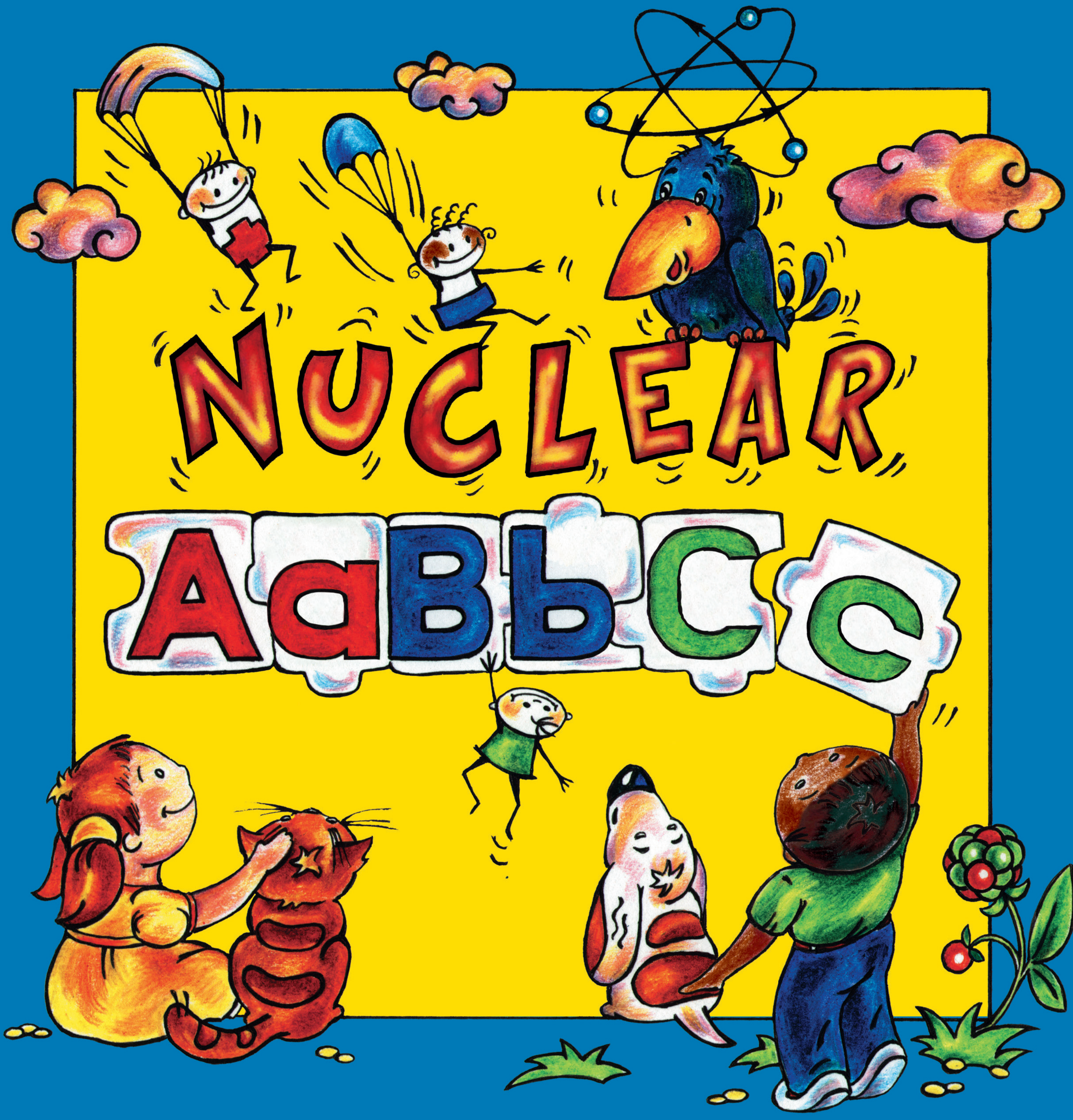
NUCLEAR AaBbCc



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ROSATOM

Dear Reader!

You hold in your hands "The Nuclear Alphabet", a book which will help you better understand how everything you see around you is held together, to find out which processes are happening around us, and how the laws of physics apply to them.

This book will lead you into the interesting world of nuclear physics. By studying the world, mankind has long learnt how to use its gifts, the most important of which is cheap and practically inexhaustible energy. Today this energy is produced by nuclear power plants, with the intention of creating thermonuclear power stations in the future. Who knows, maybe when you grow up, you'll be able to create something even better and more advanced.

But for that you need to gain some knowledge. Without this special knowledge, it is rather difficult to understand how energy is created in a nuclear power plant as a result of atomic fission. For most people it remains a mystery. But by reading this book you'll be able to understand it.

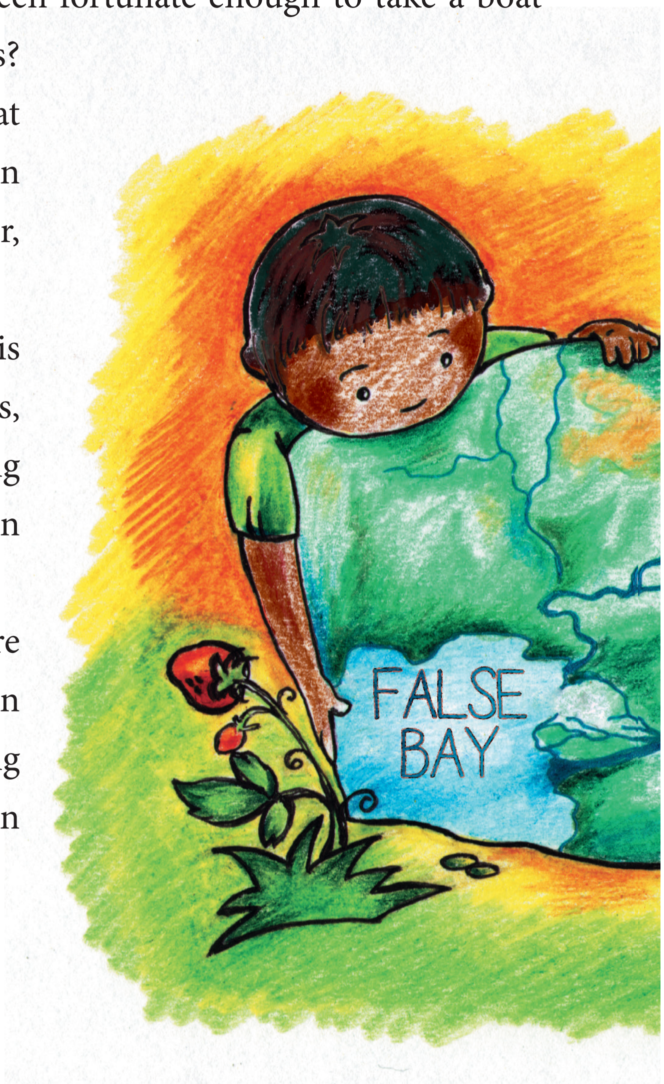
Let's set out on an exciting journey into the world of nuclear physics. You will find out what atoms consist of, what their nuclei radiate, and which mighty forces are hidden in the nucleus. And, of course, how a nuclear power station works. You will be able to better understand the nature of the world around you and the processes, which you could not imagine life without. Enjoy the journey!

Heading off on a Distant Cruise

My curious friend, perhaps you have been fortunate enough to take a boat cruise with your parents or classmates? You may remember the wind in your face, how the boat rocked on the waves, and the way the sun shimmered in the water. Let's take a trip together down the Tugela River, straight to the Indian Ocean.

Imagine us cruising on the river, but it is meandering through a green valley, flowing around islands, either narrowing down or expanding out. You are standing on deck and picturing yourself a ship captain. You are in control of the ship!

Now picture the shores fading away, and you are now no longer steering your ship on a river, but on the Indian Ocean into distant countries. There are dolphins or flying fish leaping out of the waters, and their fins are shining in the sunlight. The ship's engine is running steadily.



You are heading straight for your destination, you've already gone many miles… And then, your chief mechanic and good friend declares that the fuel tanks are nearly empty. What do you do?

There's nothing you can do – you'll need to stop your voyage and get to the closest port to fill up your fuel reserves. And so you'll need to go from one port to the next, losing precious time. Your ship is practically tied with invisible ropes to the ports where there are fuel reserves.

Yes, on a long-distance journey in the ocean, this engine won't do – it's too "greedy". It also works on fuel which is made from oil. It's a shame to burn oil, because chemists can make a lot of useful things out of it – things like plastic, fabric, medication, paint, and even perfume…

When the oil burns in a marine engine, harmful pollutants basically fly out through the pipe! So what to do?

Not a problem! We know that modern ships exist; nuclear ships that can journey for years without needing to enter a port! This is because they use very little nuclear fuel.

For example, for a hundred day journey through hard ice, two atomic reactors of a modern ice-breaker ship consume only 15kg of uranium. But if that same ice-breaker had diesel engines installed, in the same time period it would consume about 30,000 tonnes of fuel (diesel oil, fuel oil). 15 kg vs. 30,000 tonnes. That is two million times more! That amount of fuel would simply not fit on the ice-breaker ship! Not to even mention submarines, which have to be on military duty deep under the ocean for weeks or months at a time. It's quite obvious that only atomic engines would allow them to go on a journey around the world, remaining underwater for months at a time!

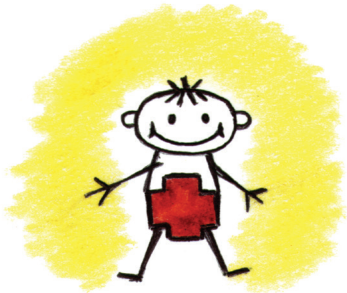
So, we've found a solution – we turn our ship nuclear! For that we install an atomic reactor and then head off. We can go to Antarctica, or even on a journey around the world, without needing to stop!

But to operate an atomic reactor, you need well-trained specialists, and to command these sailors and this ship, the captain himself needs to know how everything operates, don't you agree?

So then, my curious friend, let's first change our course and delve into the fascinating world of ATOMS.

WHAT ARE ATOMS MADE OF?

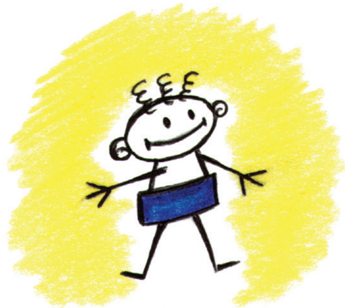
From a very young age, I am sure you have heard the words atom, nuclear energy, nuclear power station, atomic age….


PROTON

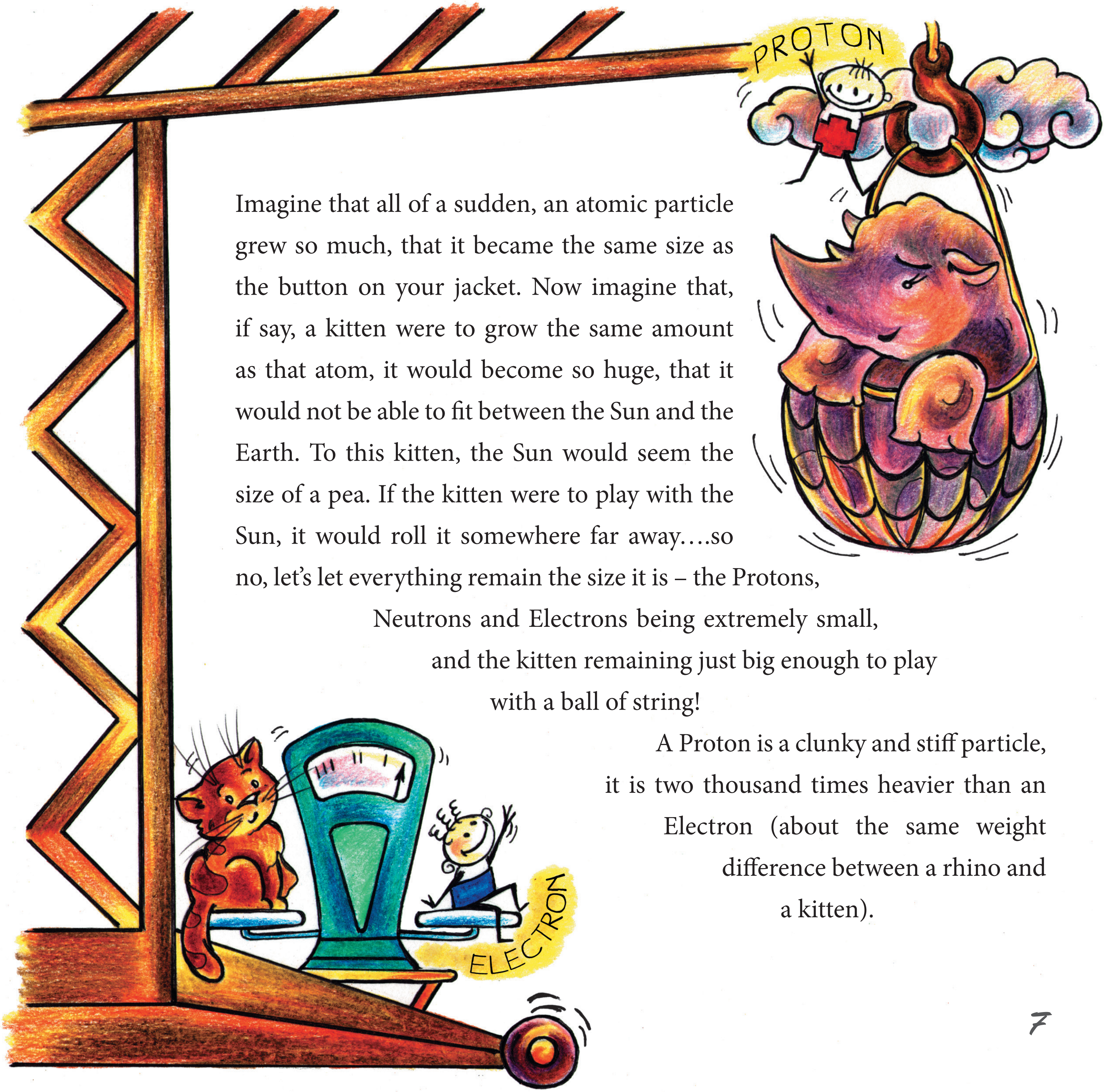
And you perhaps already know that atoms are the minuscule particles from which everything in this world is made up of. The air we breathe, the water we drink and swim in, the ground we walk on, the food we eat, dishes, toys, clothes, books, cars, houses, mountains, clouds, the Moon, the Sun, the stars… and all living creatures, including you and me, your mom and dad, your best friend and every other person on the planet.


NEUTRON

Ok, but still, what exactly are atoms? What do they look like? What do they consist of? To understand this you need to remember these three very important words: PROTON, NEUTRON AND ELECTRON. These are the names of the particles from which everything in the world is made of.


ELECTRON

These particles are so small that it would be hard for you and I to even imagine their size. But let's go ahead and give it a try.



Imagine that all of a sudden, an atomic particle grew so much, that it became the same size as the button on your jacket. Now imagine that, if say, a kitten were to grow the same amount as that atom, it would become so huge, that it would not be able to fit between the Sun and the Earth. To this kitten, the Sun would seem the size of a pea. If the kitten were to play with the Sun, it would roll it somewhere far away….so no, let's let everything remain the size it is – the Protons, Neutrons and Electrons being extremely small, and the kitten remaining just big enough to play with a ball of string!

A Proton is a clunky and stiff particle, it is two thousand times heavier than an Electron (about the same weight difference between a rhino and a kitten).

It is not surprising that a Proton "sits" in the centre of the atom, and the light and restless Electron circles around the Proton, almost like a satellite circles the Earth. Physicists call what is in the centre of the atom an ATOMIC NUCLEUS. Imagine such a picture: in 1911 a famous English physicist Ernest Rutherford exclaimed: "Now I know what an atom looks like!"

What is a simple basic atom made up of? It's made up of only one Proton and one Electron, and there are no Neutrons in it. This is an atom of hydrogen – the lightest gas. Now you understand why hydrogen is so "light". It is fifteen times lighter than air, and a balloon filled with hydrogen will float up into the sky.

So then where is the Neutron, and why is it needed? Connect it to the Proton in the nucleus, and you will get heavy hydrogen. Scientists have named it the DEUTERIUM.

So now our atom consists of all three parts; a Proton, Neutron and an Electron.

So how much heavier did the atom of light hydrogen actually get after the addition of the Neutron to its single Proton in the nucleus? Let's calculate. The mass of a Neutron is equal to the mass of a Proton. So that means that the mass of the nucleus and of the whole atom has doubled in size (the mass of an Electron is so minute, that it could be ignored), but we could make the hydrogen even heavier! Let's add another Neutron to the existing Proton and Neutron in the nucleus of the heavy hydrogen (the deuterium), and we will then get a super-heavy hydrogen also known as TRITIUM.

The atom of tritium is three times heavier than the light hydrogen atom. But even the super-heavy hydrogen, tritium, is still much lighter than oxygen – five times lighter in fact.


HYDROGEN
ORDINARY
HYDROGEN
DEUTERIUM
TRITIUM
OXYGEN
H_2O
WATER

So it turns out that the light hydrogen has heavier "hydrogen relatives" called deuterium and tritium.

Are they similar though? An atom of light hydrogen contains one Proton in the nucleus, an atom of deuterium contains one Proton and one Neutron, and an atom of tritium contains a Proton and now two Neutrons.

So why are deuterium and tritium both considered hydrogen?

Let's find out.

Hydrogen burns well. During burning, the atoms of hydrogen combine with the atoms of another gas, oxygen, and as a result you get water. Deuterium also burns well, when combined with oxygen, and as a result water is once again produced. That means that deuterium is also considered as hydrogen, "hydro" meaning water. The water created from deuterium is called heavy water, but it is no different from ordinary water. You would not be able to see the difference even in super-heavy water, which is the result of combining super-heavy hydrogen (tritium) with oxygen. In a single glass of plain water there is a little bit of both heavy water and some super-heavy water!

All three hydrogen atoms, the light, heavy and super-heavy, react equally with other substances, not only just with oxygen.

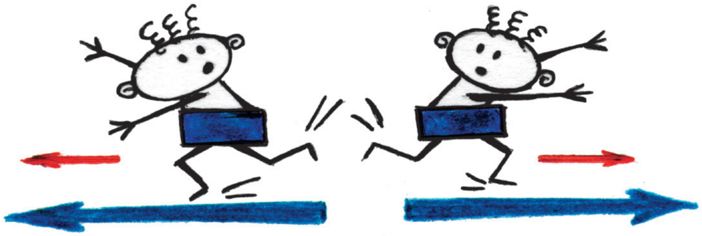
So the result is that the Neutrons added into the nucleus of the atom only increased the mass of the atom and had no actual influence on the way it reacted with the atoms of other substances!

Physicists call the atoms which only differ from one another by the amount of Neutrons in their nucleus ISOTOPES of the same exact substance.

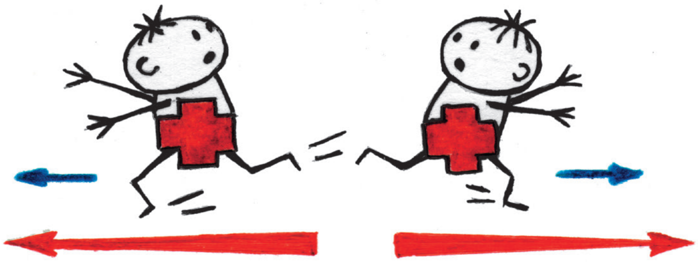
How the Particles of an Atom Attach to One Another

The Electron in an atom circles around the nucleus almost as if it's on an electric "thread". So, what is this electric "thread" and where does it come from?

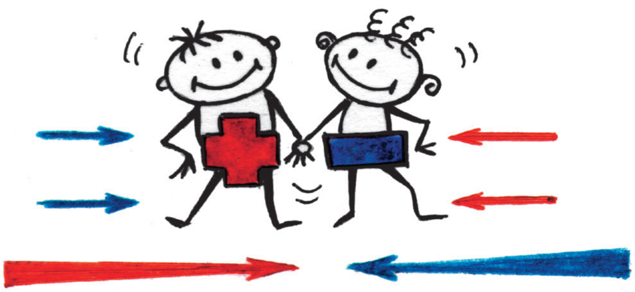
Listen, my curious friend, to this story. More than two and a half thousand years ago in the Greek city of Miletus, lived a famous academic named Thales. One day his daughter was spinning wool using a spinning wheel made of amber, and she suddenly noticed that the



NEGATIVE CHARGES
REPEL EACH OTHER



POSITIVE CHARGES
REPEL EACH OTHER



OPPOSITE CHARGES
ATTRACT EACH OTHER

wool strands clung and stuck to the spinning wheel! She told her father about it, and he started to investigate, and discovered that the amber rubbing against the wool not only attracted the wool strands, but also attracted string, hair and straw.

Amber in Greek is called "Electron", and many years later the ability of amber to attract light objects (when rubbed against wool) was called electricity. By that time it was already well known that if one were to rub a glass stem with some silk fabric, it would also start attracting light objects. What is very surprising though, is that if one were to rub some wool on two amber beads and then try to bring them together, the amber beads would repel or separate from one another. If two glass beads were rubbed with some silk material, they would also repel one another. But if you were to put the charged amber bead close to the charged glass bead, they would do the exact opposite – they would attract one another!

So academics decided that the electricity from the charged amber and the electricity from the charged glass were two different types of electricity. The "glass" electricity was called positive and was given the "plus" sign (+), and the "amber" electricity was called negative and given the "minus" sign (-). This, of course, is not completely fair because the electricity of the charged amber was discovered earlier than the glass, so why was it named negative? There's nothing we can do now, it's too late to change history!

At the end of the 19th century, physicists were able to prove the existence of tiny particles charged with negative electricity, the same electricity as the amber beads. These particles were therefore named Electrons (remember that the word "Electron" in Greek means amber).

Since then it has become obvious what happens to amber when it is rubbed against wool: it starts to collect numerous Electrons and therefore becomes negatively charged. These are all back-to-back minuses!

So where do Electrons come from? Do they come from the wool? Of course!

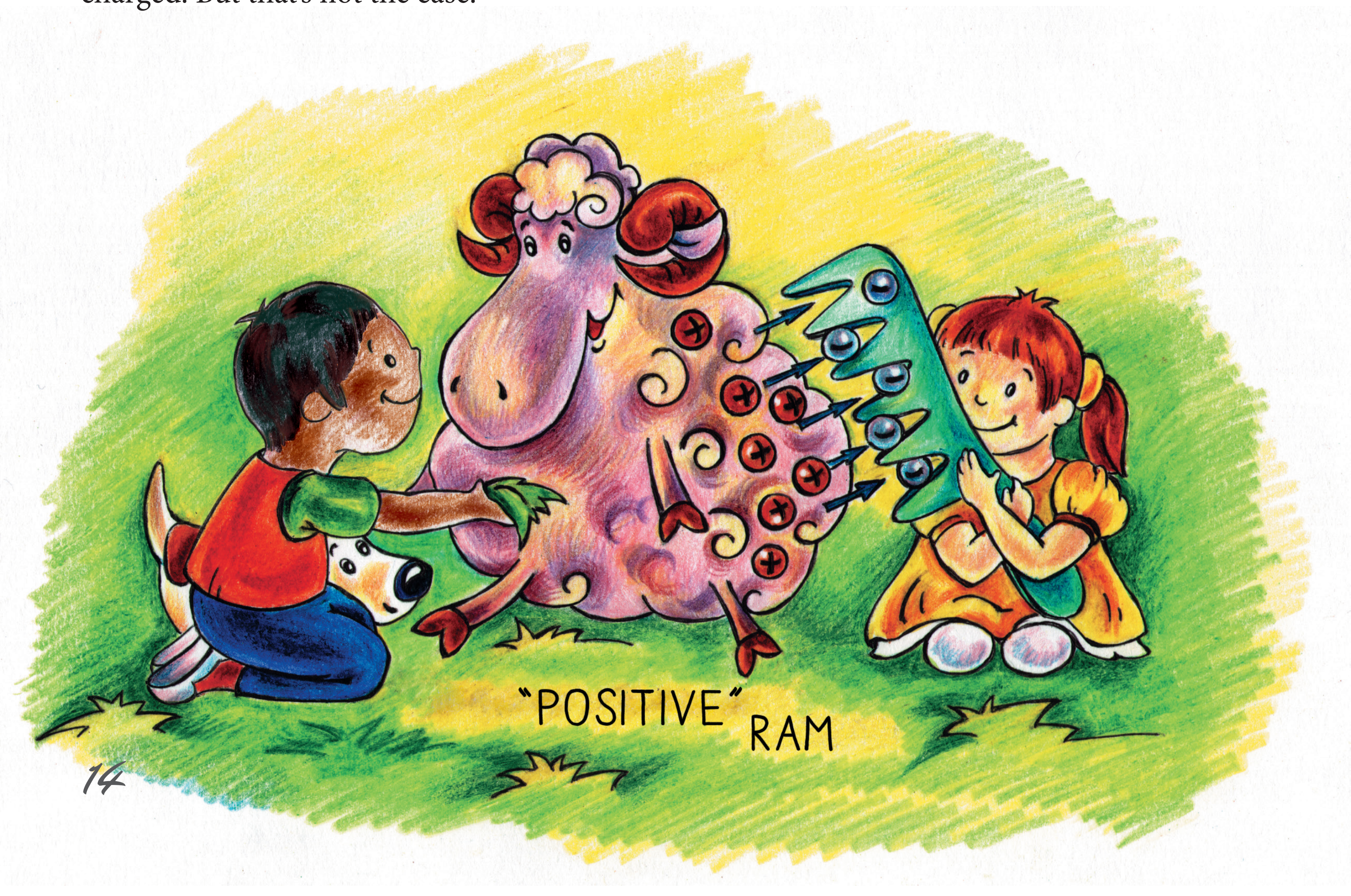
So what happens to the wool after losing the Electrons? Does it become positively charged? Yes, it does indeed!

Do you want to become "positive"? It's quite simple to achieve – all you need to do is brush as many Electrons out of your hair as possible. Take a comb and run it through your hair a couple of times (keep in mind that your hair needs to be dry and the comb needs to be plastic).

"Brushing out the Electrons"… Sounds a little strange, doesn't it?

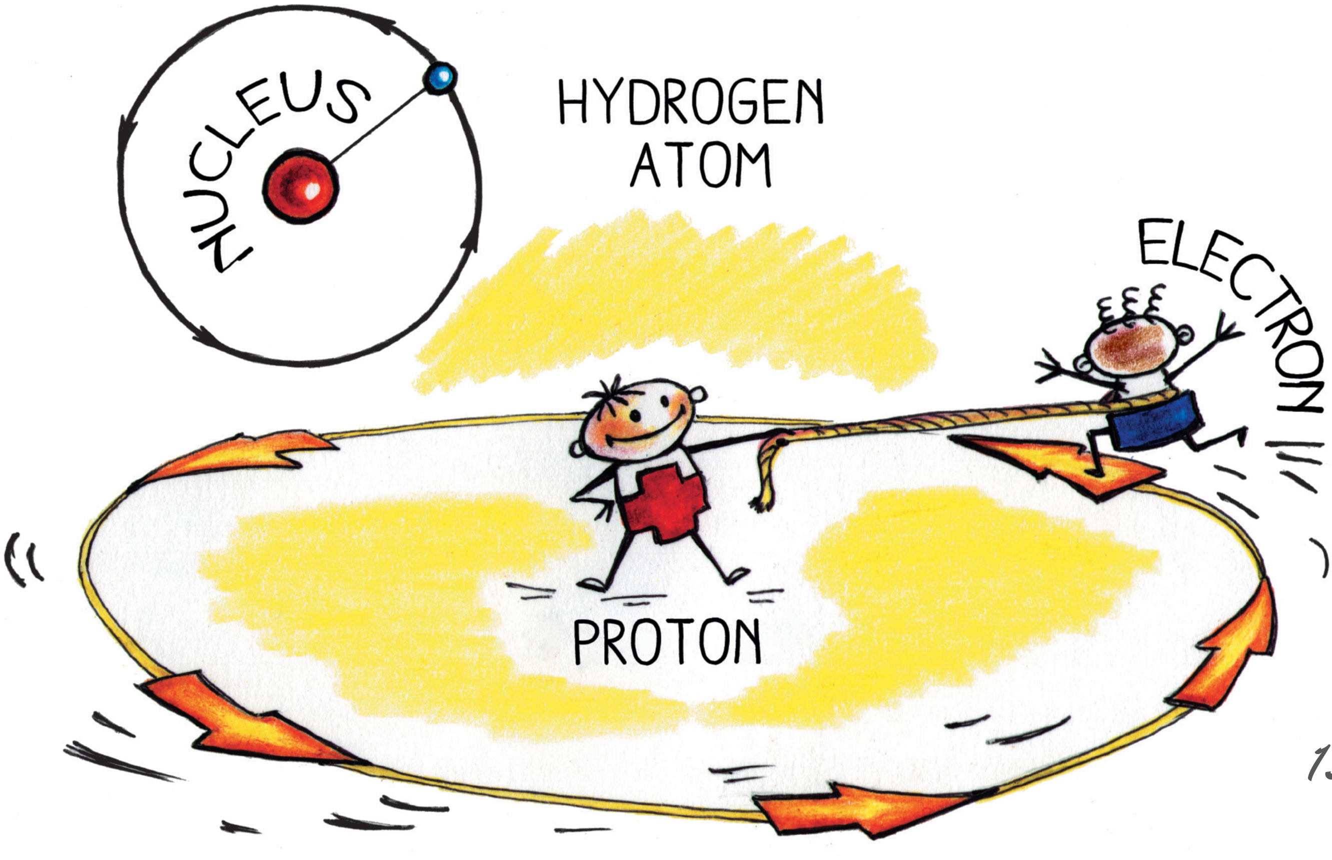
But Electrons really do transfer from your hair onto the comb, and the comb becomes negatively charged, in turn your hair becomes positively charged. That's how easily you can become "positive"!

The electric charge of Electrons is the smallest in the world. Well, academics haven't found a smaller charge anyway... Soon after the discovery of Electrons, it was found that these tiny negatively charged particles exist in every atom. It seems that atoms too should be negatively charged. But that's not the case.



Usually atoms do not display any of their electric properties! For example, in a hydrogen atom, as you already know, there is one Electron, but the atom itself is not charged at all. Why is that so? Where did the Electron's negative charge inside the hydrogen atom go?

It actually didn't go anywhere. Physicists realised that within the hydrogen atom there is one more hidden electric charge; a positive one. By magnitude, the positive charge is exactly the same as the negative charge, that's why it seems that there are no electric charges in the atom, neither negative, nor positive. It's the Proton itself that carries the positive charge!



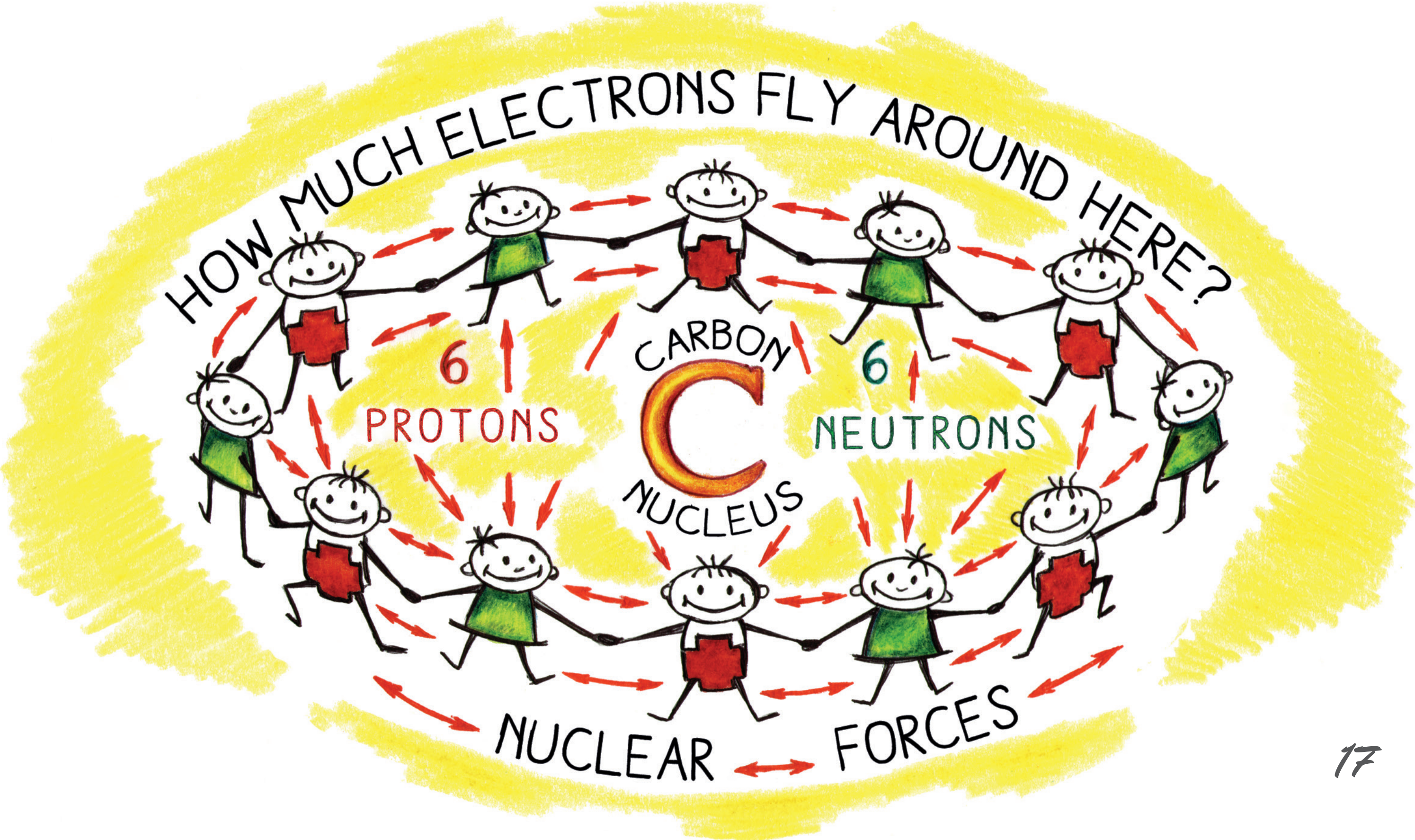
Now you understand what kind of "electric thread" connects the Electron to the Proton – a negatively charged particle attracts towards a positively charged particle! The Proton's charge is of the same magnitude as the Electron's negative charge. Therefore, one Proton is able to hold onto only one Electron within the atom using this "electric thread". One would not be able to add one more Electron as it would not be able to hold on.

To be able to add an Electron to an atom, one would need to add one more Proton into the nucleus of the atom. And only then will one be able to add a second Electron into the atom, as the nucleus will be able to hold on to it!

WHAT ARE NUCLEAR FORCES?

Imagine that in the centre of your atom, i.e. in the nucleus, there are two Protons and two Neutrons. And there are two Electrons circling them. Do you know what you've made? You've created the atom of helium – a completely different gas, with completely different, even opposite properties to hydrogen! The hydrogen atom is able to connect with many different atoms, whereas the atom of helium is the opposite, it doesn't connect with any other atom!

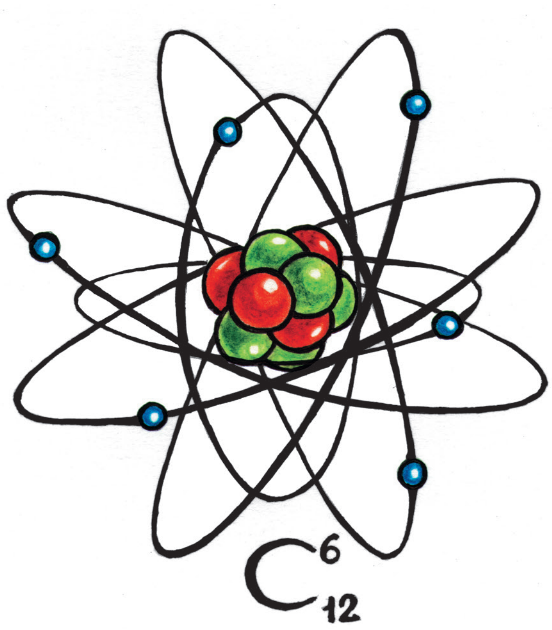
You can now see how strangely the world of atoms is created; you add a Neutron to the nucleus of the simplest atom, and the atom becomes heavier, but hydrogen still remains hydrogen. Add one more Neutron, and the atom becomes even heavier, but its hydrogen properties still remain. But should another Proton be added, then the “character” and “habits” of the atom completely change, almost as if it was touched by a magic wand! The size and mass of a Proton is the same as that of a Neutron, but the only difference is that a Proton has a positive electric charge and a Neutron doesn’t have a charge at all (its “neutral”). That is why when one adds or subtracts a Neutron, the electric charge of the atom doesn’t change.



But when one adds a Proton, the electric charge of the atom's nucleus immediately doubles in size. Therefore, the atom's properties are first of all dependant on the charge of the atomic nucleus.

But how can one connect Protons within the nucleus if they are all positively charged? Because, if you remember, similarly charged particles repel one another! So it seems that the Protons are not able to hold onto each other and the nucleus would definitely fall apart?

Can you believe it! It doesn't fall apart. Aside from that, many of the atoms' nuclei have an amazingly strong "construction". Some very strong forces compel the similarly charged Protons to hold together within the nucleus, despite their repelling actions. Physicists have called these NUCLEAR FORCES.

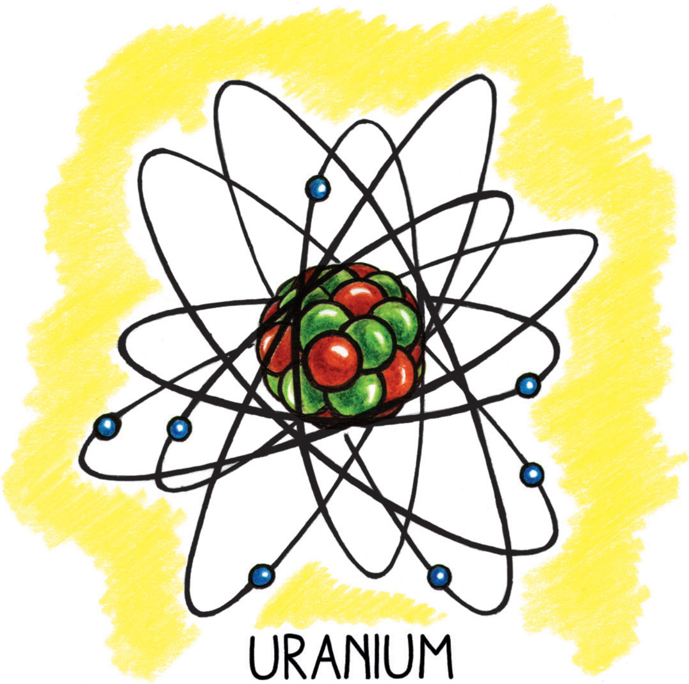


Now we'll add four more Protons and four more Neutrons into the nucleus of the helium atom. There will now be six Protons and six Neutrons in the nucleus. So have you figured out how many Electrons have to circle around this nucleus? Also six, exactly the same as the amount of Protons within the nucleus. There's a whole circular chain! You will then get the atom of Carbon, the substance you come into contact with quite often. For example, the lead of simple pencils is made of graphite, and graphite itself is made up of Carbon atoms.

We could gather the nuclei of even heavier atoms, for example iron, which contains 26 Protons and 30 Neutrons. Silver contains 47 Protons and 61 Neutrons. Gold contains 79 Protons and 118 Neutrons. Can you guess how many Protons and Neutrons there are in the nucleus of a Uranium atom?

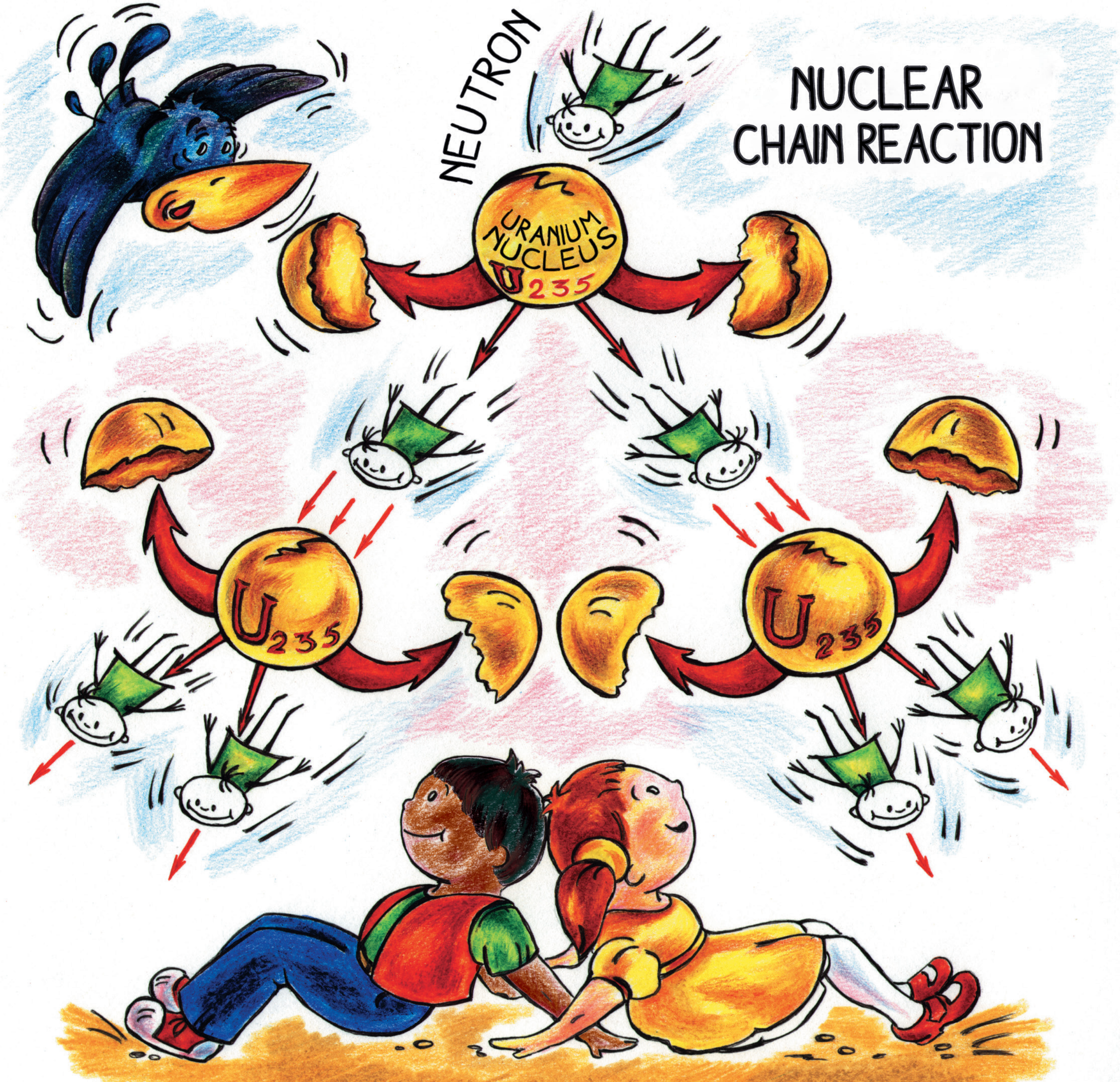
To find out let's have a closer look at the atom of Uranium. The atom itself has a basic atom structure; there's a nucleus in the centre, and at some distance from the nucleus, there is light and restless Electrons circling around it. Inside the nucleus, the heavy Protons and Neutrons are tightly sitting together. In most Uranium nuclei there are 92 Protons and 146 Neutrons (sum= 238), but in some Uranium nuclei there are 92 Protons, but only 143 Neutrons (sum= 235).

As you remember, atoms which differ from each other only in the amount of Neutrons in the nuclei are called ISOTOPES. The sum of the Protons and Neutrons inside the nucleus is called the MASS NUMBER, and it's included into the names of the isotopes. For example, we discovered two isotopes of the Uranium atom, and they are labelled as Uranium-238 and Uranium-235. Remember that for the nuclear reactor we require a lighter isotope, Uranium-235, even though in nature there is very little of it in comparison to Uranium-238.



So now, my curious friend, we have come to that important part that will help us understand how one is able to derive nuclear energy.

Do you know why Uranium-235 is the only substance you may use as fuel in your reactor? Well, this is because its atoms have unique properties. From time to time, one or other atomic nucleus of Uranium-235 suddenly goes BAM! and falls apart into two halves all by itself. In the process, two or three Neutrons fly out of the nucleus, and they race at extremely high speed – tens of thousands of kilometres per second! As soon as the Neutron lands on a different Uranium-235 nucleus, which was not preparing to fall apart on its own, BAM!, its nucleus halves itself and more Neutrons fly out of it. The nucleus is broken apart by one Neutron, but there are, once again, two or three Neutrons flying out from the broken nucleus, which land on other nuclei and break those apart too. There are more and more Neutrons, more and more broken nuclei – you now have what is called a NUCLEAR CHAIN REACTION, from which a lot of energy is released!


NUCLEAR
CHAIN REACTION
NEUTRON
URANIUM
NUCLEUS
U235
U235
U235

How atomic fuel "burns"

For the nuclear chain reaction to go the way we need it to – not too fast and without explosions – the Uranium-235 concentration within the nuclear fuel must not be too large, only a few percent.

So, my curious friend, which Neutrons do you think would break up the nuclei of Uranium-235 better? The fast or the slow ones? You're thinking maybe the fast ones? It turns out, though, the slow ones are better! These are the unique properties that appear in the tiny world of atoms!

But if the slow Neutrons break up the atomic nuclei of Uranium-235 better than the fast ones, it means that we would need to slow down the fast Neutrons! This job is done well by DECELERATORS; graphite or water. The fast Neutrons get “stuck” in them and their speed decreases, almost like a person running through water. Atomic reactors with decelerators are called reactors on slow (or thermal) Neutrons.

There are even reactors in which fast Neutrons work too. For example, in Russia there is the world’s only successfully working industrial “fast” reactor. But physicists started off with reactors working on slow Neutrons. Exactly such a reactor was launched in the world’s first nuclear power station, in the small Russian town of Obninsk, not far from the capital Moscow, which first gave power more than 60 years ago, in June 1954.

Ok, the Neutron broke the nucleus into pieces, but what’s next? In actual fact, these can no longer be called “pieces” of the Uranium-235 atom, as the atomic nuclei of two completely different substances are created during the reaction. Quite often these are the atomic nuclei of Strontium metal and the atomic nuclei of the heavy gas Xenon. Just think about all the miracles that just occurred; one substance turns into two others that look nothing like the original substance! This is just like a beetle landing on an elephant, and in the elephant’s place suddenly a crocodile and a giraffe appeared!

The "pieces" of the Uranium nucleus, just like the Neutrons, fly out with a great speed. But, unlike the Neutrons, when these "pieces" land on other Uranium atoms, they do not break the nuclei apart, they just simply force them to shake in place. The Uranium atoms "dance" faster and faster, and the fuel rods in which these atoms are placed, are heated up. They are heated up so much, that if you were to place them into water, the water would turn into steam. And we use this steam to generate electric energy. The stream of steam turns a steam turbine, and the turbine in turn rotates an electric generator which produces the electric current. Then further, the electric energy, with the aid of an electric motor, spins the propeller of our ship. But if the reactor is installed on a nuclear power station, then the electric energy travels through wires to factories and plants, and it lights up cities, schools, homes and also does thousands of other good deeds that help people to work, learn, live comfortably and rest happily.

How to catch the extra Neutrons

I'd like to warn you, my dear friend. Do you remember me saying that when one Neutron lands on a Uranium-235 atomic nucleus, there are two or three Neutrons flying out of the broken nucleus? Three Neutrons would break up three more nuclei.

Let's say that, once again, three Neutrons fly out from a broken nucleus – that means that nine new Neutrons will fly out of the newly broken nuclei. These nine Neutrons will break up nine new nuclei, and so on. The amount of Neutrons, broken nuclei and produced energy will grow very fast!

This is why it is very important to be able to REGULATE the nuclear reaction. In the unique atomic world there are always "specialists of catching Neutrons" – they will help organise the atomic reactor. They will not allow the Neutrons to fly whichever way they desire, and will only allow the Neutrons to fly freely for as long as they need – no more and no less! There exists a substance called BORON. Boron atoms will help you control the chain reaction. But take into account that not all Boron atoms are fit for this chain. There are two categories, or two brother isotopes; Boron-10 and Boron-11.

The Boron-10 atom is similar to a spider on its web – it waits for an unsuspecting Neutron to pass by and then quickly catches and "swallows" the Neutron. The Boron-10 atom attaches it to its nucleus. The Boron-11 atom doesn't "swallow" the Neutrons, it actually repels them.

It turns out that only the Boron-10 atoms will be able to help you dispose of the unnecessary Neutrons. One should say, that the property of "swallowing" the Neutrons that fly by is not only the property of the Boron-10 atom, but of the atoms of other substances too, for example the metal called Cadmium. If you add many Boron-10 or Cadmium atoms into the nuclear reactor, they will "swallow" almost all the flying Neutrons, and the "atomic furnace" will go out, similar to throwing a bucket of water into a fireplace.

You therefore make so-called control rods out of these substances and place them into our reactor. While all the control rods are inside the reactor, there is no chain reaction.

But now you lift the rods slightly…

Less Neutrons are being absorbed and more of them are flying freely, and the chain reaction has started, and the Uranium has started heating up. Lift the rods up higher, and

you'll allow more Neutrons to "fly" freely through the reactor and destroy the nuclei of more Uranium-235 atoms, and the reactor will heat up even more.

Lower the rods and there will be less Neutrons flying freely inside the reactor, less Uranium atoms will fall apart and less heat will be generated.

So, with the aid of control rods, you will be able to control the heat of your atomic reactor. Of course, people do not lift and lower the controlling rods themselves. They delegate this work to an automated control system and reactor shielding system.

So, the freely flying Neutrons do not escape but are instead limited by a special safety screen made of specific atoms that repel the Neutrons. What are the atoms that repel Neutrons? Try to remember…

That's right – Boron-11 atoms!

Let's add Boron-11 atoms into the steel, and from this steel we'll make a safety screen for your reactor. No Neutron will be able to get through to the outside. After landing onto the Boron-11 atoms, the Neutrons will bounce off them, like a bouncing ball from the wall!

What do radioactive isotopes emit?

You already know the word "isotope". These are substances of which the atomic nuclei contain an equal number of Protons but different number of Neutrons. You have already learnt about some isotopes: Uranium isotopes – Uranium-235, and Boron isotopes – Boron-10 and Boron-11. It so happens that most of the chemical elements in the periodic table have isotopes, and some of them are RADIOACTIVE.

What does "radioactive" mean? The word "radio" means "radiate" in Latin. So, radioactive isotopes are isotopes that radiate something.

An electric lamp radiates light. A hot water radiator radiates heat. A radio station radiates radio waves. And what do the radioactive isotopes radiate?

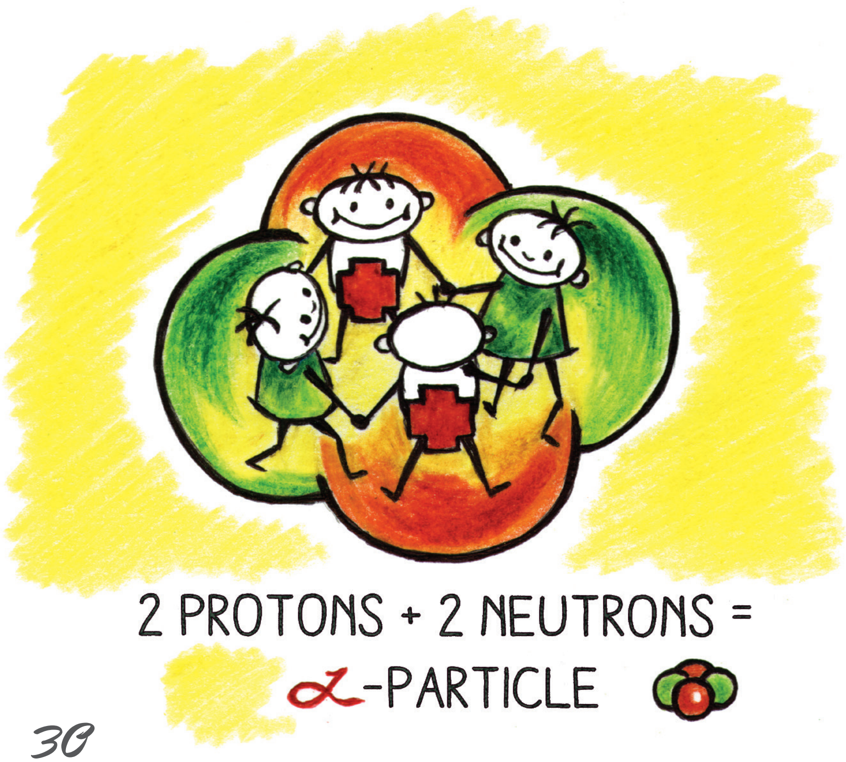
The isotopes you already know – Boron-10 and Boron-11 – are not radioactive. What will happen if we add one more Neutrons to the atomic nucleus of Boron-11? Then Boron-11 will turn into Boron-12. Maybe this isotope of Boron is radioactive?

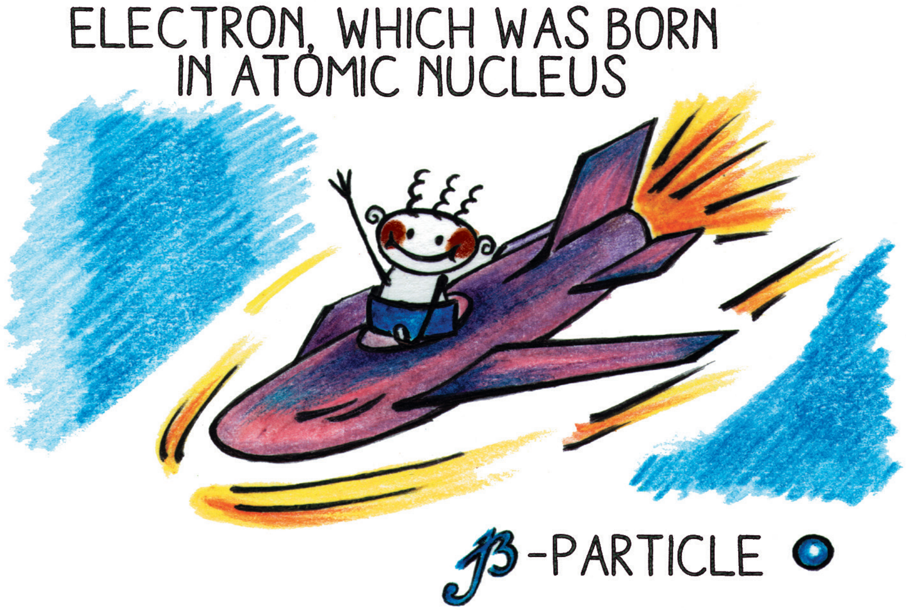
The moment we add another Neutron to the Boron-11 atomic nucleus, it immediately falls apart: two Protons and two Neutrons rush out of it at a great speed of twenty thousand kilometres per second. They do this tightly attached to each other as if it is less scary to perform such a high-speed flight together! The particle which consists of two Protons and two Neutrons tightly bound to each other is called ALPHA-PARTICLE. The flows of alpha particles are usually called ALPHA RADIATION.

So, the alpha particle “flew away” and the remaining part of the nucleus after the flight-shot underwent very interesting changes. Let us take a closer look and try solve an easy task.

In the Boron-12 atomic nucleus there were five Protons and seven Neutrons. Two Protons and two Neutrons left as alpha particle. How many Protons and Neutrons were left?

Easy task: three Protons and five Neutrons. Instead of three Protons, there are four, and instead of five Neutrons, there are also four! Where did another Proton come from and where did one Neutron go? It turns out that a Neutron turned into a Proton! And what is amazing – during the turn of a Neutron into a Proton another particle was born – an Electron. But previously there were no Electrons in the nucleus,



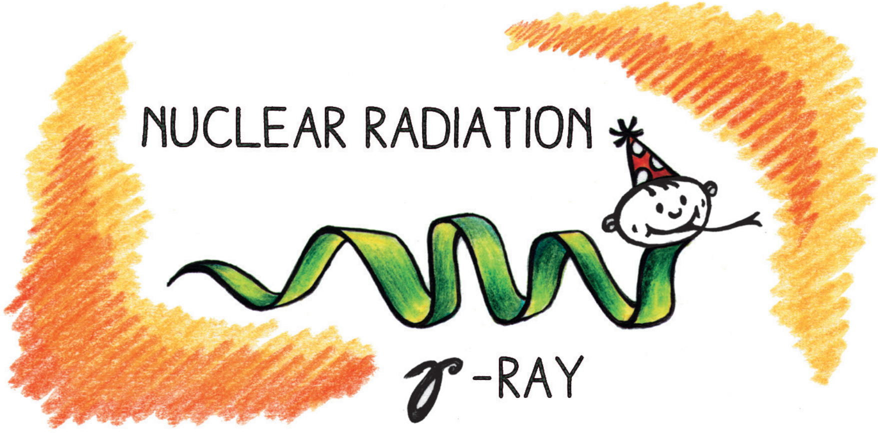


not at all! As you remember, there are Electrons around an atomic nucleus – they are rotating along certain orbits and, inside the nucleus itself, there are only Protons and Neutrons.

And where is this newly born Electron? It is already gone – it has moved away with enormous speed – nearly the speed of light, which is three thousand kilometres per second!

The electrons born in the nuclei of radioactive isotopes are called BETA PARTICLES, and the flow of beta particles are called BETA RADIATION. It means that Boron-12 radiates not only alpha particles but also beta particles. But it is not the end of story!

At the time when the Boron-12 nucleus was splitting apart, it sent GAMMA RADIATION as a farewell gesture. Gamma radiation is very close to an X-Ray in its nature and properties. And, as you know, X-ray is very widely used in medicine. The only difference is that gamma rays go through non-transparent bodies even easier than X-rays!



So, we counted three types of radioactive radiation; alpha, beta and gamma. Boron-12 radiates all three types of rays. But not every radioactive isotope is as universal, there are isotopes which radiate only alpha or only beta radiation. Atomic nuclei of radioactive isotopes do not break apart simultaneously. First one nucleus falls apart and then another one, but sooner or later the remaining isotopes become so few that the radioactive isotope ceases to exist, so to say.

How soon will this happen? Alas, it will happen very quickly with Boron-12; in less than two hundredths of a second, half of all atomic nuclei will break apart (decay), another two hundredths of a second – and again half of the remaining nuclei break apart, and so on. And before you know it, there will be nothing left of Boron-12.

But not all radioactive isotopes have such a short life. Some of them are real champions of longevity! For example, the splitting apart of half of the atomic nuclei of the heavy metal Thorium-232 will take about fourteen billion years!

The time during which half of atomic nuclei of a radioactive isotope break apart is called its HALF LIFE (or HALF DECAY).

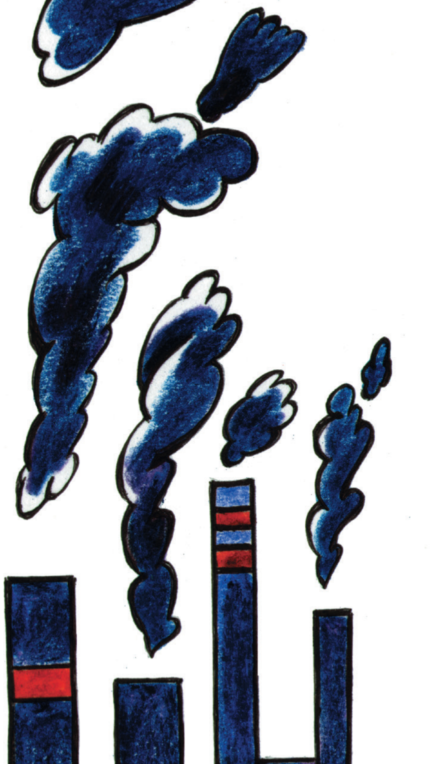
Ferrum, for example, have six radioactive isotopes with the following half life time; eight hours, nine minutes, two-and-a-half years, one-and-a-half months, three thousand years and five-and-a-half minutes. At present, there are over one thousand known radioactive isotopes. Some of them were discovered in nature, but most of them were man-made in nuclear reactors and physical laboratories.

Of course, you would like to know what the use of such knowledge is, why are scientists looking for them in nature and trying to artificially create various radioactive isotopes? Here is just one example; we have already spoken about Carbon, which everyone encounters on a daily basis. Well, a radioactive isotope of Carbon exists called Carbon-14 (it's acquired as a result of combining two Neutrons to the existing six Protons and six Neutrons inside the atomic nucleus of Carbon-12). There is some radioactive Carbon in every plant, every animal and every human and it really helps archaeologists. For example, if an archaeologist finds the remains of an ancient fire pit, they are able to analyse the coals, including how many atomic nuclei of radioactive Carbon are left and how many have fallen apart. Having found this out, they can quite accurately calculate when the fire was burnt, and how many years ago it was that our ancient ancestors sat around the fire for warmth.

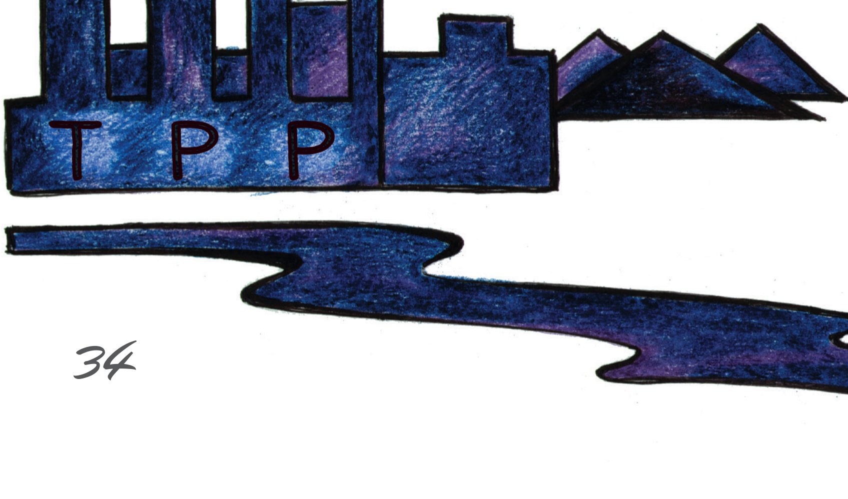
You might say: "this is impressive!" And you would be completely right, my curious friend!

GREENHOUSE GAS IN AN ATMOSPHERE

OUR JOURNEY CONTINUES



We now return from the ocean on our nuclear ship, where you imagined yourself, and continue our journey up the Tugela River, equipped with lots of interesting facts about how nuclear works and operates. To the right there are valleys and grasslands. To the left there are high banks. But what's this? A big dark cloud has floated in front of the sun. That's the smoke coming from a thermal power station, polluting nature. Thermal power stations have to burn several types of fuels gathered from the ground to be able to produce electric energy. These fuels from the ground are typically coal, oil and gas. These types of fuel are called fossil or organic fuels.



Sometimes it is called “exhaustible fuel”. There are huge reserves of such fuel deep in the earth, but it is used a lot and quickly and will therefore not last forever. There are also lots of other ways of getting energy. The Sun is one of the most powerful energy sources giving us light and warmth. The Sun’s energy is safe and practically unlimited (inexhaustible). And most importantly, it is environmentally-friendly, which means that its use does not harm nature or people.

However, there are no cost-effective and convenient methods or devices for storing this solar energy yet, so we can only use it when the sun is shining – rather inconvenient when you want to cook dinner at night. Who knows, maybe when you grow up, you will be able to develop an effective storage method!

Another type of energy which does not pollute nature is the energy produced from wind. It can be transformed into electric energy with the help of huge propellers. But you do not see many of these wind mills on our shores yet because of irregularity of work and instability of power. This is quite understandable, as the wind blows unpredictably, resulting in obstacles that prevent the efficient use of wind energy here.

A Trip To a Nuclear Power Plant

Let's now go to the home of nuclear, Russia, to a Nuclear Power Plant (NPP). Like everybody who visits an NPP, we get helmets, our documents are thoroughly checked and after that we are invited in to join a tour. We proceed to see an active power unit of the station. A huge complex of buildings, enormous transformers, pump stations, water pools with dozens of fountains of cooled water, tanks with various gases of fabulous sizes, elevated tracks, and pipelines – it is breathtaking!

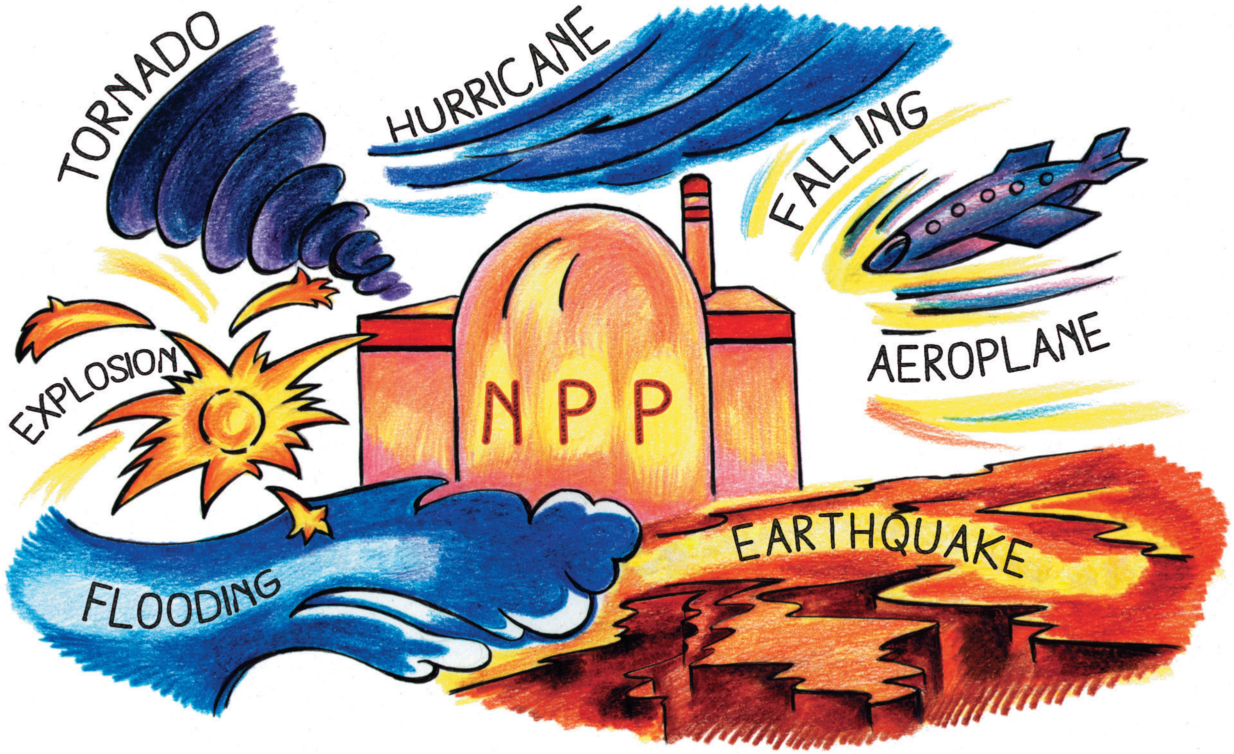
The first thing one notices is the immaculate state of everything around you. Everything is thoroughly cleaned, washed and painted. Flowers are planted between the buildings; the soil is watered and the grass is green. Neat tar roads with blooming flower beds are on both sides, the air is clean and bird nests are in the trees. All the pedestrian paths are clearly marked. There is a railway along the whole territory of the station, and one can see a train slowly dragging a carriage. And on that carriage is a container with nuclear fuel! You won't see this train very often though, as nuclear fuel "works" for three years in the reactor and then, after a certain amount of time being contained in a special pool, the worked out (spent) fuel is removed from the territory of the nuclear power station for reprocessing.

Of course, the process of power generation is a complicated one. A large number of various operations are performed and very complicated equipment must work flawlessly.

The power unit itself is a massive building. The reactor section is 67 metres high, and the whole building is nearly 200 metres long! The power unit is the main part of the nuclear power station. It contains the nuclear reactor (a "nuclear boiler" which heats water), a steam turbine and an electric power generator.

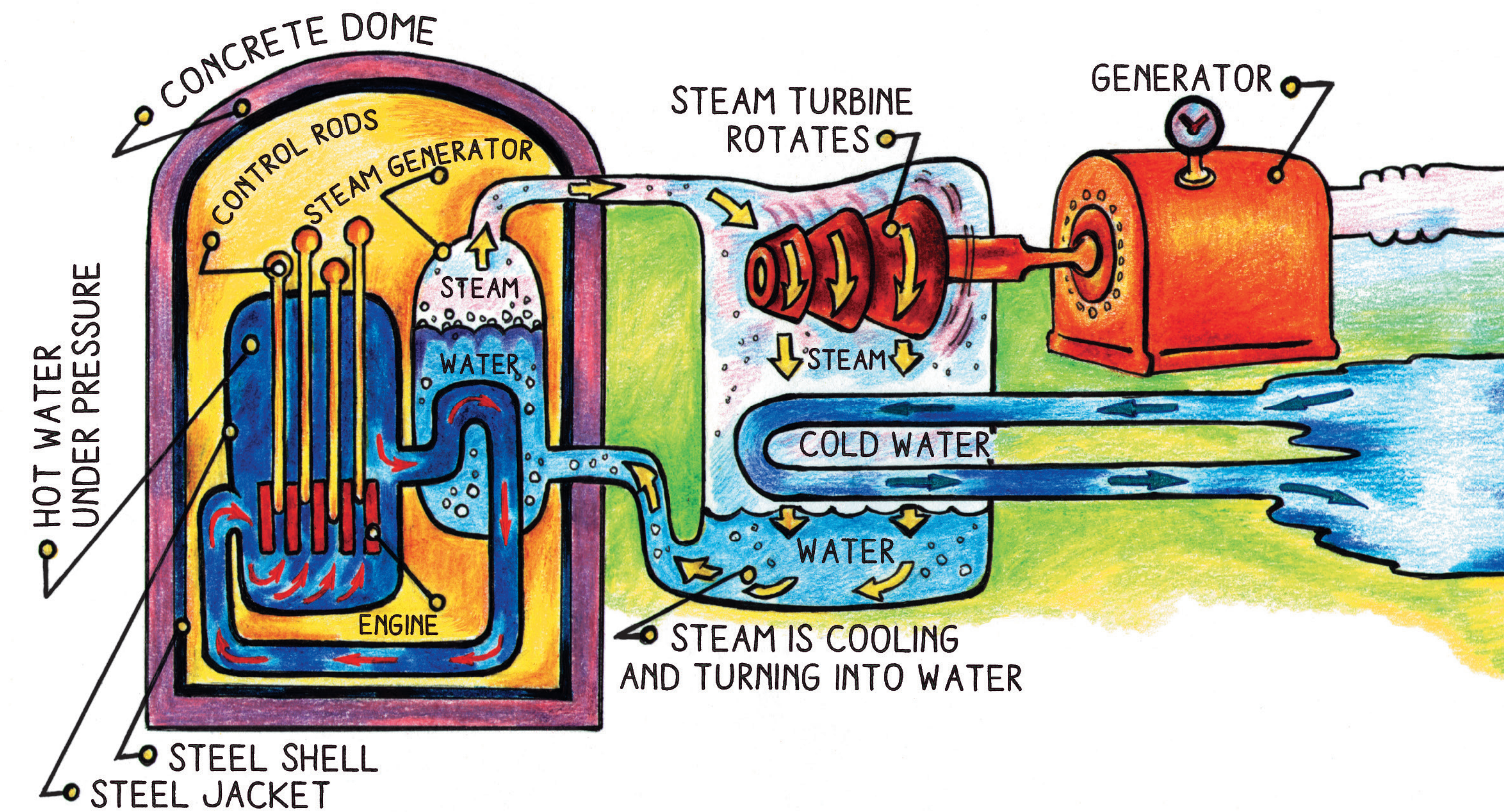
A nuclear reactor with all the auxiliary equipment is covered by a very strong reinforced concrete dome for safe containment. Its construction allows the nuclear power station to sustain earthquakes, tornadoes, hurricanes, dust storms and air shock waves. Even an aeroplane crashing into the building would not damage the station!

Like in your nuclear ship, the "heart" of the nuclear station is the nuclear reactor, and the only task of the nuclear reactor is to continuously generate a huge amount of heat. By the



way, can you imagine water heated to over 100°C? Oh yes, it is possible, if the water is under high pressure. So, at the outlet of the reactor the water temperature is 320°C! This water flows to a special heat exchanger where it heats secondary water, which flows through a steam generator. Here it is turned into steam. The steam under high pressure is fed to the steam turbine situated on the turbine island.

Here we are, on the turbine island. It is longer than a football field! We look at the huge turbine which receives the steam that makes it rotate at a very high speed. The turbine is very tall – like a two-story building. The turbine rotates the generator, which generates electric current. What we see is fascinating! All of us, even those who do not know much about aviation, admire an aeroplane taking off, likewise the process of "nuclear electricity" generating fully grips our attention.



And what is most amazing, we have not seen a single person here! All processes are fully controlled by computers located in the single control centre. And we are going there right now.

It is not easy to get there. We are going through leak tight guarded doors before we find ourselves in the main control room – this is the centre where the operators work, they control the whole production. If the nuclear reactor is the heart of the power unit, the main control room is its brains.

We are allowed to spend only a few minutes here, so that we do not to disturb the work.

Without any instructions we start speaking in soft voices.

Do you know how much electric power is generated by one power unit of the nuclear power station? The average power of one power unit is a million kilowatts! This is enough for a million irons!

A nuclear power station already exists in South Africa and is situated at Koeberg in Cape Town. South Africa also plans to build more nuclear power plants to help its people and the environment. And if you want, you can also work at these nuclear power plants!

WHY PEOPLE NEED NUCLEAR POWER

And now let us compare an NPP with a thermal power plant (TPP). To secure the work of a coal (thermal) power station with the same capacity as one power unit of an NPP during one year, one would need five million tonnes of coal. Just imagine, every 5-6 hours a train of 50 carriages each containing 60 tonnes of coal comes through the gate of the power station and goes out empty. Just think – how long does the train delivering fuel to the power station over a one-year period need to be? It will be two times longer than the distance from the North of South Africa to the South! But it is not only the fuel delivery that makes it so difficult.

Worse is that most of the five million tonnes of coal will end up in dumps called tailings – hills of ash under the open sky which are harmful. Hundreds of thousands of tonnes of dust, as well as compounds of Sulphur and Nitrogen are emitted into the air through the chimney and later fall to the ground as “acid rains”. We all saw the heavy smoke coming out from the thermal power station pipes into the air when we were sailing past it.

But even this is not the worst thing. No matter which fuel the thermal power station uses – be it coal, gas or fuel oil – a huge amount of carbon dioxide is thrust into the air through the chimney pipes. Carbon dioxide is produced as a result of organic fuel burning. Scientists have discovered that this causes the so-called “greenhouse effect” which raises the Earth’s temperature. This in turn changes the climate, increases the frequency and the strength of storms, floods, droughts and other natural events. The increase of the average temperature by even 2 to 3°C will cause the melting of ice caps in the North Pole and in the Antarctic. Europe and Australia, parts of America and many islands might disappear from the face of the Earth. The whole world’s ecosystem would collapse.

In order to avoid this, people must immediately start using so-called alternative power sources which do not need to burn coal or gas. These alternative sources include nuclear, solar energy, hydropower, wind power and others that do not cause this “greenhouse effect”.

That is why nuclear power will continue to develop all over the world. Our new nuclear power stations will be constructed and it will work for the benefit of all South Africans and the environment.

Nuclear power is the safest and most reliable source of energy. Hundreds of nuclear reactors work in developed countries of the world, helping people to live and work. New nuclear power stations are being built in many different countries, as scientists develop new projects for using atomic energy.

Through the creation of new power sources, people get more energy. And the process continues; there will be new discoveries in the field which people have no idea of now. And if you, my curious friend, decide to devote your life to the problems which have vital importance for mankind, such as the search for new power sources, you will have great opportunities to show your skills, knowledge and creativity. I wish you all the success in the world!