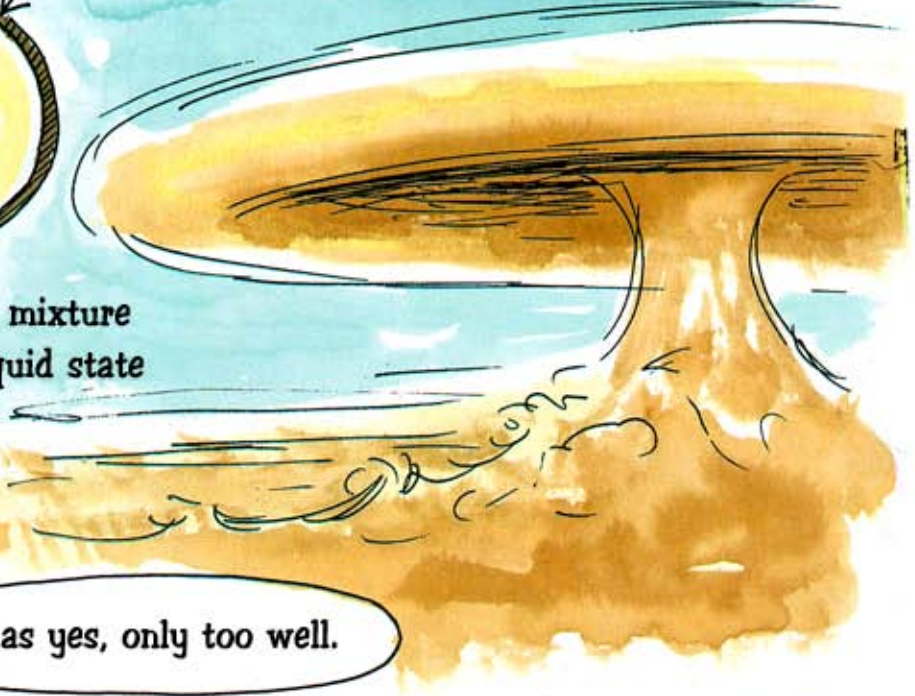
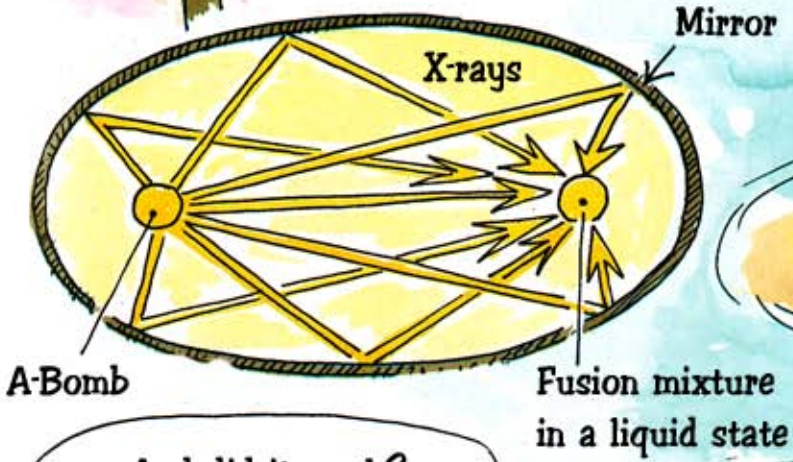
So the sun is just like embers then?

Yes, to get a nuclear "fire" you need 150 million degrees for reactions to take place in, let's say, a period of time of the order of a second.



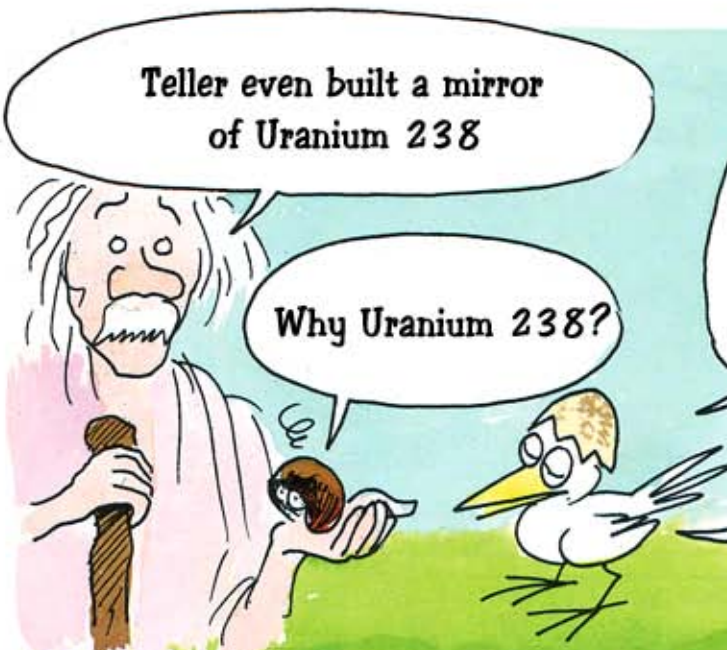


Hmm, Edward Teller managed fusion when he created a new bomb. We didn't want to do that but we did. Teller had an idea (\*). He always had good ideas. When the A-bomb exploded it began by spitting out a great quantity of X-rays during the first millionths of a second. Teller proposed reflecting these rays with a sort of mirror and focussing them on a target composed of a Deuterium-Tritium mixture.



(\* ) Edward teller, researcher at Los Alamos during the war, was the model for Doctor Strangelove in the film 'How I stopped worrying and learned to love the bomb'.





Teller even built a mirror  
of Uranium 238

Why Uranium 238?

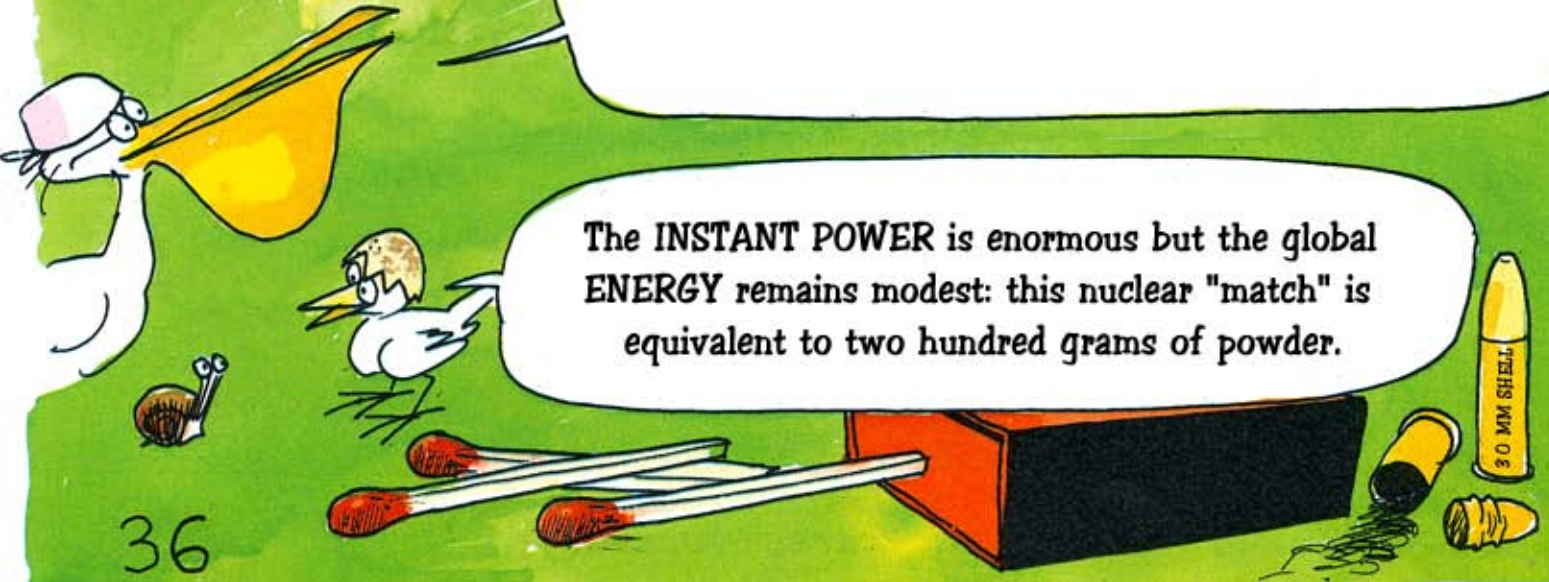
But of course, think about it.  
The H-bomb exploded. Neutrons from  
fusion attacked the FERTILE U238  
material and transformed it into  
Pu239 which fissioned immediately

That was the terrible  
FISSION-FUSION-FISSION bomb

# FUSION BY DIRECTED ENERGY



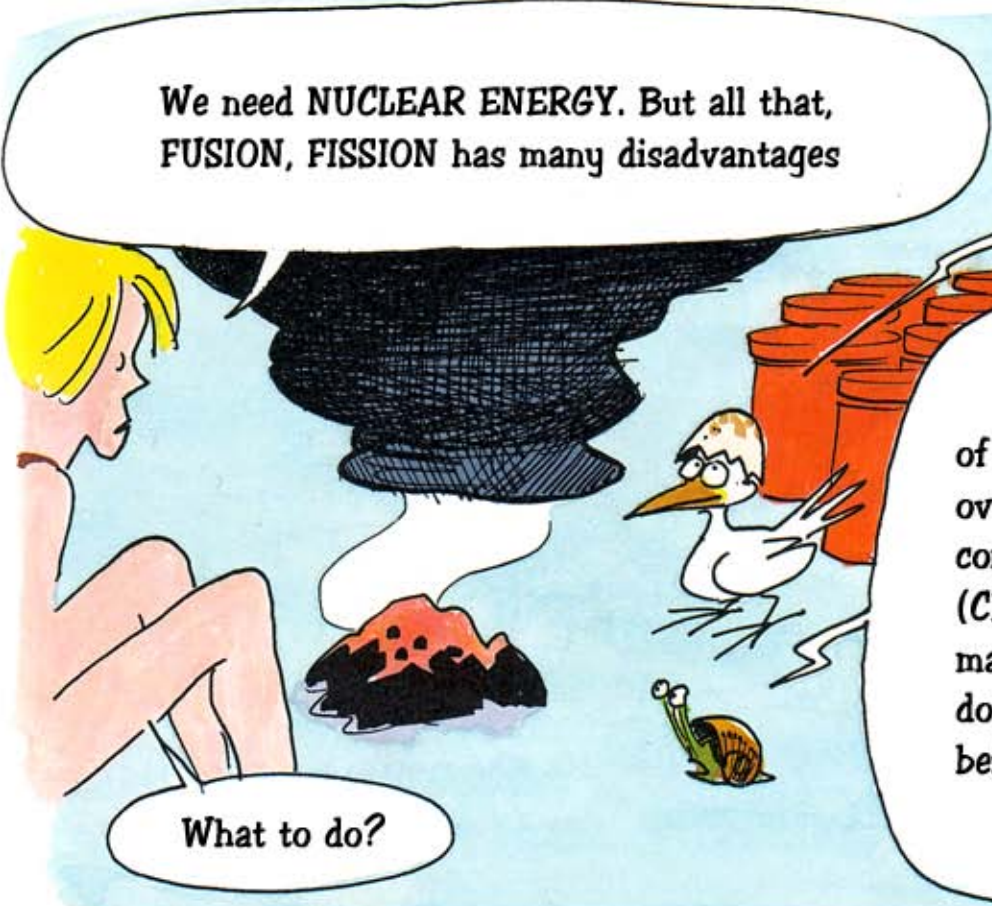
An attempt was made to create FUSION by localising onto a DEUTÉRIUM-TRITIUM mixture (in liquid state) all the energy forms: radiations, emitted by powerful LASERS, various particles: electrons, nuclei from accelerators. The POWER needed is phenomenal. To set off this THERMONUCLEAR fire, an energy equivalent to that of a solar mirror the size of France needs to be concentrated (for a few thousand millionths of a second) on a sphere of 1 mm diameter



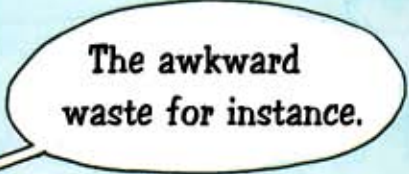
The INSTANT POWER is enormous but the global ENERGY remains modest: this nuclear "match" is equivalent to two hundred grams of powder.




# EPILOGUE



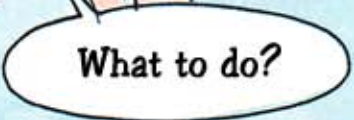
We need **NUCLEAR ENERGY**. But all that, **FUSION, FISSION** has many disadvantages




The awkward waste for instance.



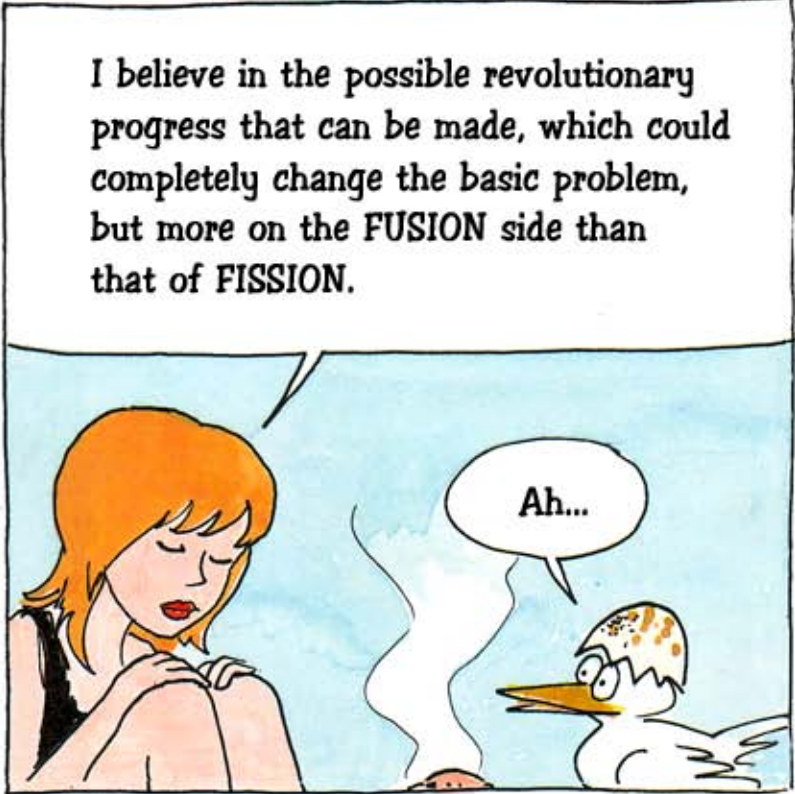
And plenty of risks of accidents. If a reactor starts to overheat it will melt the steel and concrete container, even the floor (**CHINESE SYNDROME (\*)**) and the mass in fission will force itself down into the ground without our being able to stop it.



What to do?



40 years isn't very long. We are only at the beginning of the **NUCLEAR ERA**.



I believe in the possible revolutionary progress that can be made, which could completely change the basic problem, but more on the **FUSION** side than that of **FISSION**.



Ah...

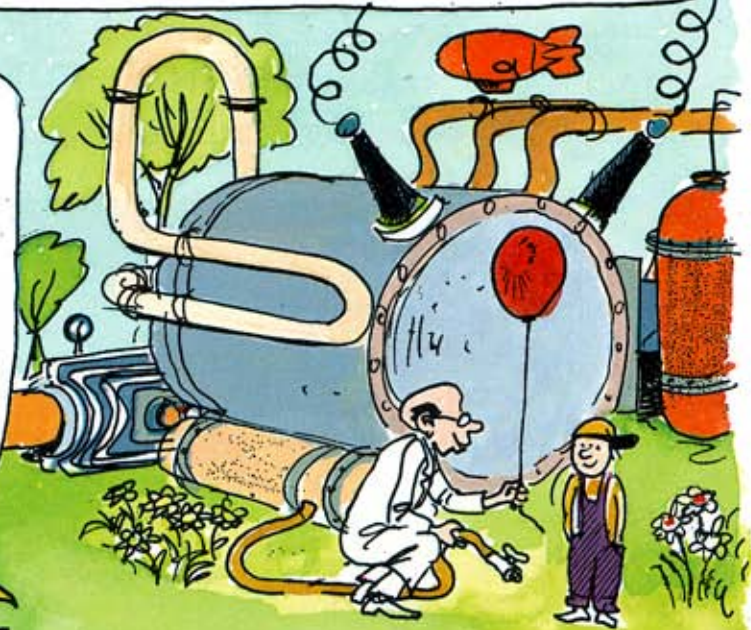
(\*) An image due to atomists, according to whom the reactor going through the Earth from one side to the other would reappear in... China!...



Theoretically, in fusion reactions, where free neutrons don't intervene, we could **CONFINE** the **FUSION PLASMAS** by using powerful magnetic equipment (charged particles "run away" from regions with intense magnetic fields).

### THE GOLDEN AGE!

The fusion generating station, non-polluting (lithium-hydrogen or boron-hydrogen). The only product of the reaction is helium which we could use to inflate balloons.



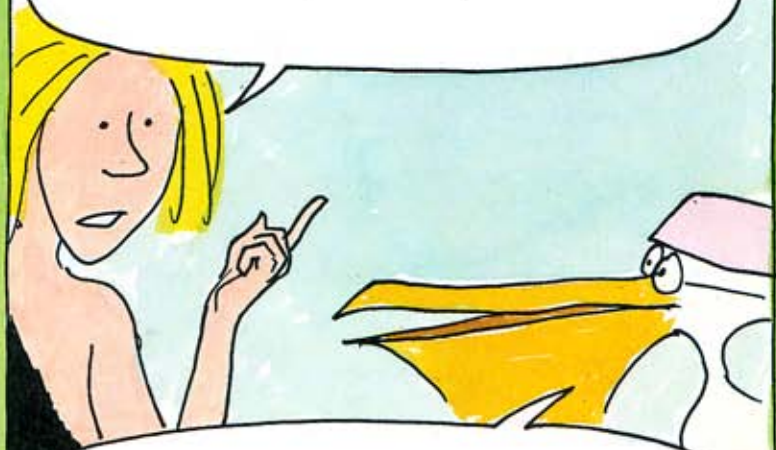
Don't make me laugh, it's a dream!

Nevertheless, catalytic stoves exist that allow heat to be produced **AT HOME** with the windows closed and without using a chimney.

It's true, it creates water vapour and carbon dioxide which can be breathed in in moderate quantities.



Could a **FUSION CATALYSER** exist that would allow operation at a suitably low temperature?



We already know one: Carbon



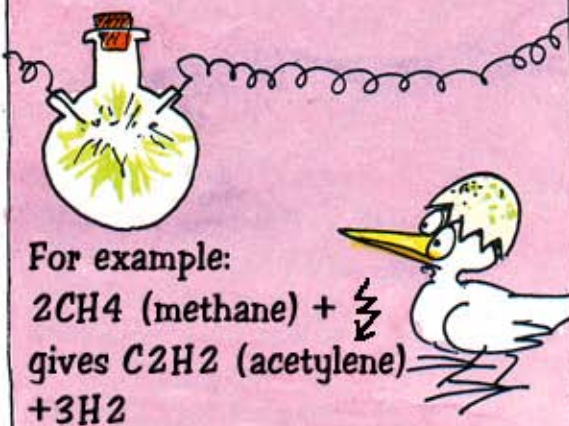
Ah yes, in fact, how does the Sun manage to work by fusion when its central boiler is at 15 MILLION DEGREES, that is to say at a temperature TEN TIMES LESS THAN THE IGNITION TEMPERATURE which is 150 MILLION DEGREES?

The Carbon serves as a catalyst. It intervenes in the stages, fairly complex ones, of the reaction and, in the end, is regenerated. It begins with Carbon 12 then Hydrogen 1 giving Nitrogen 13. Then the Nitrogen 13 is transformed into Nitrogen 15 and finally: Nitrogen 15 + Hydrogen 1  $\rightarrow$  Carbon 12 + Helium 4 (Bethe's cycle).

But this reaction is far too SLOW (except for the Sun, which has plenty of time).

# MUONS

We can create complex chemical reactions in a cold gaseous mix by bombarding the molecules with electrons via a simple electrical discharge.



In a molecule we can replace the electrons with MUONS, particles which resemble big electrons and which bring the various nuclei closer together.

So why not bombard a mixture of "lukewarm" fusion with Muons?



Does it work?

NO PROBLEM SIR. We know how to create muons in an accelerator. When they hit deuterium and tritium nuclei it creates helium. Therefore there is fusion. But between this experiment in microphysics, which just concerns a few particles, and a usable industrial fusion there is quite a distance to travel !!!

We could also play with the SPINS of nuclei. That is to say make them dance a waltz instead of a tango. It improves the efficacy of the collisions.



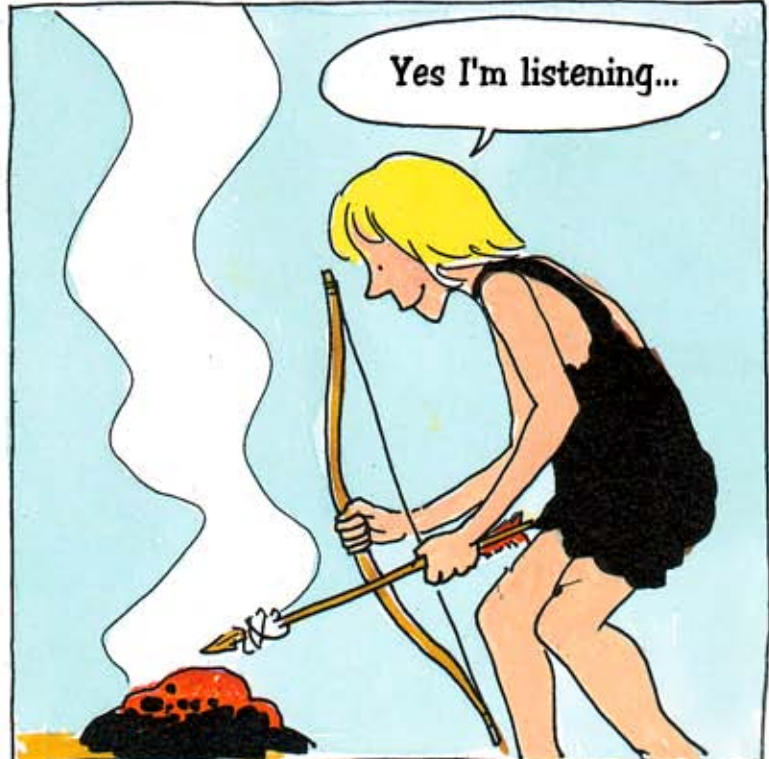
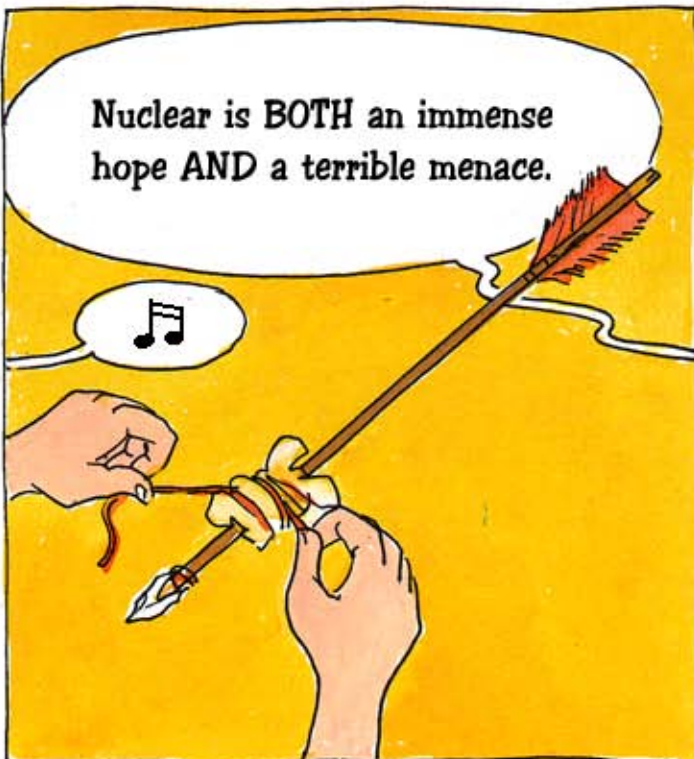
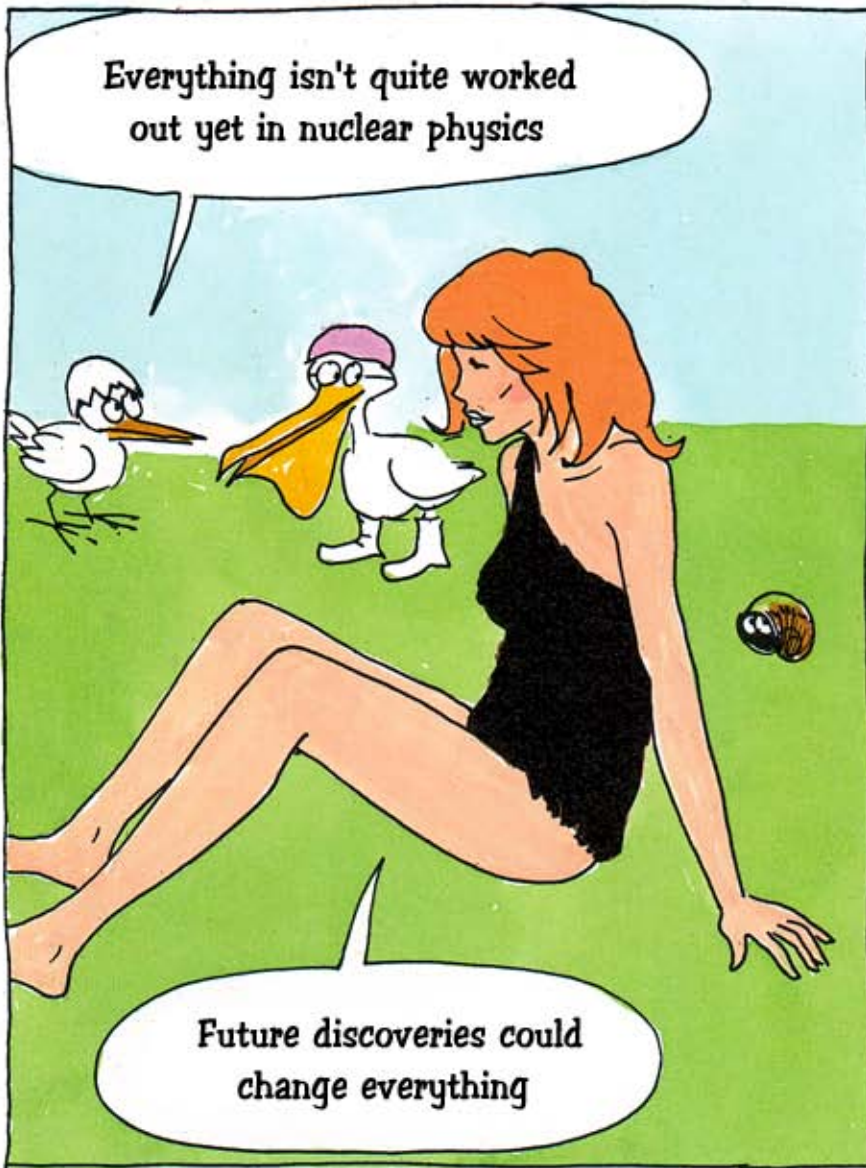
BANG

Oh sorry!

...Can't you be careful!

There you are, it's the same story all over again

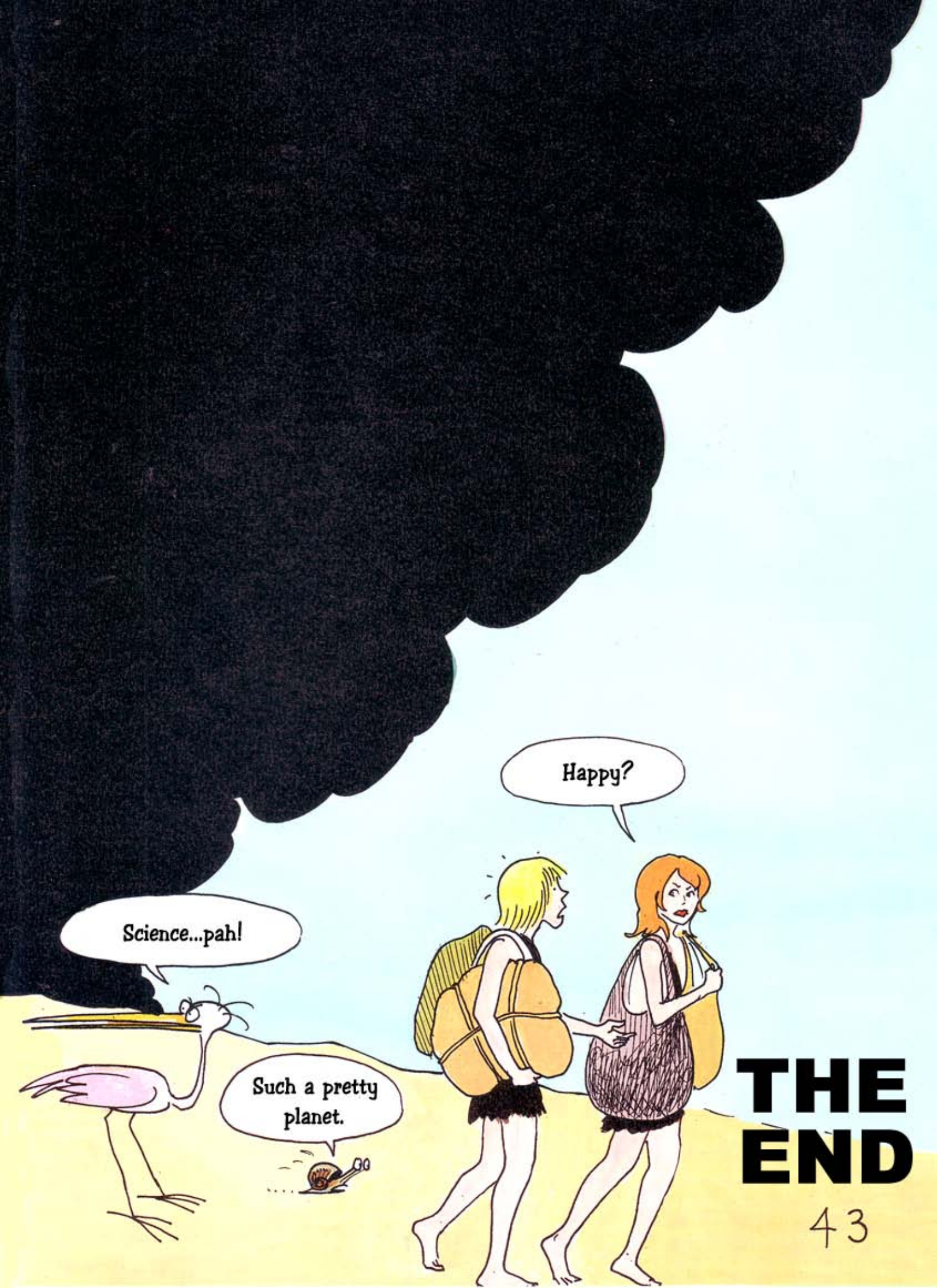












Science...pah!

Happy?

Such a pretty planet.

**THE  
END**